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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20386652
Internal Report (National Research Council of Canada. Division of Building Research), 1974-11-01

NATIONAL RESEARCH COUNCIL OF CANADA
DIVISION OF BUILDING RESEARCH

INSULATED ROADWAY ON PERMAFROST MACKENZIE HIGHWAY, INUVIK, N.W.T. – DESIGN, INSTRUMENTATION AND CONSTRUCTION OF TEST SECTIONS

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Internal Report No. 417
of the
Division of Building Research

OTTAWA
November 1974

INSULATED ROADWAY ON PERMAFROST
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PREFACE

The use of a layer of insulation in embankments constructed on permafrost to prevent thawing of underlying ice rich soils and the inevitable settlements that occur, is a construction technique of great potential in northern areas. Information, particularly on the thermal aspects, is required, however, to improve design and construction procedures. A field study was undertaken, therefore, by the Canadian Government Inter-departmental Committee on Highway Insulation, to evaluate the performance of insulated embankments constructed on permafrost.

Several insulated and uninsulated test sections were constructed on the Mackenzie Highway near Inuvik, N.W.T. in 1972. This report has been prepared to record details of the design and construction of the test sections and the instrumentation installed to monitor changes in the ground thermal regime and movements of the embankment.

The authors are research officers in the Geotechnical Section, DBR/NRCC, and were responsible for the design of the test sections and the instrumentation as well as the supervision of their construction and installation.

C.B. Crawford
Director

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I. INTRODUCTION

Degradation of permafrost under highways, railroads and runways constructed over ice-rich soils can result in significant settlement (and possibly failure due to unstable foundation and side slope conditions) and, therefore, high maintenance costs over a period of years. Whenever possible, embankments are designed to prevent thawing of ice-rich subgrades. In some areas (generally in the discontinuous permafrost zone) this is not feasible, because of the very thick fills that must be constructed. Large quantities of suitable fill material are not always readily available in some northern areas and, therefore, must be hauled for long distances at great expense. Excavation and placement of borrow materials, which are usually frozen, pose additional problems.

An alternative approach is to construct a shallower embankment that will retard, to some extent, the rate of thaw in the subgrade and accept the settlements that will occur and the maintenance that will be required. Permafrost conditions can be extremely variable over short distances, however, and differential movements and the remedial work required to maintain a good surface for traffic throughout the year may not be acceptable.

The use of a thermal insulating layer placed in an embankment is a concept that is now well established in seasonal frost areas to reduce frost penetration into a frost susceptible subgrade and thereby minimize frost heave and damage to pavements. Insulation can also be used to advantage to control ground temperature changes in permafrost. The inclusion of a layer of insulation in a road or runway to prevent thawing of ice-rich subgrades and substantially reduce the quantity of fill required is a construction technique of great potential now being investigated by the Government of Canada.

Planning for the expansion of the highway system in northwestern Canada had indicated that these problems as well as a number of others would be encountered in the design and construction of roads in permafrost areas. It was realized in particular, that thermal design procedures were not well established and that there was a need for information on the relevant parameters. Late in 1971, the Federal Government established the Interdepartmental Group on Highway Insulation (IGHI)* to examine the potential use of insulation in roadways constructed on permafrost. Following consideration of the problems involved and the need for information primarily for design, but also for construction, purposes the IGHI decided, early in 1972, to undertake a full-scale field study and construct several test sections in northern Canada to evaluate the thermal performance of an insulated roadway.

A contract had been let in mid 1971 for the construction of 33 miles (Mile 931 to 964) of the Mackenzie Highway south from Inuvik, N.W.T. (Fig. 1 and 2). It was agreed that the test sections would be installed at a suitable location on this route because it was in a permafrost area where insulation could be used to advantage and construction equipment would be available from the contractor working on the job. In addition, because the test sites would be relatively close to the major settlement of Inuvik, good access and support facilities would be available during the proposed 4- to 5- year life of the study.

Several types of insulating material were considered for the test sections; extruded polystyrene boards, having previously been used successfully in seasonal frost areas, were chosen. Great interest in the project was expressed by the Dow Chemical Company of Canada who provided all the insulation and are participating in the study.

This report describes the design, instrumentation and construction of the test sections installed on the Mackenzie Highway near Inuvik, N.W.T.

II. DESIGN OF TEST SECTIONS

Contract specifications prepared by the Department of Public Works for the 33-mile stretch of highway south from Inuvik called for a 24-ft wide roadway (shoulder to shoulder) with a 0.5-ft crown and

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* Members

Department of Indian and Northern Affairs, Technical Services Branch

National Research Council of Canada, Division of Building Research

Department of Public Works, Civil Engineering Division

Ministry of Transport, Highway Branch

Participant

Dow Chemical Company of Canada Limited

3:1 side slopes. An average fill about 5 ft thick was to be placed by end dumping material hauled from borrow pits located along the route. It was anticipated that the contractor would carry on construction operations throughout the year and that fill would be placed both summer and winter. The right of way had been hand cleared of trees and brush early in 1970.

As a first step in the design of the test sections it was necessary to predict an optimum thickness of insulation that should be used in the Inuvik area. Very limited information was available on soil (both subgrade and fill materials), permafrost and climatic conditions at potential sites along the route and, therefore, several assumptions had to be made for calculation purposes.

It was assumed that the subgrade materials would consist of high ice content silts or silty clays overlain by a 0.5- to 1-ft layer of organic material (peat). The road would be constructed of granular material about 4 ft thick with the layer of insulation placed in the fill about 1.5 to 2 ft above the original ground surface. In addition, it was assumed that fill placed during the winter would be laid directly on the snow cover so that a layer of snow would underlie the embankment.

Observations made over a number of years in the Inuvik area by DBR/NRC, indicate that the mean annual ground temperature at a depth of 50 to 100 ft is about 26.0°F.

Meteorological observations had been made at the Inuvik airport since 1958 and the air temperature data shown in Table 1 for the 10-year period 1960-69 inclusive was calculated from records obtained at that site. A preliminary review of the data obtained by DBR/NRC as part of a long term study of the performance of the Inuvik airstrip showed, for example, that during the one year period September 1970 to September 1971, the mean annual surface temperature of the gravel surface of the runway shoulder was about 16.5°F. The mean annual air temperature during the same period was 12.0°F, i.e. about 4.5°F less.

Numerical methods for ground thermal analysis developed independently by DBR/NRC and Dow Chemical were used to predict changes in the ground thermal regime. Several runs were made on the computer by both organizations using assumed values for temperature distribution in the ground, physical and thermal properties of the subgrade and fill materials and for seasonal fluctuations in air and ground surface temperatures. The ground surface temperature was assumed to be either the same as the air temperature or to be several degrees warmer and to vary sinusoidally during the year. Various thicknesses of extruded polystyrene foam insulation were considered as well as construction under winter (subgrade completely frozen and fill placed on snow cover) and summer (active layer thawed) conditions.

The results of these computations indicated that an optimum thickness of about 3 to 3.5 inches of extruded polystyrene insulation would be required to prevent thawing of the subgrade, i.e. below the original ground surface under the centre line of the roadway. Edge effects from the side slopes were not included in the calculations, nor were changes in geometry that might occur from settlement of the road resulting from thawing of the subgrade. The analyses also indicated that the major changes in the ground thermal regime due to the new conditions imposed on the ground surface (construction of a layered embankment) would occur during the initial 4 to 5 years following construction. Equilibrium conditions would not be reached until some time later.

Because construction would be carried on throughout the year it was decided by the IGHI that test sections would be installed under both winter and summer conditions. One group of test sections would be constructed in the late winter (April) when the subgrade and fill (placed directly on the snow cover) would be completely frozen and ground temperatures would be at near-minimum values for the year. A second group of test sections would be constructed in late summer (September) when the thaw (depth of the active layer) was greatest and ground temperatures would be near their maximum value for the year. The winter and summer test sites were to be located as close as possible to each other (depending on site conditions) to simplify making observations and comparisons.

It was considered important that the performance of sections containing different thicknesses of insulation should be included in the experiment for comparison with each other and with that of an uninsulated embankment. The thermal behaviour of all test sections, both insulated and uninsulated, would also be compared with the ground thermal regime in an adjacent undisturbed area.

Although it was recognized that the rate and depth of thaw would be greater under the side slopes, and thus cause slumping and decrease the roadway width, no special measures were taken to insulate or protect the slopes. Observations would be made, of course, to assess their behaviour. Based on the highway specifications (24 ft top width, 3:1 side slopes) and assuming that 2 ft of backfill would cover the insulation, the width of the layer of insulation at all test sections would be 36 ft.

Three 125-ft long test sections would be constructed at each of the "Winter" and "Summer" sites. At the winter site, two insulated sections (one containing a 2-in. thick layer of extruded polystyrene boards, the other a 3.5-in. thick layer) would be separated by an uninsulated test section for comparison. At the summer site, two insulated sections (one having a 3.5-in. thick layer of insulation, the other a 4.5-in. thick layer) separated by an uninsulated section would be constructed.

