

G-R-05-016

Drawer # 24

GEOTECHNICAL INVESTIGATION

DEMPSTER HIGHWAY

MILE 0 TO 78

PREPARED FOR

DEPARTMENT OF PUBLIC WORKS OF CANADA

VOLUME I



R.M. HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING



R.M.HARDY & ASSOCIATES LTD.

TRANSPORTATION
ENGINEERING, S-3

1968-06-20-1

9

GEOTECHNICAL INVESTIGATION

DEMPSTER HIGHWAY

MILE 0 TO 78

PREPARED FOR

DEPARTMENT OF PUBLIC WORKS OF CANADA

VOLUME I

E-3098

(PRELIMINARY)



R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING • GEOTECHNICAL DIVISION

File No. E-3098

April 2nd, 1975

Mr. J. Y. C. Quong, P.Eng.
Manager of Technical Services
Department of Public Works of Canada
201 Range Road
Whitehorse, Yukon Territory

Re: Geotechnical Investigations,
Mile 0 to Mile 78, Dempster Highway
Your file 1004-6

Dear Mr. Quong:

Attached is a copy of our preliminary report on the geotechnical conditions for the above project. The report is in two volumes of which Volume I deals with specific questions of highway construction for this project while Volume II is a more general discussion of the various factors affecting highway construction in this area.

Owing to the urgency with which this report is required, we have proceeded with the preparation and printing within the shortest possible time. We therefore expect that minor changes, including corrections to spelling and grammatical errors, will be required. In addition, it is possible that you may require some further explanation or amplification of certain parts of the report before we issue the final version. We would be happy to receive your comments at your earliest convenience.

The reports on the geotechnical conditions of the several bridge sites on this project are in course of preparation.

Yours very truly,

R. M. HARDY & ASSOCIATES LTD.

Per: 

G. McCormick, P.Eng.

GM:cmg



INDEX VOLUME I

<u>Section</u>	<u>Subject</u>	<u>Page</u>
1.	INTRODUCTION	1
1.2	Classification of Soils and Ground Ice .	1
1.3	Bridge Foundation	2
1.4	Drainage	2
1.5	Compaction Control	2
2.	DISCUSSION ON SOIL TYPES	3
2.2	Rock	3
2.3	Gravel	4
2.4	Sand	4
2.5	Silt	5
2.6	Clay	5
2.7	Organic Soils	5
3.	TERMS OF REFERENCE	6
4.	AREA DESCRIPTION	7
4.2	Geology	7
4.3	Physiography and topography	8
4.4	Climate	9
4.5	Vegetation	9
4.6	Wildlife	10
4.7	Logistics	10
5.	PROGRAM DESCRIPTION	11
6.	MILE 0 - MILE 11	12
6.2	Soils	12
6.3	Borrow Material	13
6.4	Stability Problems in Cuts	14
6.5	Erosion	14
6.6	Seepage	14
6.7	Construction Methods and Scheduling . .	15
6.8	Further Laboratory Testing	15



6.9	Discussion and Recommendations	15
7.	MILE 11 - MILE 24	17
7.2	Soils	17
7.3	Borrow Material	18
7.4	Stability Problems in Cuts	19
7.5	Erosion	19
7.6	Seepage	20
7.7	Construction Methods and Scheduling . .	20
7.8	Further Laboratory Testing	21
7.9	Discussion and Recommendations	21
8.	MILE 24 - MILE 32	23
8.2	Soils	23
8.3	Borrow Material	24
8.4	Stability Problems in Cuts	24
8.5	Erosion	25
8.6	Seepage	25
8.7	Construction Methods and Scheduling . .	25
8.8	Further Laboratory Testing	26
8.9	Discussion and Recommendations	26
9.	MILE 32 - MILE 42	27
9.2	Soils	27
9.3	Borrow Material	28
9.4	Stability Problems in Cuts	29
9.5	Erosion	29
9.6	Seepage	29
9.7	Construction Methods and Scheduling . .	29
9.8	Further Laboratory Testing	30
9.9	Discussion and Recommendations	30
10.	MILE 42 - MILE 60	31
10.2	Soils	32
10.3	Borrow Material	33
10.4	Stability Problems in Cuts	35
10.5	Erosion	35



10.6	Seepage	35
10.7	Construction Methods and Scheduling . . .	36
10.8	Further Laboratory Testing	36
10.9	Discussion and Recommendations	36
11.	MILE 60 - MILE 78	39
11.2	Soils	39
11.3	Borrow Material	41
11.4	Stability Problems in Cuts	41
11.5	Erosion	42
11.6	Seepage	42
11.7	Construction Methods and Scheduling . . .	42
11.8	Further Laboratory Testing	43
11.9	Discussion and Recommendations	43

APPENDIX A - Photographs

APPENDIX B - Explanation Sheets



INDEX VOLUME II

<u>Section</u>	<u>Subject</u>	<u>Page</u>
21.	INTRODUCTION.	1
22.	PERMAFROST.	2
22.2	Thermal Regime.	3
22.3	Effects of Disturbance.	3
22.4	Influence of Vegetation.	4
22.5	Depth of Thaw.	5
22.6	Effects of Water Bodies.	7
22.7	Effects of Highway Embankments.	10
23.	THAW-SETTLEMENT OF SOIL.	15
24.	WINTER CONSTRUCTION.	31
25.	EROSION.....	36.
	REFERENCES	
	APPENDIX C - Charts and Diagrams	



1. INTRODUCTION

1.1.1 This report covers geotechnical field work executed in connection with the proposed upgrading and partial relocation of Mile 0 to Mile 78 at the Dempster Highway in the Yukon Territory. The field work, including drilling, was carried out by personnell. of the Pacific Region of the Department of Public Works of Canada under the supervision of an engineer seconded from R.M. Hardy & Associates Ltd.

1.1.2 The text of this report is divided into two volumes. Volume I contains information which will be of specific value to engineers designing and constructing the section of highway between Mile 0 and Mile 78. Volume II contains background information on permafrost and related engineering problems together with a list of references.

1.1.3 The test hole logs and laboratory test data sheets, are contained in separate volumes. Separate reports will be issued for the bridge site investigated as part of this program.

1.1.4 A search for possible sources of granular surfacing material was made between Mile 78 and, approximately, Mile 220. The results of this search will be the subject of a separate report.

1.2 Classification of Soils and Ground Ice

1.2.1 Soils were classified according to the Unified Classification System which is described in Appendix B, Volume I.



1.2.2 Ground ice was classified according to the National Research Council Classification System which is described in "Guide to a Field Description of Permafrost" published by the National Research Council, Ottawa. A brief description of the NRC System is contained in the explanation sheets in Appendix B, Volume I.

1.3 Bridge Foundation

1.3.1 It is expected that bridges will be required at: Wolf Creek, Grizzly Creek, North Klondike River, Upper North Klondike River, Fox Creek, Upper Blackstone River, and the Blackstone River. Each of these bridge sites will form the subject of a separate report.

1.4 Drainage

1.4.1 Drainage problems are not within the terms of reference for this study. However, they have been mentioned occasionally where they may have an influence on soil behaviour which may affect the highway. In general, the drainage problems in this section of the Dempster Highway are not considered to be serious..