Special problems arise when roads are constructed in areas underlain by ice wedges. Thawing and erosion of the buried ice masses often cause drainage problems and severe differential settlement, difficult and costly to repair. It was suggested, therefore, that if ice wedge terrain existed along the route, consideration should be given to installing a third test site to evaluate the usefulness of an insulated embankment in preventing or reducing thaw and settlement problems and extensive maintenance work.

III. SITE INVESTIGATION AND SELECTION

1. General Considerations.

The contractor (Catre Construction) had started work during the late summer of 1971 and, by the end of March 1972, had constructed a rough embankment 2 to 3 ft thick from Mile 964 (junction of the Mackenzie Highway with the Inuvik airport road) south to Mile 950. Every effort was being made by the contractor to cover as much distance as possible towards the south end of his contract (Mile 931) before spring break-up to give access to as many borrow pits as possible. During the summer of 1972 the contractor proposed completing the section already constructed, that is, bring it up to grade and trim it to the required standards.

It was hoped (and highly desirable) that the test sections could be constructed on previously undisturbed terrain, either by placing them on the right of way adjacent and parallel to the highway or ahead of where the contractor was working. However, this was not possible for several reasons, including environmental restrictions on overland travel, the very high cost of constructing a separate test roadway using fill that had to be hauled perhaps for several miles, difficult access to investigate and prepare potential sites ahead of the contractor and because construction of the test sections might seriously hamper and delay the contractor in his attempt to cover as much distance as possible before break-up. The test sections had to be constructed, therefore, at the best possible location on the partially constructed road between Mile 964 and Mile 950.

Several important factors, which could greatly influence the ground thermal regime and thus evaluation of the test results, had to be considered in selecting suitable test areas. These included alignment, design grades, general drainage patterns, location of streams and lakes adjacent to the highway, topography (e.g. patterned ground, side hills, micro-relief features, etc.), surface cover, subsurface (soil and permafrost) conditions and the type of material used in the rough grade already constructed. It was hoped that the test sites could be located on level, previously undisturbed terrain, on an east-west tangent section of road (i. e. not on a super elevated curve) underlain by relatively uniform frozen soils (preferably ice-rich) and free of drainage influences (e.g. side hills or downgrades, culverts, ponding, etc.) in order to eliminate or minimize the effect of as many variables as possible and to evaluate southern versus northern exposure.

The authors had not seen the highway route south of Inuvik under summer conditions and were not familiar with details of the local terrain. Considerable time was spent, therefore, examining air photos in detail and reviewing design drawings and soils information provided by DPW, before proceeding to the field in mid-March, 1972. Two days were spent in a very careful ground examination of the route between Miles 964 and 950. Snow cover did not permit a detailed assessment of surface features, but many potential test site locations were eliminated almost immediately because they were on side hills, downgrades, at culvert locations or immediately adjacent to lakes, were probably underlain by bedrock at shallow depth, etc. and , in particular, because the highway had been constructed in many places along the route of an access trail used by construction forces during installation of the C.N.T. telephone land line some 2 to 3 years previously. Heavy traffic on this access road had seriously damaged or destroyed the original ground cover and created changes in the ground thermal regime which would complicate analysis of observations at test sections constructed in such areas.

The only location that satisfied most of the requirements lay between contract stations 380 and 400 (Mile 956.6)--immediately west of Campbell Creek (Fig. 2). This section contained no culverts, was in relatively flat terrain (no sidehills or downgrades), on an east-west tangent approaching the Creek (located at sta. 405). The surface cover had not been disturbed. In addition, the C.N.T. access trail bypassed this part of the highway right of way to the south and, therefore, could be used by the contractor's hauling equipment (at least during the winter) when the first test sections were being prepared and constructed.

There was a possibility that during the spring break-up period, flood waters from the Mackenzie River might encroach on this area.

Elevation control used along the highway is based on an assumed datum established in April 1954 at Inuvik (L. W. L. of the East Channel = 0.00 ft). High water levels during the spring flood at Inuvik frequently reach 20 ft above this datum. The elevation of the ground surface at the proposed location of the test site is also about 20 ft; and it was anticipated that flood waters from Campbell Lake (just south of the test area), which is upstream of Inuvik and directly connected to the Mackenzie River Delta, could reach that elevation, or even higher, in peak flood years. It was concluded that if flood waters did reach the highway at the proposed test site location, they would only persist for a very short time (perhaps 3 or 4 days) and, therefore, would not have any serious or lasting effect on the ground thermal regime or the test sections in general.

Examination of air photos showed that the highway crossed polygonal features (presumably underlain by ice wedges) at several locations but none of these sites were considered suitable for the construction of a test section for evaluation of an insulated fill placed over ice wedge terrain. Polygons were clearly visible on the air photographs (and on the ground) just north of the highway at Mile 957 but were not evident on the adjacent right of way. Despite this it was decided that a test section could be located about sta. 370 (Mile 957) anticipating that ice wedges might be present at that location.

Before the final selection of the test sites was made, a subsurface exploration program was carried out to determine soil and permafrost conditions at the proposed locations.

2. Soil and Permafrost Conditions

Early in March, 1972 DPW forces drilled 17 holes on the right of way between sta. 386 and 393 + 50 to depths of from 12 to 20 ft with a track mounted drill using an air-flush, non-coring bit. Bag samples of the cuttings were taken for identification and classification of the soils and moisture content determinations. More complete information was required, however, and Mackenzie Valley Pipeline Research Ltd., (MVPRL), who were carrying out a detailed drilling program in the area in connection with oil pipeline route studies, was retained under contract to obtain undisturbed cores at the proposed test sites using two track-mounted Failing drills. Cores were taken with 4-inch diameter hollow stem flight augers about 2 ft long--commonly referred to as the "Gas Arctic" barrel or modified SIPRE barrel (Fig. 3). The core bit was set with 2 or 4 replaceable tungsten carbide teeth.

Six holes were cored under NRC supervision on 30 and 31 March 1972 at 4 locations to depths ranging from 9 to 60 ft. Two holes (D-1 and -1A) were drilled on centreline at the proposed location for the summer test site. At the proposed winter test site, two boreholes (D-2 and -2A) were drilled on centreline and one hole (D-4) was drilled 87 ft south of centreline. Hole D-3 was drilled on centreline at the proposed polygon test site. Undisturbed cores were taken for the full depth of all holes with the exception of hole D-4 where 2-ft long cores were obtained at about 3 to 4 ft intervals between 30 ft and 55 ft. The location of all boreholes (both DPW and MVPRL) are shown on Figure 4.

All cores were examined and logged as soon as they were extruded from the barrel at the drill hole. They were then wrapped in cardboard insulation and placed in an insulated box for transportation to the laboratory in Inuvik where they were maintained in a cold room at a temperature of about 28°F until they were tested within a week or two. Most of the core samples were trimmed on a lathe in the cold room to remove the thin skin of partially disturbed material resulting from the coring operation. The frozen bulk density of all intact cores was determined by carefully measuring and weighing the trimmed samples. Photographs were taken of most cores either in the frozen state or after they had been allowed to thaw slightly at room temperature. Moisture contents were measured and dry densities calculated for all samples. Representative samples were selected and shipped by DBR/NRC to the DPW soils laboratory in Edmonton for identification and classification tests.

Borehole logs and soil test results are given in Appendix 1. Photographs of typical cores are shown in Figures 5 to 8.

The above investigations showed that a typical soil profile for the area consists of a layer of organic material from 6 to 24 inches thick underlain by a grey, silty clay to a depth of from 10 to 15 ft. Beneath the silty clay is a dense grey sandy silty till extending to a depth exceeding 60 ft. The organic layer contains typical random inclusions and lenses of ice and the layer of silty clay is ice-rich containing as much as 50 per cent ice by volume mainly in the form of lenses from hairline to 1 in. thick. The underlying till is generally well bonded with very little visible ice segregation. The visible ice content in the till varied from 0 to 15 per cent by volume with occasional lenses up to 1/2 in. thick.

The entire area is covered with hummocks ("frost boils") ranging from 0.5 to 1.5 ft in height and 2 to 6 ft in diameter. On 26 September 1972, 32 hand probings (16 in the centre of the hummocks and 16 in the depressions between hummocks) were made in undisturbed areas at all test sites to determine the depth of thaw. The depth of thaw in the trenches between the hummocks ranged from 0.5 to 2.3 ft (average thaw = 1.6 ft); the depth of thaw in the hummocks ranged from 1.5 to 3.3 ft (average thaw = 2.3 ft).