1.5 Compaction Control

1.5.1 Compaction control and density tests were not within the terms of reference of this report.



2. DISCUSSION ON SOIL TYPES

2.1.1 The soil types encountered in the area of the study can be divided into six groups: rock, gravel, sand, silt, clay and organics. A brief discussion on the problems of: excavation, transportation, placing and construction scheduling for each type follows:

2.2 Rock

2.2.1 Weathered and broken bedrock was encountered along the valley wall of the North Klondike River and had been used in certain sections for embankment construction in the past. Bedrock may influence the foundations of some of the bridges as, at some bridge sites, the bedrock is at relatively shallow depth.

2.2.2 The geology of the area, as reviewed in a subsequent section, is complex with an extreme variety of sedimentary, metamorphic and igneous rocks being found. While the weathered and broken rock along the hillside can be easily moved by bulldozers, the intact sand bedrock could only be excavated by drilling and blasting. Fortunately, little or no excavation into sound bedrock will be required for this project.

2.2.3 Broken and weathered bedrock is one of the less desirable types of embankment material available along this project. The broken bedrock is often in large slabs which leads to the creation of voids in the embankment. Because of the large amounts of gravel, and other coarse granular



material available in the area, it is recommended that the weathered and broken bedrock only be used in those areas where it is necessary to cut through them to maintain a design grade.

2.3 Gravel

2.3.1 Large quantities of gravel are available through almost the entire length of the project. Excavation of this material could be carried out by loaders, scrapers, or shovels.

2.3.2 Transportation of gravel along the grade can be by means of scrapers or dumptrucks. Loading and transportation by means of scrapers is usually the most economical system although, for this particular project, it may be more economical to use dumptrucks.

2.3.3 Placing of gravel presents no problems in either summer or winter due to the low water content. High standards of compaction are easily obtained without the use of special equipment. However, as shown in Volume II, Page 34, frozen gravels are particularly hard to excavate. Therefore, while winter excavation and transportation of gravel will be feasible it is unlikely to be economical.

2.4 Sand

2.4.1 Sand was encountered along the most entire route with it usually forming part of a gravel sand mixture. No prospective borrow areas which consisted entirely of sand



material were encountered. The remarks above on the difficulties of excavating gravel in the winter also apply to sand.

2.5 Silt

2.5.1 Only small quantities of silt were encountered in this project. It was invariably associated with other materials and generally formed only a minor fraction of the total materials available for construction.

2.6 Clay

2.6.1 Clay was encountered in the subgrade at several locations in the interval Mile 11 to 24 and Mile 60 to Mile 78. It generally forms part of a till deposit and is generally in a fairly dense state.

2.6.2 Very little clay was encountered in potential borrow areas. In view of the large amounts of coarse granular material available for embankment construction, we do not recommend the use of clay as fill.

2.7 Organic Soils

2.7.1 The thickness of organic soils in the area south of Mile 60 is generally quite thin with the maximum thickness of the deposits seldom exceeding 2 feet. In the area north of Mile 60, far thicker deposits of peat were often encountered but were invariably in a frozen condition.

2.7.2 It is recommended that the existing peat cover be left in place where any embankments are constructed and that any trees or shrubs which are to be cleared from the right-of-way be cleared by hand.



3. TERMS OF REFERENCE

3.1.1 The terms of reference for this work call for the geotechnical consultant to provide supervision for the field work and to prepare a report to be used as the basis for design.



4. AREA DESCRIPTION

4.1.1 The southerly terminus of the Dempster Highway is located on the Klondike Highway approximately 28 miles south easterly of Dawson City. From this point, the Dempster Highway follows the valley of the North Klondike Riverr for approximately 44 miles at which point it ascends into the North Fork Pass and then drops into the valley of the Upper Blackstone River. At approximately Mile 71 the road crosses the Blackstone River and follows that water course until Milee 95. The route is located in Map Sheets 115-0 and 116-B of the National Topographic Series.

4.1.2 The area has been mapped under the Land Use Information Series produced by the Department of the Environment for the Department of Indian and Northern Affairs. These maps show the various wildlife habitats, recreational potential, existing hunting and trapping activities, forest resources and other environmental information.

4.2 Geology

4.2.1 The earliest reports on the geology of the area were prepared by McConnell (21) published in 1901. McConnell mentions that permafrost, although he did not use that term, was encountered by many of the Placer miners in the Dawson area. The depth to the bottom of the permafrost range from 60 to 200 feet. Vernon and Hughes (31) reported on the surficial geology of the area and included a map showing the



physiographic divisions of the north-central Yukon. Green (12) also reported on the geology of the area and also gives some data on the climate and the vegetations.

4.3 Physiography and topography

4.3.1 A map showing the physiography of the north-central Yukon was prepared by Bostok which was used by Vernon and Hughes (31). According to this physiographic division, Mile 0 of the Dempster Highway lies within the Tintina Trench and at approximately Mile 7 the highway crosses the extreme westerly limit of the Stewart Plateau. At approximately Mile 16 the highway comes into the Southern Ogilvie Range and then, after passing through the North Fork Pass, traverses the Taiga Valley. Mile 78 on the highway lies within this valley.

4.3.2 Within the stretch of highway from Mile 0 to the North Fork Pass, drainage is excellent. The highway crosses numerous small creeks which are tributary to the North Klondike River but the principal drainage path is southerly parallel to the highway. Within the Taiga Valley itself, north of the North Fork Pass, drainage is, relatively, poorer but does not pose any problems.

4.3.3 There is considerable variation in the elevation of the highway. At Mile 0, the ground elevation is approximately 1400 from which the road climbs to an elevation of approximately 4400 at the height of land in the North Fork Pass. From that point the road then drops through the Taiga



Valley to an elevation of 3100.

4.4 Climate

4.4.1 The climate is continental with low precipitation and a wide temperature range. The local climate varies considerably due to the influence of topography. Green (12) is of the opinion that the records for Dawson City are not truly representative of the area due to the location of the weather station in a deep valley. However, Dawson City is the only location for a weather station reasonably close to the project. Meteorological data from Dawson City are as follows:

mean annual temperature: 23.1^o F.

mean annual snowfall: 54 inches

mean annual rainfall: 7.4 inches

mean annual total precipitation: 12.8 inches

mean freezing index: 6,500 degree-days f

lowest freezing index: 5,300 degree-days f

highest freezing index: 7,800 degree-days f

mean thawing index: 3,200 degree-days f

lowest thawing index: 2,800 degree-days f

highest thawing index: 3,600 degree-days f

4.5 Vegetation

4.5.1 The principle trees in the area are: white spruce, black spruce, aspen, poplar, balsam poplar, birch, alpine fir, willows, and some alder.



4.6 Wildlife

4.6.1 Hunting, trapping and fishing are relatively unimportant for the permanent population. Hunting and fishing, however, are important economically and are probably responsible for considerable inflows of cash into the local economy. The numbers of species of wild animals is varied, due to the considerable variation in habitat produced by the mountain environment, but numbers are generally low.