IV. CONSTRUCTION OF TEST SECTIONS

1. Winter and Polygon Test Sites -- April 1972

The three test sections (two insulated and one uninsulated) at the "Winter Site" (sta. 386 + 00 to 389 + 75) and one insulated test section at the "Polygon Site" (sta. 369 + 50 to 370 + 50) were constructed between 3 and 22 April 1972 (Fig. 9). A 2- to 3-ft thick embankment had been built in this area by end dumping in late November, 1971. The fill, which was placed on the snow covered ground surface, was obtained from a borrow pit located approximately 1/2 mile west of the highway at Mile 958.6 and consisted of frozen lumps, some as large as 2 ft in size, of medium to coarse sand and fragments of sandstone and shale. The only compaction achieved when the fill was placed resulted from the tractor levelling the material as it was dumped and from the equipment (self propelled scrapers) travelling over it. Thus, some lumps were broken down but much of the fill was still quite coarse and in a "loose" frozen condition.

The polystyrene insulation boards (2 ft wide by 8 ft long) must be laid on a relatively level surface, to prevent them from breaking when covered with backfill. A "bedding" layer, 6 in. to 1 ft thick was required on the ground surface, therefore, to fill in the troughs between the hummocks and provide a level surface.

A D-9 tractor with ripper and bulldozer blade was used to excavate about 2 ft of the existing fill and stockpile or spread it at the ends of the test sites. The remaining 0.5 to 1 ft of fill was then levelled and compacted by a motor patrol and grid roller. A suitable, level surface could not be obtained, however, because of the hard frozen lumps of sand and the rock fragments and, therefore, a relatively dry, silty sand was hauled by scrapers from a borrow pit near Mile 948.4. About 6 in. of this material was spread on the test sections and levelled and compacted by the grader and grid roller to provide a satisfactory bedding layer for the insulation (Fig. 10). After installing thermocouple cables (details given later) in the bedding layer and subgrade, the insulation boards were laid by hand.

At the winter site a 36-ft wide, 3.5-in. thick layer of insulation, consisting of a bottom layer of 2-in. thick boards and a top layer of 1.5-in. thick boards, was placed from sta. 386 + 00 to 387 + 25 and a 36-ft wide layer of 2-in. thick boards was placed between sta. 388 + 50 and 389 + 75 (Fig. 11). These insulated test sections were separated by an uninsulated (control) section.

At the polygon site, 1.5-in. thick boards were laid over an area 42 ft wide by 100 ft long (sta. 369 + 50 to 370 + 50). At this location a wider layer of insulation was placed because 3 ft of backfill (3:1 side slopes) was to cover the boards to maintain the original gradeline set by DPW, whereas, at the winter site 2 ft of backfill would cover the insulation.

The first row of boards was placed along the centreline of the road with the long side parallel to the centreline. Each successive row was laid working from one end of the test section and outwards from the centreline. The boards were laid (and cut where necessary) so that all joints in adjacent rows were staggered, not only laterally, but also vertically in the case of the 3.5 in. of insulation which consisted of two layers of boards. Two 6-in. steel spikes were driven through each of the boards around the perimeter of the test section (and occasional boards within the section) into the frozen bedding layer to prevent movement of the insulation when the backfill was placed. Each of the 1.5-in. boards was pegged to the underlying 2-in. board, in the 3.5-in. thick test section, with two or four, 6-in. long wood skewers. Settlement plates (described later) were installed on all test sections prior to backfilling.

Suitable backfill material had not been found within reasonable hauling distance of the sites but, quite unexpectedly, a pocket of dry, loose granular material was discovered in the borrow pit near Mile 958.6. Enough of this material was stockpiled in the pit and reserved for use at the test sites. The backfill was hauled by scrapers and dumped at one end of the test section to be covered. A bulldozer then pushed the material onto the insulation. Care was taken to ensure that the 'dozer "rolled" the backfill onto the insulation to prevent movement of the boards. This worked very well for the single layer of boards--an occasional board was buckled or cracked by the backfilling operation. At the 3.5-in. thick insulated section, however, it was found that, as the backfill was placed, the top layer of boards for three rows either side of the centreline occasionally tended to slide along the lower layer, i.e. the wood skewers did not hold them in place. Consequently, joints from 1/2-in. to 2-in. wide opened up between the ends of some boards, such that when backfilling had been completed at this test section (worked from west to east) the top layer of 1.5-in. boards extended 1 ft beyond the underlying 2-in. layer over a 12-ft width (6 ft either side of centreline) at the east end. In a few cases, random boards were displaced laterally 1 or 2 in. Movements were relatively minor, however, and will not affect the performance of the test sections. It does, however, point out that the boards must be well secured to the bedding layer and to the layer of boards beneath and backfilling must be carefully done to prevent unacceptable displacement of the boards.

After the backfill had been placed on the three winter test sections the crown and side slopes were levelled and trimmed by a motor patrol as close as possible to the desired specifications (Fig. 12). In general, however, the shoulder to shoulder width exceeded 24 ft and the toe of the slope could not be properly trimmed because of the danger of damaging the insulation, which extended to the side slope, and the natural ground surface at the toe. Consequently, a windrow of material was left along the toe of the slope on both sides of the road. At the polygon test site, although the crown was shaped by the grader, the side slopes were not trimmed because it was impossible for the grader to operate on the steep slopes.

The contractor was hauling fill from the quarry at Mile 958.6 (west of the test sites) to approximately Mile 950 (south east of the test sites). Therefore the insulation had to be laid and backfilled over one half of the road at a time at the polygon site, so that construction of the test section would not interfere with the movement of hauling equipment (scrapers) and other vehicles using the road. Fortunately, the heavy traffic could bypass the winter site on the old C.N.T. access trail, and preparation and construction of the three test sections at this site was carried out over the full width of the roadway without interference by or interfering with the contractor's operations.

2. Summer Test Site--September 1972

The three test sections (two insulated and one uninsulated) at the summer site (sta. 392 + 00 to 395 + 75) were constructed between 13 and 27 September 1972. During the summer of 1972 pit run shale and limestone rock from a quarry opened up in a bedrock outcrop immediately adjacent to the highway at Mile 959, had been added to the original fill to bring the road up to the design grade from the winter site easterly. Thus the embankment was about 5 ft thick in this area. The contractor was still hauling material from this quarry using trucks during installation of the summer test sections and to minimize interference with his operation the test sections were constructed on one half of the road at a time. No detour or bypass road was available and the traffic therefore had to use the other half of the road.

The south half of the roadway from sta. 391 + 00 to 395 + 90 was excavated first, using a D-9 tractor with ripper and bulldozer blade. The excavated material was loaded into trucks by a rubber tired, front end loader and hauled away. About 3 ft of the fill was excavated leaving a 1.5- to 2-ft thick bedding layer over the subgrade which, having thawed to a depth of about 2 ft, was quite soft. The excavated area, which extended from 2 to 5 ft north of the centreline, was graded with a motor patrol but a level surface could not be obtained because of the large, angular, rock fragments. Thermocouple cables (described later) were then placed in drilled holes in the bedding layer and subgrade. To provide a suitable surface on which to lay the insution, several truck loads of crushed rock (1/4 in. to 3/4-in. material) were hauled to the site from a quarry at the Inuvik airport. This was spread and raked by hand (1 to 2 in. thick) over the 2 insulated test sections on the south half of the road.

A 3.5-in. thick layer of insulation (1 layer of 2-in. boards covered by a layer of 1.5-in. boards) was laid by hand between sta. 392 + 00 and 393 + 25 and a 4.5-in. thick layer (1 layer of 3 in. boards covered by a layer of 1.5-in. boards) was laid between sta. 394 + 50 and 395 + 75 (Fig. 13 to 15). All joints, both horizontally and vertically, were staggered. Two 6-in. steel spikes were driven through each board in the bottom layer to secure them to the bedding material. Each board in the top layer was pegged to the board beneath with four or six 6-in. long wood skewers. Settlement plates (described later) were then installed on the three test sections.

Suitable backfill could not be obtained from borrow pits and, therefore, a silty, sandy granular material which had been used to construct the roadway about one half mile west of the test sites, was excavated from the embankment and hauled by truck to the summer site to cover the test sections. As the material was removed from the road (from sta. 360 to 365) the excavation was backfilled with rock from the quarry at Mile 959. The trucks end-dumped the material at the test sections and a bulldozer "rolled" it onto the insulation. None of the insulation boards in either of the insulated sections were displaced by the backfilling operation.

As soon as the south half backfill had been placed, traffic was diverted from the north to the south side, and the north half of the road was excavated by bulldozer and front end loader and the material hauled away. The bedding layer (about 1.5 ft thick) was levelled with a motor patrol, crushed rock from the airport quarry was spread and raked by hand on the insulated test sections and insulation laid in the same manner as on the south half of the road (Fig. 16 and 17). Backfill was again obtained from the road about one-half mile to the west and hauled by trucks to the summer site where it was "rolled" onto the insulation by bulldozer. Again, no displacement of the insulation boards, either longitudinally or laterally was observed. The total width of the insulation laid at the summer site was 36 ft based on a 2-ft thick backfill (with 3:1 side slopes) covering the layer of insulation. A motor patrol then completed the job, shaping the crown and trimming the slopes (Fig. 18).

When the initial fill had been placed the previous winter and also when the material from the quarry at Mile 959 had been added during the preceding summer, to bring the road up to design grade, the roadway was wider than intended. In addition, during excavation of the fill when preparing the test sections, the bulldozer had difficulty in handling the coarse rock fill which spilled off the blade and widened the toe of the slope even more. Thus, although the top of the road was cut to the desired width (24 ft) and the upper portion of the side slopes was trimmed satisfactorily, the grader could do little with the rock at the toe of the slope. Consequently, the lower portion of both the north and south side slopes is rather irregular and wider than desired over much of the summer test site.

Centreline profiles and plans of the summer and winter test sites are shown in Figures 19 and 20 respectively.

3. Bedding and Backfill Materials

After the bedding layer had been prepared at the winter and polygon sites, undisturbed core samples were taken from shallow holes drilled at each of the 4 test sections (three at the winter site and one at the polygon site). Unfortunately, bulk densities of the bedding material could not be determined because the samples were very stony and dry and fell apart when handled. Good samples of the peat and subgrade material immediately beneath, however, were obtained. In addition, large grab samples of the original fill, bedding and backfill materials were taken.

At the summer site, field densities of the bedding material were obtained using the sand cone method. Large grab samples of the bedding and backfill material were also obtained for identification and classification of the materials. Logs of the holes drilled on the winter test site and the results of all tests performed by DBR/NRC on these materials are given in Appendix 2.

V. INSTRUMENTATION AND OBSERVATION PROGRAM

The primary purpose of this study is to assess the thermal performance of an insulated roadway on permafrost and to obtain information on parameters which will enable improvements to be made in the design of embankments (insulated and uninsulated). Measurement of ground temperatures to determine and compare the changes that occur with time in the embankment and subgrade is of major importance.

Correlation of the ground thermal regime with the local climate (as indicated primarily by air temperature) is of equal importance and essential for analysis of the results. Of particular interest, is the determination of the relationship between air temperature and ground (embankment) surface temperature. In addition, measurement of movements (settlement) and changes in geometry of the embankment, are necessary. The fabrication and installation of the instrumentation used at the test sites is described below.

1. Ground Temperature Measurement

Copper-constantan thermocouples were used for all ground temperature measurements. Fifteen cables (each containing 10 or 12 sensing junctions) were installed at each of the Winter and Summer sites. Six thermocouple sensors were installed at the Polygon site. Twelve of the fifteen cables at each site were fabricated of 12 pair multi-conductor cable; duplex wire was used for the other three cables and at the polygon site. All cables were prefabricated at DBR/NRC, Ottawa and shipped to Inuvik ready for installation.

At the winter site, cables were placed in drilled holes to measure ground temperatures to depths of 20 ft below the top of the bedding layer (or original ground surface) under the centreline, south shoulder and south toe of slope at the centre of the 3.5-in. insulated and control sections, and under the centreline of the 2-in. insulated section. Two 20-ft cables and one 10-ft cable were installed on centreline at the junctions of the 3.5-in. insulated and control sections. Three cables (#12, 13 and 14) were placed to measure temperatures on the bottom and top surfaces of the insulation and/or in the backfill of the three test sections. Two cables (one 10 ft long, the second, 50 ft long) were installed in one drill hole in an undisturbed area off the right of way.

All cables were installed in 3- to 4-in. diameter drill holes before the insulation was laid and the lead wires were buried in a shallow trench below the surface of the bedding layer. A 10- to 12-lb brass weight was attached to the end of each cable to aid in lowering it down the hole and to keep it taut when the hole was backfilled with a dry silty sand and cuttings from the drill hole. The thickness of the compacted snow and peat layers under the embankment was determined when the cable holes were drilled.

When the insulation was laid, thermocouples were taped to the bottom and top surfaces of the boards and the thermocouple junctions to be placed in the backfill were coiled on top of the insulation. After the backfill had been placed and the embankment shaped by the grader, pits were dug by hand to retrieve these thermocouples and position them in the fill in the insulated and control sections on centreline and the south shoulder.

The cables at the summer site were installed in a similar manner. At the polygon site, thermocouples were attached to the bottom and top surfaces of the 1.5-in. thick insulation boards at three locations on centreline.

The location of all thermocouple cables and the position of each thermocouple junction, as installed when the test sections were constructed, are shown in Figs. 19, 20, 21 (a) to (e), 22 (a) to (e) and 23. A summary of the cables is given in Table II.

Ground temperatures were to be monitored weekly using manually operated equipment until an automatic data acquisition system could be installed. All lead wires were placed in a plywood box laid on the ground surface to protect the cables, and brought to a switch box located on the south side of the right of way at the centre of each of the winter, summer and polygon sites to facilitate making observations.

Although weekly readings of ground temperatures are generally sufficient at depths greater than about 10 ft, measurement of temperatures at depths above 10 ft, and particularly for those near and at the surface of the ground or fill, must be obtained almost continuously for proper analysis and evaluation because of their relatively rapid response to air temperature fluctuations. An automatic data acquisition (DA) system which will operate unattended has been specially designed at DBR/NRC for continuously monitoring ground temperatures at the test sites. The system will be installed in the spring of 1974 in a heated hut located midway between the winter and summer sites. Power to operate the DA system is provided by a thermo-electric generator. Data from 350 thermocouple points will be recorded hourly on magnetic tapes. Arrangements have been made with the Telecommunications Branch, Ministry of Transport to have their Inuvik staff check and service the equipment and change tapes at regular intervals once the DA system is installed.

In preparation for installation of the DA system, the instrument hut was erected and the thermo-electric generator, propane tanks and auxiliary equipment installed at the site in September 1973. At the same time, all the thermocouple cables from both the winter and summer sites were disconnected from the temporary switch boxes and extension cables spliced on to bring all cables to the hut where they were reconnected to the switch boards. Temperatures are being read approximately once a week or bi-monthly until the DA system is installed and operational.

2. Embankment Movements

To determine movements resulting from thawing and compaction of the subgrade and/or fill, settlement plates were placed in all test sections at the winter and summer sites. At the winter site, four brass plates (18" x 18" x 1/4") were placed on top of the insulation (or the bedding layer in the control section) in each of the test sections. A spike was driven through the centre of each plate to hold it in position when the sections were backfilled. Two plates were placed on centreline and two on the south shoulder at the third points of each of the test sections. Four brass plates (12" x 24" x 1/4") were placed in an identical manner and position in each of the three test sections at the summer site. The elevation of each plate was established before the backfill was placed. The locations of the plates are shown in Figs. 19 and 20 and the initial elevations of each plate prior to backfilling are given in Table III. Holes are drilled in the embankment to relocate the plates and engineering surveys are made periodically (two or three times a year) to determine the elevations of the plates and movements that have occurred.

Changes in the shape of the embankment are determined periodically (2 or 3 times a year) by running cross-section surveys at 25 ft intervals over all the test sites. With the exception of normal maintenance grading of the road surface, no major remedial work by maintenance forces is permitted on the test sites without prior approval. This is enforced to ensure that instrumentation is not damaged or destroyed and to allow changes in geometry of the embankment to be determined with reasonable accuracy during the life of the study.

No reliable datum point for elevation survey control was available in the area. A special bench mark (Fig. 24) was installed at the winter test site, therefore, and all surveys are based on this common datum. The elevation of this bench mark (27.26 ft) was obtained from a temporary bench mark on a nearby tree stump established and used by survey crews during construction of the highway. The temporary bench mark was tied in originally to a bench mark on rock at the Inuvik airport which was based on the assumed elevation of 0.00 ft = low water level, April 1954, on the East Channel at the Inuvik wharf.

3. Thermal Conductivity Probes

Information on the thermal properties of the fill and subgrade materials is required for analysis of the heat transfer in the test sections. A fairly rugged thermal conductivity probe had been designed by DBR/NRC for use in the field and laboratory. Four of these probes were installed at the winter site in the walls of test pits excavated in September 1973. Two probes were installed under the insulation near the thermocouple cables in the centre of the 3.5-in. insulated test section; one was placed in the bedding material, the second at shallow depth in the subgrade. Two probes were also placed near the thermocouple cables in the centre of the control section; one in the bedding layer, the other at shallow depth in the subgrade. Lead wires from all probes were brought to the instrument hut. Observations will be made 2 or 3 times a year to determine the thermal conductivities of the materials in the frozen and/or thawed condition.

The location of the probes is shown in Fig. 25 and 26.

4. Air Temperature and Snow Cover Observations

A thermograph and standard Meteorological Service maximum and minimum thermometers were placed in a Stevenson screen at the winter site to obtain air temperatures for comparison with those measured at the Inuvik airport weather station some 6 to 7 miles to the west. Thermograph charts are to be changed weekly and the maximum and minimum thermometers read once a week. When the DA system is installed, air temperatures will be measured continuously by thermocouples placed in Stevenson screens at the winter and summer sites.