4.7 Logistics

4.7.1 The logistics connected with a construction problem along the highway are relatively simple. An all-weather road runs from Whitehorse to Mile 0 of the highway while the existing grade along the Dempster Highway is in good condition. Scheduled air service is maintained out of Dawson City and there is an emergency landing strip at approximately Mile 78.



5. PROGRAM DESCRIPTION

5.1.1 The field work consisted of drilling along the centerline and in prospective borrow areas using two B-40 augers, one of which had a 5 foot stroke and the other had a 20 foot stroke. Both of these machines could be adapted for rotary drilling using either air or water. In this program, rotary drilling, using water as the drilling fluid, was used in investigating some of the bridge sites. For the centerline and borrow area drilling, dry auger only was used. Photographs showing the drilling equipment are in Appendix A of this volume.

5.1.2 In addition to the drilling, some samples of potential borrow and surfacing material were obtained by using a backhoe and also by hand digging.

5.1.3 Concurrent with the field work, air-photo interpretation and terrain evaluation was carried out from the field office.

5.1.4 All laboratory testing of samples was carried out in the Whitehorse Laboratories of the Department of Public Works. Laboratory testing consisted principally of: visual examination, water content determinations, grain size analyses and some Atterberg Limits determinations.

5.1.5 Evaluation of the field data, analysis, computation of borrow availability and requirements and all reporting was completed at the Edmonton office or R.M. Hardy & Associates Ltd.



6. MILE 0 - MILE 11

6.1.1 This section covers the 11 miles of the existing road from its junction with the Klondike Highway to Mile 11. The route lies along the west side of the valley of the North Klondike River with the location being restricted by the river on one side and the steep valley walls on the other. For approximately the first 6 miles, the road is located on a wide glacio-fluvial terrace which is composed of coarse granular material with a generally thin organic cover. At approximately Mile 8 the terrace starts to narrow and at Mile 11 the road moves onto the slopes of the valley wall.

6.1.2 The elevation of the ground surface at Mile 0 is approximately 1433 from which elevation the road climbs in a series of fairly gentle gradients, seldom exceeding 2 percent to an elevation of 2000 at Mile 11 which is approximately the limit of this first terrace.

6.1.3 There are no creeks of any significant size in this section of the road and the number of small drainage paths is quite limited. At Mile 3.9 the road crosses a artificial water course which is presently spanned by a Bailey Bridge. It is planned to remove this bridge and fill the ditch.

6.2 Soils

6.2.1 The soils in this section consist predominantly of coarse granular material ranging from sand through gravel to cobbles. Very little silt and clay was



encountered during test drilling. The thickness of organic material is generally quite thin although depths of up to 3 feet were occasionally encountered in depressions. There appears to have been very little sorting of the soil material by running water which would indicate that these soils were deposited between a glacier occupying the present valley of the North Klondike River, and the valley wall.

6.2.2 From visual observations of the existing borrow pits and the performance of the existing embankment, we conclude that the original ice contents in the soils in this section were very low and that these soils could be classed, where permafrost still exists, as thaw stable. Therefore, only very minor settlements of the grade would be expected following construction of an embankment.

6.3. Borrow Material

6.3.1 There are 22 existing borrow pits in this section of the road of which 15 are of significant size. The material in these borrow pits is invariably coarse in texture with the predominant gradation size being gravel.

6.3.2 If excavation for borrow material is to take place during the winter, it will be found that excavating the frozen coarse granular material, even with an exceptionally low water content, would produce excessive wear and tear on equipment. We therefore recommend that, while



winter construction is possible, summer construction would definitely be more economical.

6.4 Stability Problems in Cuts

6.4.1 There are some low side hill cuts between approximately Mile 6.8 and the end of this section. These side hill cuts are low in height and entail excavation into granular material which can be classified as thaw-stable. Such slopes can be cutback to an inclination of 1.75 horizontal to 1.0 vertical although slightly flatter slopes (two horizontal to one vertical) might be advantageous. The material removed in such cuts could be used in embankment construction.

6.4.2 Shallow cuts are shown on the profile drawing on both sides of the small creek at Mile 5.9. As these cuts will be in the aforementioned coarse granular materials, which are thaw-stable, there will be no problem in either construction or maintenance.

6.5 Erosion

6.5.1 Problems with erosion are not expected in this section due to the coarse nature of the soil and the excellent natural drainage.

6.6 Seepage

6.6.1 Problems with seepage of groundwater during the winter from the sides of cut sections are often experienced in mountainous terrain during the winter. In this section



seepage from the sidehill cuts between Mile 7 and 8 is not expected to be a serious problem.

6.7 Construction Methods and Scheduling

6.7.1 Because of the large amounts of granular borrow material available in this section, construction would be possible during the winter. However, as mentioned above, excavation of frozen granular material is unlikely to be economical and summer and fall construction season is therefore recommended.

6.8 Further Laboratory Testing

6.8.1 No further laboratory testing is recommended in this section. It is our opinion that sufficient data on the soils is available from previous work.

6.9 Discussion and Recommendations

6.9.1 The topographic conditions in this section do not pose any particular problems in highway design and construction. Borrow material is plentiful and there will be no unusual problems encountered in connection with excavating and transporting this material during the summer and fall. It is our opinion that the construction of this section can be carried out most economically during the summer and fall although winter construction could be considered under exceptional circumstances.

6.9.2 Construction activities in this section will consist almost entirely of widening the existing embankment and, in



some places, raising the grade. The only part of this section where entirely new embankment will be constructed is at Mile 8 where some realignment of the existing road will take place.

6.9.3 The material available for embankment construction can be easily placed to a high standard of density without resort to special compaction techniques. A satisfactory standard of compaction can be reached by simply relying on the hauling equipment to provide the necessary mechanical effort. It would be preferable to exclude stones larger than six inches in diameter from the top 2 feet of the embankment profile as it has been found that such stones may work their way to the surface of the road during the winter as a result of frost action. However, the exclusion of such material from the upper part of the embankment would require a screening and rejection system in the borrow pits and the resulting added cost may not be justified.

6.9.4 Coarsegranular material can be placed with side slopes of 1.75 to 1. However, we recommend that the side slopes be made at a slope of three horizontal to one vertical in order to facilitate snow removal from the road shoulders. During the latter part of the winter, it will probably be found that the snow banks which have built up along the sides of the embankment will have to be cleared by bulldozers and the relatively shallow sideslopes of the embankment will facilitate this work.



7. MILE 11 - MILE 24

7.1.1 At Mile 11 the location leaves the terrace, at an elevation of approximately 2000, and is then located on the valley wall slope which is mantled with glacio-fluvial material over weathered bedrock with till also being encountered in approximately the last half of the section.

7.1.2 From an elevation of 2000 at Mile 11, the road climbs almost 500 feet in three miles to an elevation of 2480 with some gradients being approximately 6 percent. From that point, the elevation of the road drops, with generally gentle gradients, to an elevation of 2150 at Mile 16.3. The elevation then varies, with the trend being towards higher elevations, to Mile 24 where the elevation is approximately 2530 immediately before the end of the section is reached.