Graduated stakes, for measurement of snow depth, were placed at the location of the thermocouple cables in the undisturbed areas at both sites and at the thermocouple cables at the toe of the slope of the 3.5-in. and 4.5-in. insulated sections on the winter and summer sites respectively. Observations of snow depth at these locations and also on the centreline of the road at both sites are to be made weekly.

Snow density measurements are to be made periodically in undisturbed areas at both sites. Observations of snow depth and density are being made to evaluate the effect of the snow cover on the ground thermal regime.

VI. SUMMARY

This report has been prepared to record details of the construction of test sections and installation of instrumentation for an evaluation of the thermal performance of insulated road embankments on permafrost. Measurement of ground temperatures, embankment movements and changes in geometry of the roadway, and local climatic factors are included in the program. It is anticipated that the study will be carried on for a period of at least 4 to 5 years.

VII. ACKNOWLEDGEMENTS

Many people, too numerous to mention individually, have participated, in various ways, with the installation of instrumentation and construction of the test sections. The authors wish to express their appreciation to them all for their cooperation and assistance. We are particularly grateful for the guidance received from and the continuing interest shown by members of the IGHI (Mr. K. W. Stairs, Chairman).

Members of the Edmonton and Inuvik offices of DPW participated in many ways from arranging with the contractor for the use of heavy equipment to providing survey crews and helping with installation at the site. Representatives of the Dow Company (which provided the insulation) were on site each time work was being carried out and were most helpful in many ways.

Funds covering most of the expenditures for the project have been provided by DIAND and MOT.

TABLE 1

AIR TEMPERATURE DATA - INUVIK WEATHER STATION - 1960-69

10 Year Period 1960-69 inclusive

Mean Annual Air Temperature	=	13.8°F
Max. Mean Annual Air Temperature	=	17.1°F (1962)
Min. Mean Annual Air Temperature	=	10.9°F (1964)

10 Year Monthly Mean Air Temperatures (1960-69)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
-23.4	-22.3	-12.8	5.2	30.6	49.8	55.7	50.1	36.9	18.4	-7.5	-14.6

10 Year Mean Thawing Index	=	2068 Degree Days (1960-69)
10 Year Max. Thawing Index	=	2375 Degree Days (1962)
10 Year Min. Thawing Index	=	1802 Degree Days (1969)

10 Year Mean Freezing Index	=	8687 Degree Days (1959-60 to 1968-69)
10 Year Max. Freezing Index	=	9618 Degree Days (1963-64)
10 Year Min. Freezing Index	=	7757 Degree Days (1962-63)

TABLE 2

DETAILS OF THERMOCOUPLE CABLES

A. WINTER SITE

CABLE NO.	NO. OF POINTS	LOCATION		REMARKS
(a) 3.5" insulation section				
1	12	Sta. 386 + 62.5:	on Centreline	Below insulation--in fill and subgrade
2	12	Sta. 386 + 62.5:	12.0' R of Centreline	Below insulation--in fill and subgrade
3	12	Sta. 386 + 62.5:	25.0' R of Centreline	Toe of slope
12	1-5	Sta. 386 + 62.5:	1.2' R of Centreline	In fill--on and above insulation
	6-10	Sta. 386 + 62.5:	7.2' R of Centreline	In fill--on and above insulation
	11-12	Sta. 386 + 62.5:	13.2' R of Centreline	On insulation
(b) Transition--3.5" insulation/control				
4	12	Sta. 387 + 20.0:	on Centreline	Below insulation--in fill and subgrade
5	12	Sta. 387 + 30.0:	on Centreline	In fill and subgrade
15	12	Sta. 387 + 25.0:	on Centreline	In fill and subgrade--edge of insulation
(c) Control section				
6	12	Sta. 387 + 87.5:	on Centreline	In fill and subgrade
7	12	Sta. 387 + 87.5:	12.0' R of Centreline	In fill and subgrade
8	12	Sta. 387 + 87.5:	22.2' R of Centreline	Toe of slope
13	1-5	Sta. 387 + 87.0:	on Centreline	In fill
	6-10	Sta. 387 + 87.0:	12.0' R of Centreline	In fill
(d) 2" insulation section				
9	12	Sta. 389 + 12.5:	on Centreline	Below insulation--in fill and subgrade
14	1-5	Sta. 389 + 12.5:	1.0' R of Centreline	In fill--on and above insulation
	5-10	Sta. 389 + 12.8:	7.0' R of Centreline	In fill--on and above insulation
	11-12	Sta. 389 + 12.5:	13.0' R of Centreline	In fill--on insulation

TABLE 2 (cont'd)

CABLE NO.	NO. OF POINTS	LOCATION	REMARKS
(e) Undisturbed area			
10	10	Sta. 387 + 82.5: 86.6' R of Centreline	Below original ground surface
11	12	Sta. 387 + 82.5: 86.6' R of Centreline	Below original ground surface

B. SUMMER SITE

CABLE NO.	NO. OF POINTS	LOCATION	REMARKS
(a) 4.5" insulation section			
1	12	Sta. 395 + 12.7: 0.5' R of Centreline	Below insulation--in fill and subgrade
2	12	Sta. 395 + 12.7: 12.7' R of Centreline	Below insulation--in fill and subgrade
3	12	Sta. 395 + 12.7: 31.3' R of Centreline	Toe of slope
12	1-5	Sta. 395 + 12.7: on Centreline	In fill--on and above insulation
	6-10	Sta. 395 + 12.7: 6.0' R of Centreline	In fill--on and above insulation
	11-12	Sta. 395 + 12.7: 12.0' R of Centreline	On insulation
(b) Transition--4.5" insulation/control			
4	12	Sta. 394 + 55.0: on Centreline	Below insulation--in fill and subgrade
5	12	Sta. 394 + 45.0: on Centreline	In fill and subgrade
15	12	Sta. 394 + 50.0: on Centreline	In fill and subgrade--edge of insulation
(c) Control section			
6	12	Sta. 393 + 87.0: on Centreline	In fill and subgrade
7	12	Sta. 393 + 87.0: 13.2' R of Centreline	In fill and subgrade
8	12	Sta. 393 + 88.5: 36.6' R of Centreline	Toe of slope
13	1-5	Sta. 393 + 87.0: on Centreline	In fill
	6-10	Sta. 393 + 87.0: 12.0' R of Centreline	In fill

TABLE 2 (cont'd)

CABLE NO.	NO. OF POINTS	LOCATION		REMARKS
(d) 3.5" insulation section				
9	12	Sta. 392 + 62.6:	on Centreline	Below insulation--in fill and subgrade
14	1-5	Sta. 392 + 62.6:	on Centreline	In fill--on and above insulation
	6-10	Sta. 392 + 62.6:	6.0' R of Centreline	In fill--on and above insulation
	11-12	Sta. 392 + 62.6:	12.0' R of Centreline	In fill--on insulation
(e) Undisturbed area				
10	12	Sta. 393 + 78.0:	76.0' R of Centreline	Below original ground surface
11	12	Sta. 393 + 78.0:	76.0' R of Centreline	Below original ground surface

C. POLYGON SITE

1	A	Sta. 369 + 75:	on Centreline	On bottom of insulation
	B	Sta. 369 + 75:	on Centreline	On top of insulation
2	A	Sta. 370 + 00:	on Centreline	On bottom of insulation
	B	Sta. 370 + 00:	on Centreline	On top of insulation
3	A	Sta. 370 + 25:	on Centreline	On bottom of insulation
	B	Sta. 370 + 25:	on Centreline	On top of insulation

TABLE 3

DATUM ELEVATIONS FOR SETTLEMENT PLATES

1. WINTER TEST SITE (20 April, 1972)

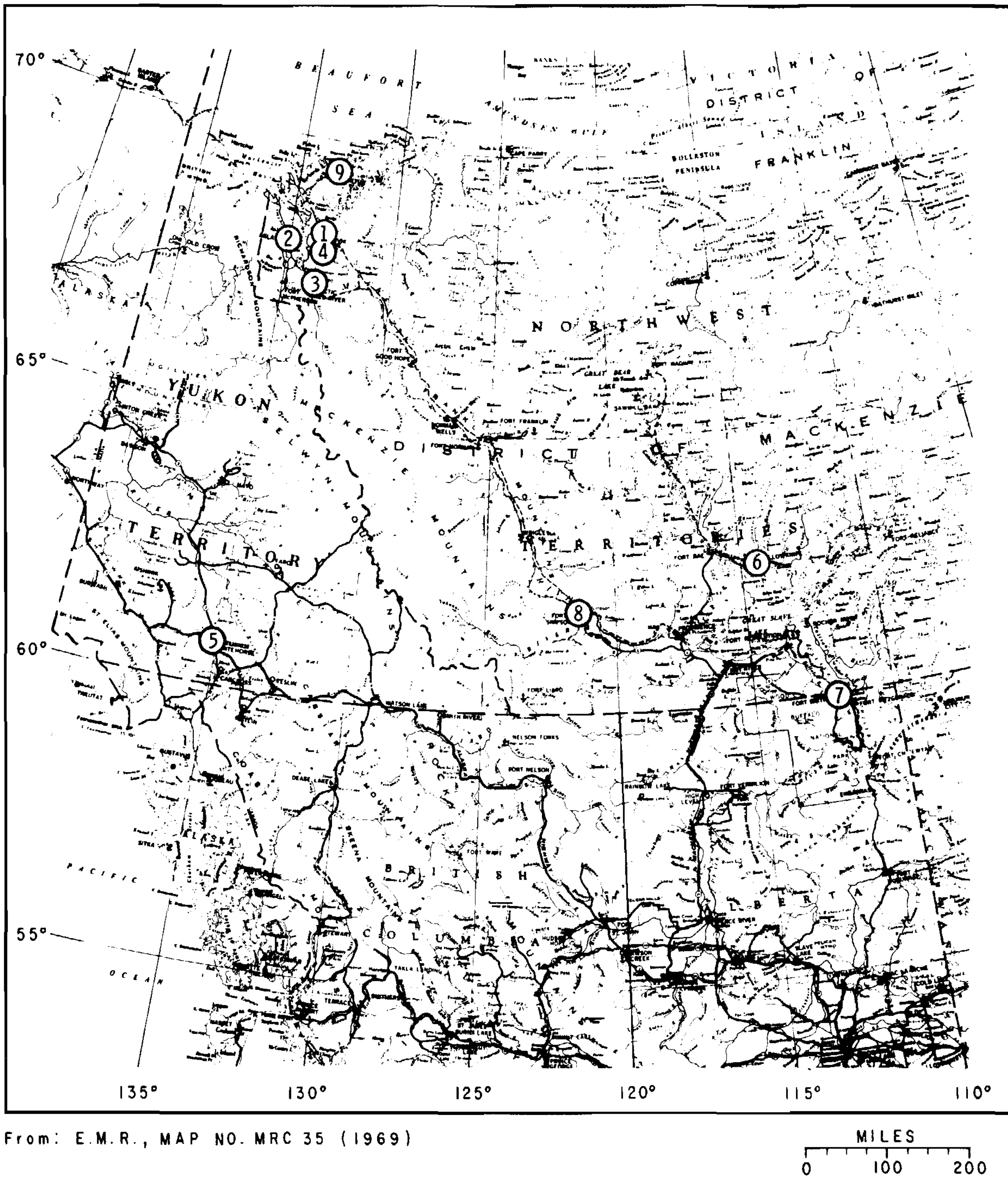
PLATE NO.	ELEVATION	LOCATION (centre of plate)	
3.5" Section			
1	28.23	Sta. 386 + 32.0:	on Centreline
2	28.05	Sta. 386 + 32.0:	11.3' R of Centreline
3	28.07	Sta. 386 + 93.4:	on Centreline
4	28.02	Sta. 386 + 93.0:	11.3' R of Centreline
Control Section			
5	27.63	Sta. 387 + 57.0:	on Centreline
6	27.68	Sta. 387 + 57.0:	11.3' R of Centreline
7	27.28	Sta. 388 + 18.0:	on Centreline
8	27.19	Sta. 388 + 18.0:	11.3' R of Centreline
2" Section			
9	27.16	Sta. 388 + 82.0:	on Centreline
10	27.25	Sta. 388 + 82.0:	11.3' R of Centreline
11	26.95	Sta. 389 + 43.0:	on Centreline
12	26.88	Sta. 389 + 43.0:	11.3' R of Centreline

2. SUMMER TEST SITE (19 September, 1972)

PLATE NO.	ELEVATION	LOCATION (centre of plate)	
4.5" Section			
1	25.15	Sta. 395 + 43.0:	on Centreline
2	25.24	Sta. 395 + 43.0:	11.3' R of Centreline
3	24.96	Sta. 394 + 82.0:	on Centreline
4	24.85	Sta. 394 + 82.0:	11.3' R of Centreline
Control Section			
5	24.73	Sta. 394 + 18.0:	on Centreline
6	24.82	Sta. 394 + 18.0:	11.3' R of Centreline
7	24.92	Sta. 393 + 57.0:	on Centreline
8	24.93	Sta. 393 + 57.0:	11.3' R of Centreline
3.5" Section			
9	25.19	Sta. 392 + 93.0:	on Centreline
10	25.27	Sta. 392 + 93.0:	11.3' R of Centreline
11	25.04	Sta. 392 + 32.0:	on Centreline
12	25.08	Sta. 392 + 32.0:	11.3' R of Centreline

Note:

Elevations based on assumed datum of 0.00 ft = low water level on East Channel at Inuvik wharf - April 1954.

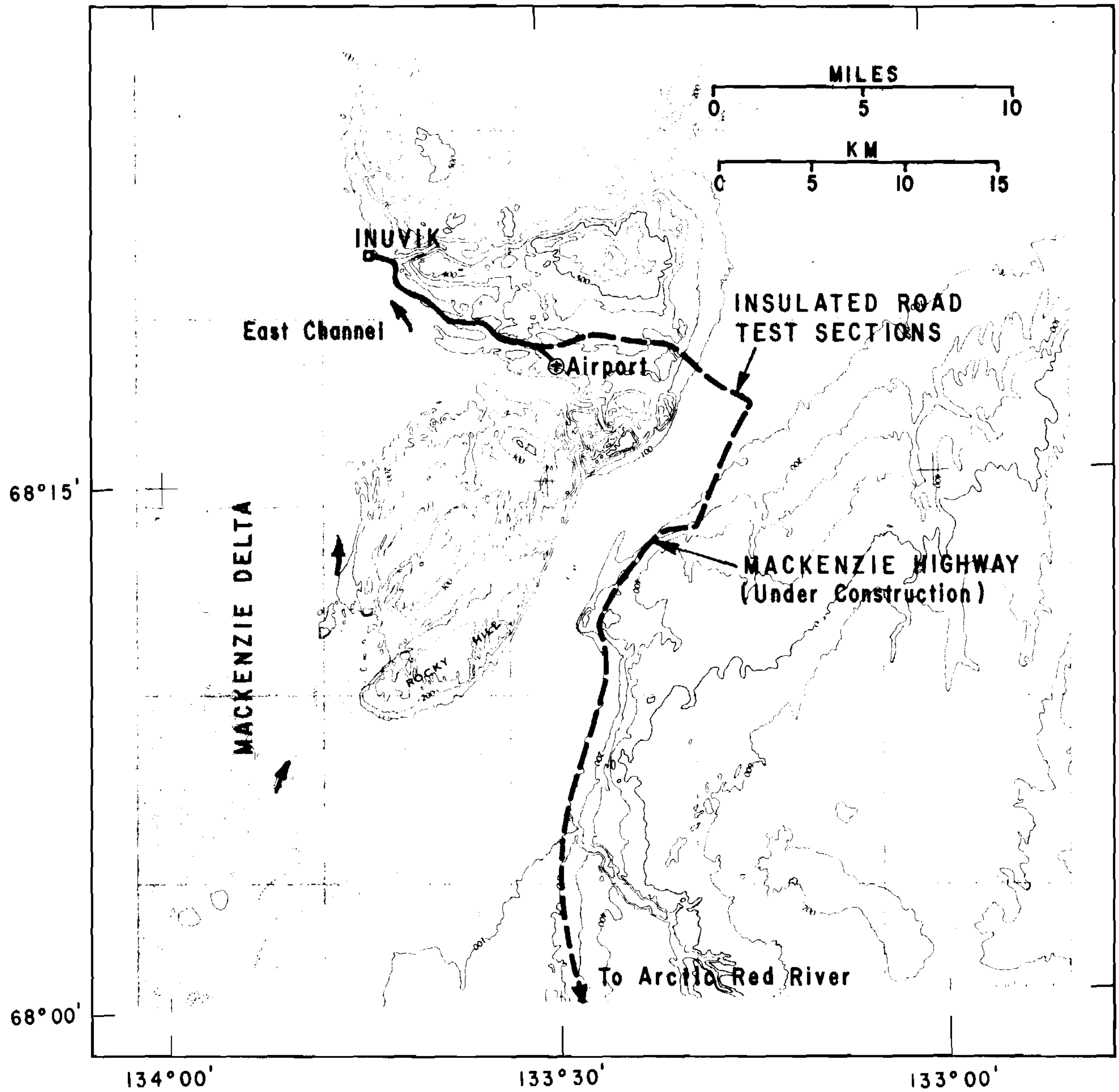


From: E.M.R., MAP NO. MRC 35 (1969)

① INUVIK
② AKLAVIK
③ ARCTIC RED RIVER
④ INSULATED ROAD TEST SITES
⑤ WHITEHORSE
⑥ YELLOWKNIFE
⑦ FORT SMITH
⑧ FORT SIMPSON
⑨ TUKTOYAKTUK

FIGURE 1

NORTHWESTERN CANADA, LOCATION PLAN INSULATED ROAD STUDY



From: NATIONAL TOPOGRAPHIC MAP AKLAVIK 107B, E.M.R.