7.1.3 The drainage is perpendicular to the road with the small creeks and drainage paths draining into the North Klondike River. There are only two streams of sufficient size to warrant bridges in this section.

7.2 Soils

7.2.1 Glacio-fluvial materials are still encountered in this section although the materials form a mantle over the weathered bedrock of the valley walls and are not in the form of a terrace as in the previous section. Till, in the form of clay containing stones and cobbles, was also encountered between Mile 18 and 24. The thickness of



peat is generally quite thin although, in some places, thickness of up to 2 feet were reported.

7.2.2 Very few examples of excess ice content in the subgrade soils are believe to have existed in this section prior to construction of the present embankment. Frozen soil was reported in the drill logs vary infrequently and only where a comparatively thick layer of organic material had been left in place beneath the embankment. Due to the low ice contents in the original subgrade material, settlement of the existing embankment is believed to have been extremely small since construction took place.

7.3 Borrow Material

7.3.1 There are thirty existing borrow pits in this section of the route, not including several extremely small pits which would have yielded only small quantities of borrow. In addition, there are also some places where sidehill cuts were made and where suitable embankment material would have been obtained. Of the existing borrow areas, eight were selected for testing. In addition, there is a sidehill cut at approximately Mile 23 which, a widening of the road takes place, will yield significant quantities of material.

7.3.2 The borrow material in the existing pits along this section of the road consists of coarse granular



material with weathered and broken bedrock being found in many pits.

7.4 Stability Problems in Cuts

7.4.1 There is one cut section at Mile 11.3. In addition, there are also six locations where sidehill cuts were made although, in most of these cases, the object of the original constructors would appear to have been to obtain borrow. Between Mile 23 and 24 there is a fairly long section of sidehill cut although the height of the cut face is not great.

7.4.2 The existing slopes on sidehill cuts all appear to be stable and we have no reason to fear instability should these cuts be further cutback due to road widening. The coarse granular material and weathered bedrock will stand at slopes of 1.75 horizontal to 1 vertical although it would be preferable to cut back the slopes so that they are no steeper than 2 horizontal to 1 vertical. As cutting back the slopes will yield usable embankment material there would be no actual extra cost involved.

7.5 Erosion

7.5.1 Due to the coarse nature of the subgrade materials throughout most of this section, we do not expect that erosion of exposed surfaces will be a problem. In some cases, clay till may be encountered in excavating for



ditches. This material has a high resistance to erosion due to its cohesive properties.

7.6 Seepage

7.6.1 It is possible that seepage or groundwater from sidehill cuts may be experienced in some part of this section particularly during mild winters. This problem is most likely to occur where the thickness of glacio-fluvial material on the slopes is thickest. We suggest that any seepage problems, as they cannot be accurately predicted, should be dealt with as part of the normal winter maintenance program.

7.7 Construction Methods and Scheduling

7.7.1 It is recommended that sources of borrow for this section be restricted to the eight borrow pits investigated and that some material also be obtained from the sidehill cut at approximately Mile 23. If borrow sources are restricted to the nine locations the maximum length of haul will be 1.4 miles and the average length of haul will be 0.4 miles.

7.7.2 While scrapers could be used as haulage equipment, we believe it would be more economical to use large dump-trucks as, in many of the borrow pits in this section, it will be necessary to push the material downslope to a loader. Furthermore, some ripping of the weathered bedrock may also be necessary.



7.8 Further Laboratory Testing

7.8.1 No further laboratory testing is recommended in this section. It is our opinion that sufficient data on the soils and borrow sources is now available.

7.9 Discussion and Recommendations

7.9.1 The topographic and soil conditions in this section do not pose any particular problems in highway construction. Borrow material is plentiful although, for the most part, the quality is inferior to the material available in the first eleven miles of the highway. Excavation of the borrow material, and also excavation in sidehills cuts, will be relatively simple and can probably most economically be accomplished by pushing with bulldozers and loading into dumptrucks. However, there are many borrow pits where it would be economical to use scrapers. It is our opinion that the construction of this section can be carried out most economically during the summer and fall.

7.9.2 There are three sections requiring realignment and construction of a fresh embankment in this section. There is one very short section at Mile 22 and two fairly long sections at Mile 12.5 and Mile 13.7. In the latter case, there may be some small sidehill cuts required of low height. The subgrade soils are generally coarse textured with some silt and clay being reported. We do not expect any problems in construction



of these sections of embankment nor have we any reason to believe there would be problems with settlement due to thawing of any permafrost which may still exist.

7.9.3 We recommend that in construction of the new alignment, and also any widening of existing embankments, the organic surface cover should be left in place and the embankment material should simply be placed on the existing ground surface. Sideslopes should be no steeper than 3 horizontal to 1 vertical in order to facilitate snow removal during the winter.



8. MILE 24 - MILE 32

8.1.1 In this eight mile section of the road, the location crosses a series of alluvial fans which were formed by various streams depositing granular material at the base of the mountains. The elevation of the ground surface in this section ranges from a low of 2470 at Mile 24 to a high of 2780 at Mile 32. The profile of the road is generally gently undulating with gradients being generally less than 3 percent with one short stretch having a gradient in excess of 6 percent.

8.1.2 Drainage is perpendicular to the right-of-way towards the North Klondike River. The principal streams are found at approximately the centers of the alluvial and with the result that many of the large culverts and existing bridges are found at the tops of rises in the road profile. There are only three streams in this section which are crossed by bridges. Two of these bridges are to be replaced by culverts and one Bailey Bridge, at Mile 31.3, is to be replaced by a 40 foot span steel beam bridge.

8.2 Soils

8.2.1 The soils in this area have been sorted during deposition by running water. In general, in alluvial fans, the coarser material is found at the upper end of the fan with the fine material being deposited at the bottom.



8.2.2 The organic cover on the surface of alluvial fans is generally poorly developed and very thin. Thicknesses of peat as great as 2 feet are usually quite exceptional. Ice contents in the alluvial material are generally low with excess ice being most unusual at least in this area.

8.3 Borrow Material

8.3.1 There are more than twenty existing borrow pits in this section of which several are of small size. There are approximately twenty pits of significant size and also two places where material was obtained from sidehill cuts. Although there is a plentiful supply of borrow in this section we would recommend obtaining additional borrow from a limited number of pits. Samples were obtained for further testing from four borrow pits and also from two sideslope locations.

8.3.2 The borrow material available in this section is generally excellent and can be excavated by scrapers or by loading into dumptrucks. While excavation would be possible during the winter, it would almost certainly prove costly and it is therefore recommended that construction of this section take place during the summer and fall.

8.4 Stability Problems in Cuts

8.4.1 The existing slopes cut into the upper side of the alluvial fans in this section are stable and do not exhibit any signs of potential instability. We recommend that, where the existing road is widened, new slopes be



cutback to a slope no steeper than 1.75 horizontal to 1 vertical and that, if possible, slopes be cut back to 2 horizontal to 1 vertical. As the extra~~d~~ excavated material can be used in the embankment, there will be no actual extra expenditure involved.