FIGURE 2

LOCATION MAP INSULATED ROAD TEST SECTIONS

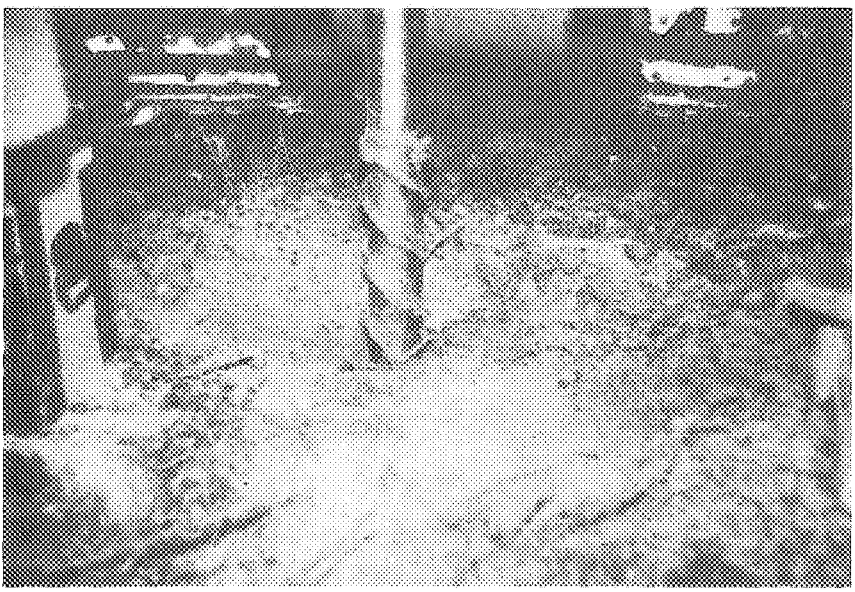


Fig. 3. "Gas Arctic" core barrel.

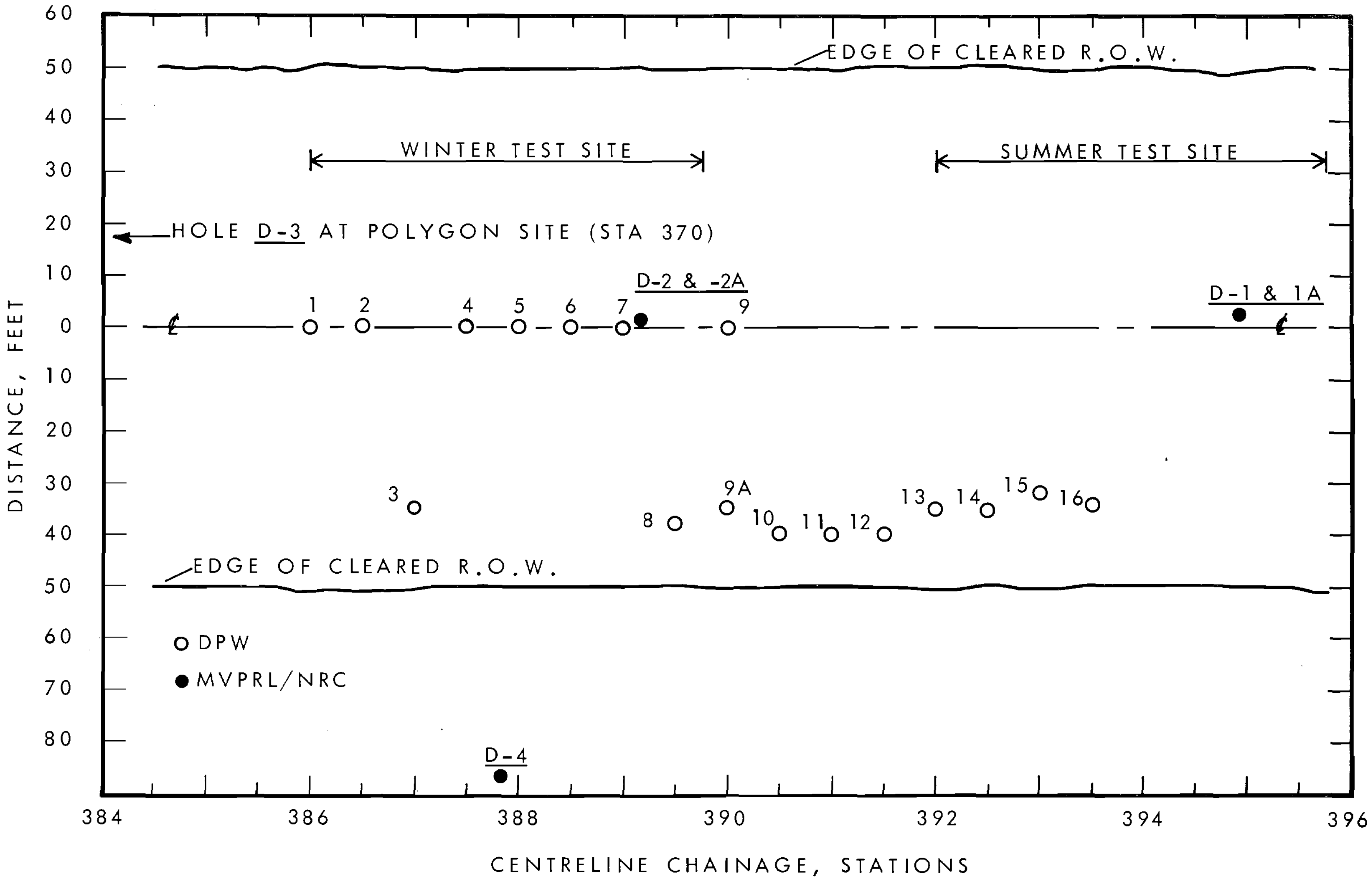


FIGURE 4 LOCATION OF EXPLORATORY BOREHOLES

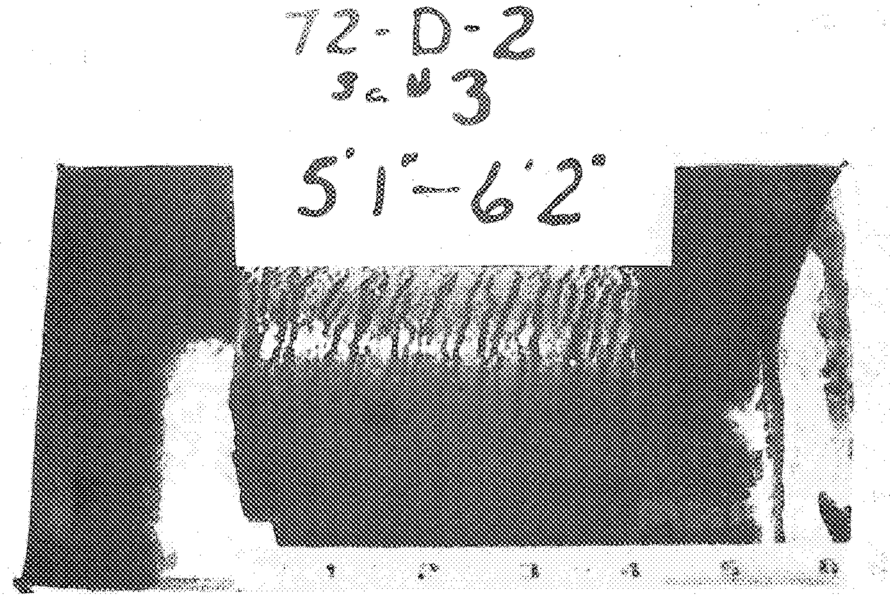


Fig. 5. Hole D-2--Frozen core.
Depth--Below top of road fill = 5.8'
--Below original ground surface = 3.3'.