8.5 Erosion

8.5.1 Due to the granular nature of the soils in this area, no problems of erosion of cut slopes or ditches are expected.

8.6 Seepage

8.6.1 Seepage of groundwater through the alluvial fan material will probably occur during the winter particularly in periods of mild weather. We would expect seepage of groundwater to emit from sidehill cuts in this material. As the locations of such seepage cannot be predicted in advance, we recommend that any problems connection with this phenomenon be dealt with as part of a normal winter maintenance program.

8.7 Construction Methods and Scheduling

8.7.1 Where excavation into sidelopes is required, it will be found that excavation with bulldozers and loading by means of loaders into dumptrucks will probably be the most satisfactory procedure. In the case of borrow, as mentioned above, loading and hauling would probably be most economically accomplished by means of scrapers. However, transport by dumptrucks would permit greater



flexibility in the operation and, in view of the conditions in the preceding section, may well be more economical.

8.8 Further Laboratory Testing

8.8.1 No further laboratory testing is recommended in this section. It is our opinion that sufficient data on the soils is already available.

8.9 Discussion and Recommendations

8.9.1 The topographic and soil conditions in this section are excellent. There is a plentiful supply of borrow material available and the gradients both along the road and perpendicular to it, are not great. Construction would most economically be carried out during the summer and fall and, due to the cost of excavating granular material in the winter, a winter operation is unlikely to be an economical alternative.

8.9.2 It is recommended that the sideslopes of embankments be 3 horizontal to 1 vertical and the cutslopes in sidehill locations be no steeper than 2 horizontal to 1 vertical. Due to the nature of the subgrade soils we see no particular merit in leaving the organic surface cover in place ahead of embankment construction although this material could be left intact to ensure uniformity of construction operations throughout the entire length of the project.



9. MILE 32 - MILE 42

9.1.1 In this section, the road is confined in a very narrow band between the base of the mountains and the North Klondike River. The location generally lies along the river bottom lands. However, in places, the road crosses alluvial fans and there are also some small narrow terraces. The road climbs from an elevation of 2760 to 3260 in a fairly gentle gradual climb with gradients exceeding 5 percent being exceptional. At approximately Mile 41.7 the road crosses the North Klondike River and this section ends, somewhat arbitrarily, on an alluvial fan at Mile 42.

9.1.2 There are nine sections of realignment in this section of the road with some realignment sections being of considerable length.

9.1.3 With the exception of the North Klondike River, there are only two creeks in this section which are presently crossed by bridges. These two latter bridges are to be replaced by culverts. The bridge over the North Klondike River is to be removed and replaced by another bridge.

9.2 Soils

9.2.1 Coarse granular soils predominate in this section with the most common soil mixture being sand gravel and cobbles. Boulders were also commonly reported while silt was often encountered as a thin surface layer



in material close to the river. Clay was very seldom encountered. The peat cover is generally thin.

9.2.2 Excess ice is unlikely to have existed in the subgrade in this section before the permafrost degraded. Frozen ground was only reported during the drilling operation very occasionally.

9.3 Borrow Material

9.3.1 There are numerous very small existing borrow pits in this section of the route with the greatest potential for borrow development being at four locations which are all on alluvial fans. While further development of some of the smaller pits is quite possible, it is believed that a more economical operation would result from developing only the four pits mentioned with some borrow at the north and south ends being brought in from outside the section. The length of haul would be a maximum of 2.1 miles while the average length of haul from the pits would be 0.5 miles.

9.3.2 The borrow material available is granular material which has been sorted by alluvial action during deposition. It could be excavated by scrapers or by loaders loading into dumptrucks. In view of the considerable lengths of new embankment to be constructed in this section, a scraper operation would probably be most economical. However, due to conditions in the other sections along the road, dumptrucks might be less costly.



9.4 Stability Problems in Cuts

9.4.1 There are some existing sidehill cuts in the alluvial fans but the height of the slopes is quite low as mentioned in the previous section, the granular material in the alluvial fans will not lead to any problems in slope stability and can be cutback to a slope of 1.75 horizontal to 1.0 vertical although slightly flatter slopes would be preferable. The material from these cuts can be used in embankment construction.

9.5 Erosion

9.5.1 No problems with erosion are expected in this section due to the coarse nature of the soils.

9.6 Seepage

9.6.1 As mentioned in the previous section, seepage of groundwater through the alluvial fans should be expected during the winter particularly if the weather conditions are unusually mild. However, such seepage is not expected to be serious and, as the locations of seepage cannot be accurately predicted, we recommend that problems due to seepage be dealt with as part of a normal winter maintenance program.

9.7 Construction Methods and Scheduling

9.7.1 As with the previous section, we recommend that construction be carried out during the summer and fall due to the higher cost of excavation in the granular material



during the winter. The better quality borrow material will be found in the alluvial fans and development of the existing pits in these areas should be used to obtain borrow.

9.8 Further Laboratory Testing

9.8.1 We do not recommend any further laboratory testing in this section.

9.9 Discussion and Recommendations

9.9.1 The topographic and soil conditions in this section are good. No problems due to drainage are anticipated and settlement beneath new construction due to thawing of the subgrade is not expected to be a problem.

9.9.2 We recommend that sideslopes on embankments be 3 horizontal to 1 vertical to facilitate the removal of snow from the shoulders and that slopes in cut sections be no steeper than 2 horizontal to 1 vertical.



10. MILE 42 - MILE 60

10.1 For the first 2.5 miles of this section, the existing road runs close to the North Klondike River crossing many small alluvial fans, areas of slope wash and river deposited gravels with most of this material appearing to have been reworked by the river. At Mile 44.5 the road swings away from the river and crosses an area of weathered bedrock where the intact bedrock appears to be close to the ground surface. At Mile 48.0 the terrain changes and the road for the next three miles lies along a dividing line between slope wash on the right and basal till on the left. At approximately Mile 51 the road enters the flatter area of the Taiga Valley. Ground polygons were first observed at approximately Mile 52.

10.1.1 At Mile 53.5 the road location crosses the Upper Blackstone River and then follows close to this water course with the soil materials generally being reworked river gravels. At Mile 56 the alignment cuts across an area of till and then crosses a braided creek bed at Mile 56.6. ^(for creek) The road alignment then lies quite close to the Upper Blackstone River from Mile 57.5 on. Between Mile 58.5 and Mile 59.0 the road location is practically within the river bed.

10.1.2 The lowest elevation of the road in this section is at Mile 42 where the elevation of the ground surface is 3260. From this point the road climbs gently to Mile 44.4



where the elevation is 3480. The road then climbs very steeply, with gradients of up to 8 percent, to Mile 47 where the elevation is 4100. The gradient then drops, fairly rapidly, to the Upper North Klondike River at Mile 47.8 where the elevation of the road is 3990. There is then a steep climb to Mile 50.4 (the summit) where the elevation is 4300. At this point, the road passes its highest elevation between Mile 0 and Mile 78. The alignment then drops rapidly for three miles to an elevation of 3830 at Mile 53.4 and then drops gently to an elevation of 3660 at Mile 59.

10.1.3 The alignment crosses many small creeks in this 17 mile section. There are three river crossings where bridges are planned. These are: the Upper North Klondike River (Mile 47.8), the Upper Blackstone River (Mile 53.7), and Fox Creek (Mile 56.6). All other water courses in this section are to be crossed by culverts.

10.2 Soils

10.2.1 The dominant feature of the soils in this section of the route is the influence of bedrock, and weathered bedrock, which are completely covered by a thin mantle of slope wash and alluvial materials. In general, the soil conditions in this section of the route are more complex, and change much more rapidly, than in previous sections.

10.2.2 In the first two miles of this section, the soils generally consist of a thin covering of silty, sandy gravel



overlying weathered bedrock. Numerous cobbles and boulders were reported in the subgrade although it is possible that many of the boulders were actually slabs of rock. Between Miles 44 and 53, the soil conditions are somewhat similar although silty clay was often encountered, particularly after Mile 46. In the higher areas, broken rock and boulders were reported at very shallow depths. After Mile 53, gravel was more common, particularly in the vicinity of the Upper Blackstone River.

10.2.3 Frozen ground was reported quite commonly beneath the organic surface cover after Mile 54. Ground polygons, indicating severe permafrost conditions, can be observed on the aerial photographs from Mile 52 northwards. The soil in most of these polygon areas is sandy gravel with relatively low ice contents.

10.3 Borrow Material

10.3.1 There are over forty existing borrow pits along this section of the route with the majority being extremely small. The large number and small size of these pits indicates that the original constructors of the road encountered a severe shortage of borrow material. Following a visual examination of the existing pits, it was decided, in the field, to obtain samples from eight existing pits for laboratory testing. It is believed that a more economical operation would result from concentrating borrow excavation in this relatively small number of pits rather than attempting



to develop a larger number of pits which, on visual examination, appear to hold little promise of yielding significant quantities of borrow material.

10.3.2 The borrow material along this section of the road consists, to a considerable extent, of weathered and broken bedrock. The surficial material, generally consisting of slope wash, is less desirable as borrow material but could still be used where material with more desirable properties is in short supply. It would appear that the borrow material in this section of the road is of much lower quality than in any of the sections to the north or south.

10.3.3 It is expected that permafrost will be encountered at relatively shallow depths in most of the borrow areas in this section. The most economical method of excavating such material in the summer would be to strip off the thawed material each day by means of bulldozers and to load the material into trucks by means of loaders. It would probably be necessary to "juggle" the excavating equipment in order to allow the thaw to penetrate to sufficient depth between different phases of the excavation process. The influence of permafrost on the economics of construction in this section may therefore be quite serious. An alternative source of borrow would be in the gravels found in some of the creeks in this area, particularly the Upper Blackstone River. However, it is probable that environmental considerations would prohibit this approach.



10.4 Stability Problems in Cuts

10.4.1 There are numerous small sidehill cuts in the section Mile 45 to Mile 50 and also between Mile 55 and Mile 56. Most of these sidehill cut sections are relatively short and the height of cut is usually low. The existing slopes appear to be stable although it is possible that individual large pieces of broken rock may break away from exposed faces during the early summer.

10.4.2 Cutting back the existing slopes in order to widen out the road will, in many cases, entail excavating into bedrock. Drilling and blasting may therefore be required. It is probable that cutting back existing sidehill slopes will not, therefore, be an economical means of obtaining borrow material.

10.5 Erosion

10.5.1 There is no evidence of serious erosion of the soils in this section. Revegetation of exposed soil proceeds extremely slowly when left to natural sources. It is possible that some erosion of fine grained surface soils_{SSS} may be encountered following construction but the extent of such erosion damage will be very small due to the small drainage areas producing the runoff water.

10.6 Seepage

10.6.1 It is possible that seepage of groundwater from sidehill cuts may be experienced in some parts of this section



during mild winters. This problem may occur where the seepage originates from the bedrock. As seepage problems cannot be accurately predicted, we suggest that they be dealt with as part of a normal winter maintenance program.

10.7 Construction Methods and Scheduling

10.7.1 It is recommended that sources of borrow for this section be restricted to the eight borrow pits investigated with some material being obtained where sidehill cuts are widened. If borrow sources are restricted to these eight locations, the maximum length of haul will be 1.7 miles and the average length of haul will be 1.0 miles.

10.7.2 For the reasons stated above, we believe it would be more economical to use dumptrucks with the material in the pits being handled by bulldozers and loaders. The scheduling of excavation operations in the borrow pits in this section will probably be fairly complex.

10.8 Further Laboratory Testing

10.8.1 Should the length of haul for the material, as given in the previous section, be considered to be excessive, it may be advisable to obtain samples from other borrow pits and make the test data available to prospective bidders.

10.9 Discussion and Recommendations

10.9.1 The topographic, soil and permafrost conditions in this section of the Dempster Highway are the most serious encountered within the first 78 miles. Borrow material is



sufficient for the purposes of reconstruction although it is concentrated in relatively few pits. Furthermore, the quality of much of the borrow material is inferior to the material available in other sections of the highway.

Excavation of the borrow material, and also excavation in sidehill cuts, will be complicated by the presence of relatively large pieces of weathered bedrock which will be too large for inclusion in the embankment. It is our opinion that the construction of this section can be carried out most economically during the summer and fall.

10.9.2 During construction of new embankment in the lower lying areas of this section, we recommend that the organic surface cover should be left in place and the embankment material should simply be placed on the existing ground surface. In the higher ground, which lies on either side of the summit, the existing organic cover is extremely thin and, as the bedrock is relatively close to the surface, we do not believe its removal would materially affect the performance of an embankment placed upon it. It should be pointed out, that, in the higher parts of this section the amount of realignment of the existing embankment is extremely small due to the constraints imposed by the topography.

10.9.3 Sideslopes on embankments should be no steeper than 3 horizontal to 1 vertical in order to facilitate snow removal by both wind action and snow ploughs. In the case of cuts the excavated slopes should be cutback to no steeper than



2 horizontal to 1 vertical, where surficial overburden is encountered, but can be almost vertical in sound bedrock.



11. MILE 60 - MILE 78

11.1.1 In this section, the highway follows along the valley of the Upper Blackstone River for the first ten miles to Mile ~~60~~⁷⁰ where the Upper Blackstone River has its confluence with the Blackstone River. From that point to Mile 78 the road follows the Blackstone River.

11.1.2 The gradient drops gently from an elevation of 3650 at Mile 60 to an elevation of 3100 at Mile 78. The drop in elevation is almost continuous with there being very few positive gradients in the northward direction. In only a few locations does the gradient exceed 3 percent.

11.1.3 As in all the preceding sections, the main line of drainage is parallel with the road although, in contrast with the preceding sections, the main line of drainage is now northwards. The secondary drainage is perpendicular to the road alignment with there being numerous small creeks which are spanned by culverts. There is to be a bridge over the Blackstone River at Mile 72.8.

11.2 Soils

11.2.1 Gravels were encountered in almost all test holes in this section. In those locations close to the river bed, the gravels were encountered close to the surface. At locations further from the river, the gravels were covered by organic and fine grained soils with the latter apparently being deposited by slope wash. The bulk of the fine grained



soils consisted of silt although clay was often found as a constituent part of the soil mass but never as the dominant soil type.

11.2.2 Considerable thicknesses of organic material, mainly peat, were encountered in this section with thicknesses exceeding 6 feet being quite common. The thickness of the peat in this section is in contrast with thicknesses encountered in previous sections which were generally quite thin.

11.2.3 Large masses of clear ground ice were also quite commonly encountered in this section. The most southerly location of mass ice was at approximately Mile 62 although it should be pointed out that similar clear ice masses could be found further south than this point although they were not encountered during the drilling. It is significant that masses of clear ice were encountered in some sections beneath the existing road embankment which has been in place for several years. In these cases, it was noted that the original peat cover had been left in place during road construction so that the insulation of the peat has retarded the penetration of the thaw plane into the ground.

11.2.4 Ground polygons are very commonly observed in this section. These polygons, and the paucity of tree cover, indicate the severity of the climate which, owing to its northerly location and the elevation, probably produces conditions which are more nearly Arctic than sub-Arctic in nature. Brown (7) is of the opinion that the thickness



of the permafrost in this area could be as much as 1000 feet
which is similar to the thickness encountered near the
Arctic coast.

11.3 Borrow Material

11.3.1 There are more than 60 existing borrow pits in this section of the route, many of which are quite small. Twelve of these existing pits were selected, on the basis of visual examination, as being most desirable for further exploitation for embankment material. In addition, there are a number of small cuts which will be made in this section of the route which may yield small quantities of suitable material.

11.3.2 The material in the existing pits which were selected for further laboratory testing is generally coarse granular material, mainly gravel with cobbles, but with significant proportions of silt and fine sand. Generally speaking, the amount of stripping of unsuitable material will be relatively small.

11.4 Stability Problems in Cuts

11.4.1 There are five proposed cut sections in this section of the highway. The depth of proposed cut ranges from 6 to 20 feet with the average depth of cut being approximately 10 feet. The test hole logs indicate that the soil type at the locations of these cuts is generally gravel with ice contents being usually low. We are of the opinion that the side slopes in these cuts should be stable on



completion of excavation with slopes of 1 vertical to 2 horizontal. However, it may be preferable to make the slopes somewhat flatter to allow for some sloughing particularly in the first two or three years following construction. As the material in these cuts will be suitable for embankment use, the extra excavation will not involve any significant increase in cost.

11.5 Erosion

11.5.1 The gravels in this section are resistant to erosion due to their size. Those areas which are still covered by peat will also be resistant to erosion and, for this reason, it is important that as little damage as possible be done to the peat cover outside the limits of the embankment fill.

11.6 Seepage

11.6.1 Problems due to seepage of groundwater are not expected to arise in this section.

11.7 Construction Methods and Scheduling

11.7.1 It is recommended that borrow material for embankment construction in this section be obtained from the twelve pits selected for testing. If borrow sources are restricted to these locations, the maximum length of haul will be 1.4 miles and the average length of haul will be 0.7 miles.

11.7.2 Due to the presence of permafrost in most of these pits, we believe it would be more economical to use dumptrucks with the material in the pits being worked by bulldozers and loaders.



11.8 Further Laboratory Testing

11.8.1 No further laboratory testing is recommended in this section. It is our opinion that sufficient data on the soils and borrow sources is now available.

11.9 Discussion and Recommendations

11.9.1 The topographic and soil conditions in this section do not pose any particular problems in highway construction. Borrow material is reasonably plentiful and the quality is generally fairly good. Excavation of the borrow material will be complicated by the presence of permafrost which will require scheduling of the construction operation so as to take advantage of natural thawing action. It will therefore probably be more economical to use dumptrucks for hauling the material than scrapers. It is our opinion that the construction of this section can be carried out most economically during the summer and fall.

11.9.2 As stated above, Brown is of the opinion that the thickness of the permafrost in this area could reach 1000 feet. While we have no actual climatic data on which to base our judgement, we believe it is safe to assume, based on Brown's opinion and the presence of frost polygons, that the climatic conditions are very similar to those found in the Inuvik area. We would therefore suggest that the degradation of the permafrost beneath a highway embankment is unlikely to exceed 8 feet, measured from the surface of the embankment, where the fill



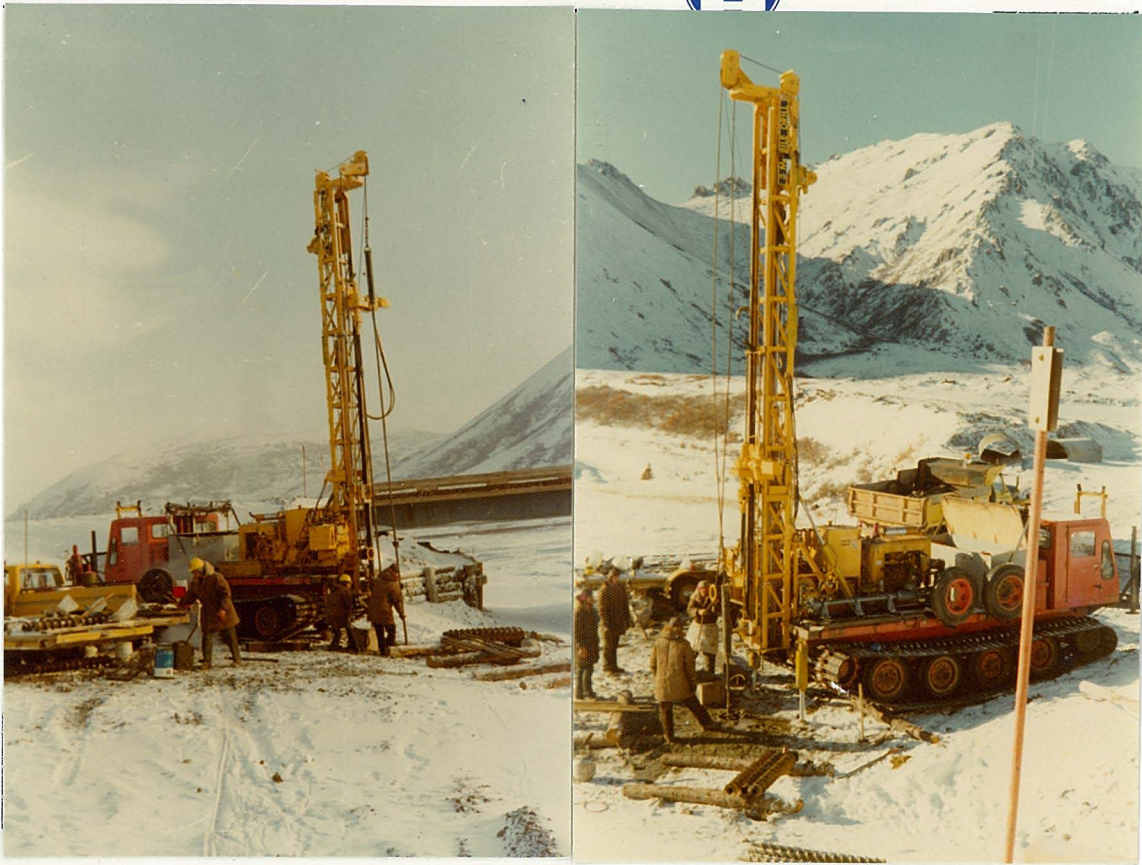
in the embankment is gravel. Therefore, we do not recommend attempting to excavate any of the massive ice deposits encountered on the route. It would of course be impossible to locate all of them except by drilling an extremely large number of test holes. Such an investigation program is unlikely to be economical.

11.9.3 It is imperative that the existing peat cover be left intact and that the embankment be constructed by end dumping the material from dumptrucks with no equipment being permitted to operate off the embankment or haul roads.

11.9.4 We recommend that the sideslopes on embankments should be no steeper than 3 horizontal to 1 vertical in order to facilitate snow removal by wind action and mechanical equipment. Slopes in cut sections can be 2 horizontal to 1 vertical but flatter slopes may be advisable to allow for sloughing of material.



APPENDIX A
Photographs



Photograph No. 1 (above left): The Mobile B-40L drill rig drilling at a bridge site. This machine has a 20 foot stroke which increases the efficiency of the operation considerably.

Photograph No. 2 (above right): Another view of the same drill rig. The crew is about to start a Standard Penetration Test. At this test hole, auger of 6 inch diameter was being used. Some of the 5 foot long auger sections can be seen in the foreground. In the left foreground can be seen some drill rod lying across the rough dunnage. Note the stabilizer hydraulic jacks at the rear of the Nodwell tractor. This same drill rig can be adapted for rotary drilling, including coring, using either water or compressed air as the drilling fluid.



Photograph No. 3: A view of the existing grade at approximately Mile 5 looking north. Note the excellent state of this section of the highway which is typical of long stretches between Mile 0 and Mile 60. The tree cover on the left is typical for the first 43 miles of the highway. The dominant tree is white spruce.



Photograph No. 4: A view from an old borrow pit looking south easterly across the existing road with the North Klondike River in the background. Note the abundance of coarse material in the borrow pit. Most of the existing borrow pits in the first 50 miles of the highway could be reopened, and extended, as required to obtain fill material.



Photograph No. 5: Looking from the highway grade down Benson Creek at approximately Mile 17.8. Note the extremely coarse granular material in the stream bed.



Photograph No. 6: A closeup of some of the stream bed material in the previous photograph. The cap in the foreground gives the scale.



Photograph No. 7: The existing Bailey Bridge at Wolf Creek at approximately Mile 31.4, looking upstream. This Bailey Bridge has a 40 foot span and is of single-single construction. It is to be replaced with a steel beam bridge. Note the abundance of coarse granular material in the stream bed and the proximity to the mountains in the background.



Photograph No. 8: Looking northerly from approximately Mile 30 with the valley of the North Klondike River to the right. The existing road can be observed in the centre background on the left side of the valley.



Photograph No. 9: The existing bridge where the road crosses the North Klondike River at approximately Mile 41.7. This view is looking upstream in a northerly direction. It is at approximately this point along the highway that the road passes out of the zone of thick spruce forest and into an area of scrub and alpine tundra.



Photograph No. 10: A closer view of the existing bridge on the North Klondike River shown in the above photograph. In the background, can be seen extensive talus slopes.



Photograph No. 11: The existing Bailey Bridge over the Upper North Klondike River at approximately Mile 47.8. Upstream is to the right of the photograph.



Photograph No. 12: Looking southerly from approximately Mile 58. Note the very few scattered spruce trees and the shape of the valley. The road can be observed crossing from the left foreground to the right background.



Photograph No. 13: Looking northerly from approximately Mile 50 near the "summit" which is the highest point between Mile 0 and Mile 78.



Photograph No. 14: Looking northerly at approximately Mile 75. Observe the flat bottom of the valley in this area. Drainage in this section is relatively poor with a thick peat and moss cover and a very shallow active layer.



APPENDIX B
Explanation Sheets



EXPLANATION OF TERMS AND SYMBOLS

USED ON TEST HOLE LOG SHEETS

Depth

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

Sample Number

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

Sample Type

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

Disturbed samples were obtained from the returned cuttings.

T indicates tube sample

C indicates core sample

indicates large grab sample

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

Percent Recovery

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



Penetration Resistance

Unless otherwise noted this column refers to the number of blows (N) of a 140 pound hammer dropping 30 inches required to drive a 2 inch O.D. open end sampler a distance of one foot from 0.5 to 1.5 feet into the soil. This is the standard penetration test referred to in ASTM, D1586.

Unified 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.



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 interstitial 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

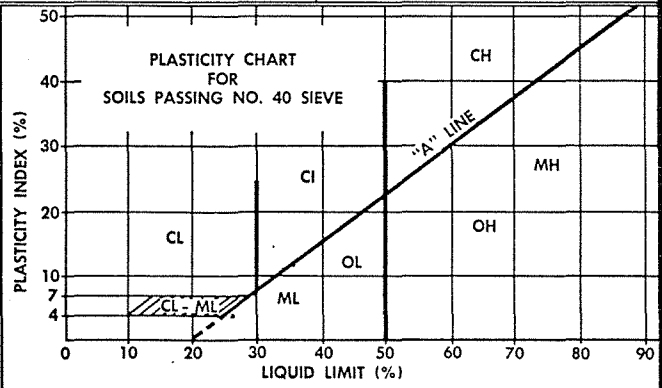
The plastic and liquid limits are shown on the water content chart by a horizontal bar. The Atterberg system is discussed in the following section.

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	[Symbol: Small triangles]	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	[Symbol: Small circles]	RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS			
		DIRTY GRAVELS (WITH SOME FINES)	GM	[Symbol: Vertical lines]	YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4		
			GC	[Symbol: Diagonal lines]	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	[Symbol: Small circles]	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	[Symbol: Small dots]	RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS			
		DIRTY SANDS (WITH SOME FINES)	SM	[Symbol: Vertical lines]	YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4		
			SC	[Symbol: Diagonal lines]	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 NEGLECTIBLE ORGANIC CONTENT	$W_L < 50\%$	ML	[Symbol: Vertical lines]	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	[Symbol: Vertical lines]	BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS			
CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLECTIBLE ORGANIC CONTENT		$W_L < 30\%$	CL	[Symbol: Diagonal lines]	GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS				
		$30\% < W_L < 50\%$	CI	[Symbol: Diagonal lines]	GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS				
		$W_L > 50\%$	CH	[Symbol: Diagonal lines]	BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS				
ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART		$W_L < 50\%$	OL	[Symbol: Vertical lines]	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	[Symbol: Diagonal lines]	BLUE	ORGANIC CLAYS OF HIGH PLASTICITY				
HIGHLY ORGANIC SOILS		Pt	[Symbol: Wavy lines]	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

<u>Predominant Characteristic</u>	<u>Category</u>	<u>Name</u>
	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 TRANSPORTATION
ENGINEERING, S-3

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

<u>Symbol</u>	<u>Description</u>
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.