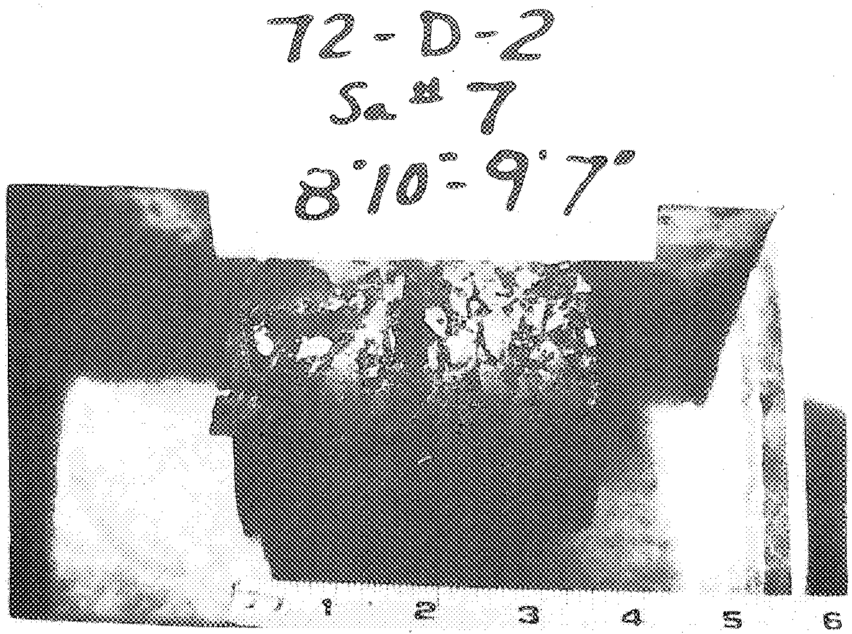


Fig. 6. Hole D-2--Frozen core.
Depth--Below top of road fill = 9.3'
--Below original ground surface = 7.0'.

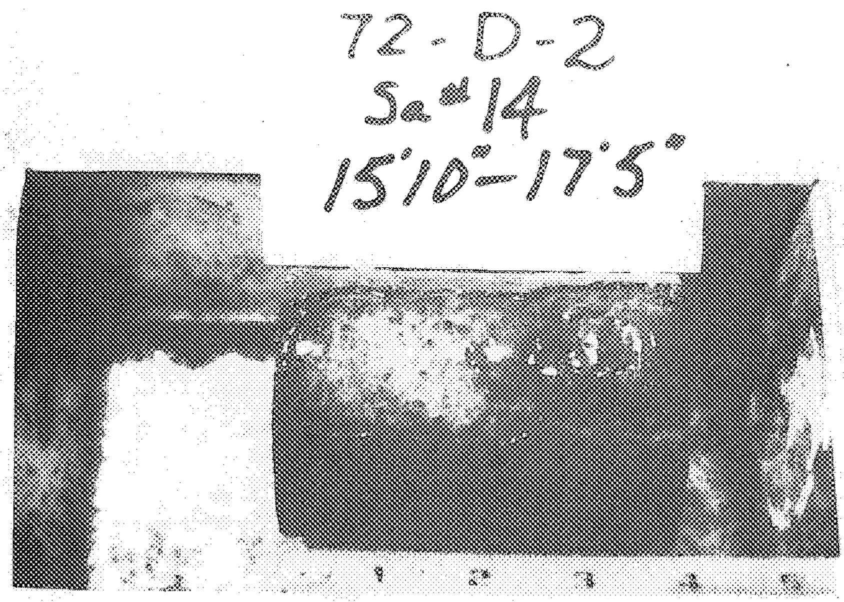


Fig. 7. Hole D-2--Frozen core.
Depth--Below top of road fill = 16.5'
--Below original ground surface = 14.2'.

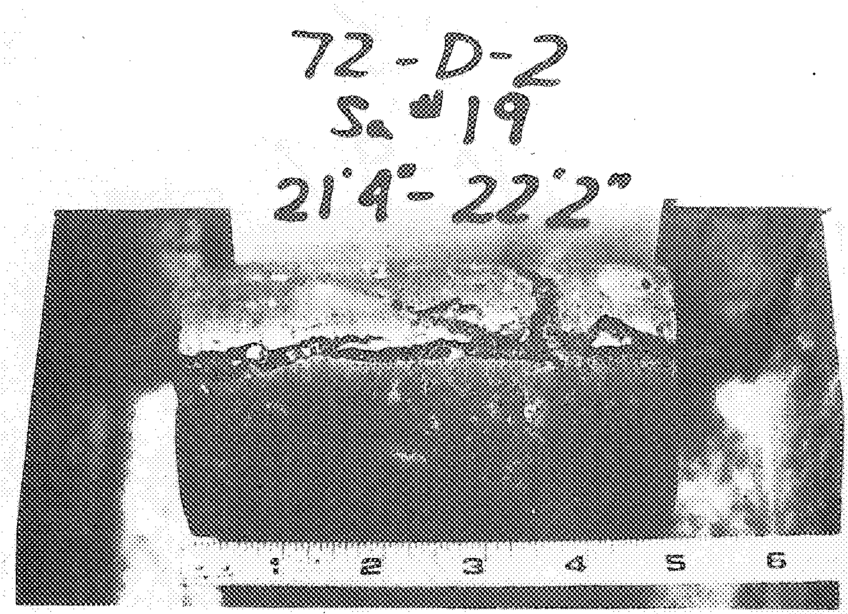


Fig. 8. Hole D-2--Frozen core.
Depth--Below top of road fill = 21.9'
--Below original ground surface = 19.6'.

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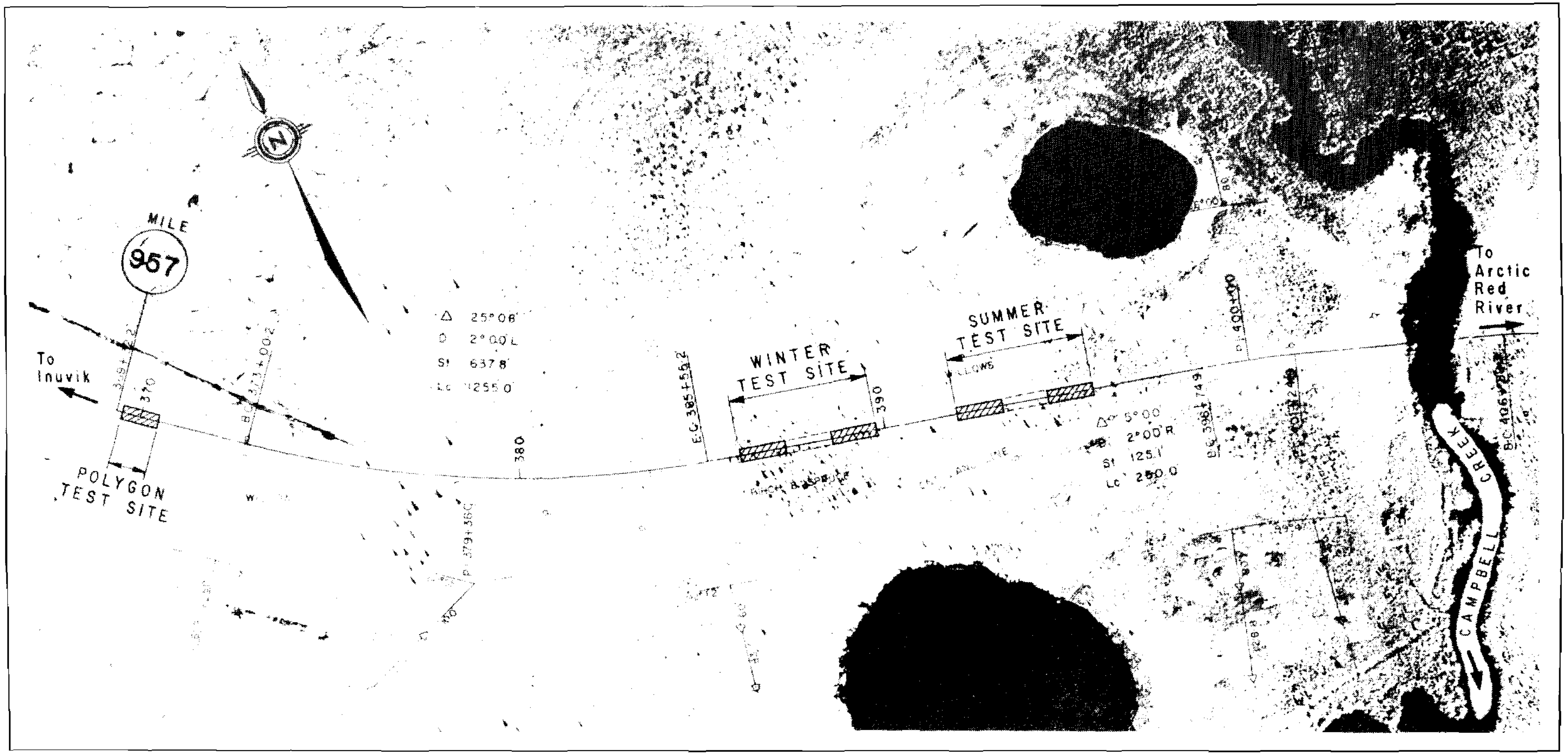


From: DPW DWG NO. L.A. 70.1.a SHEET NO. 10

▨ INSULATED TEST SECTIONS

FIGURE 9

INSULATED ROAD TEST SECTIONS - MACKENZIE HIGHWAY - INUVIK, N.W.T.

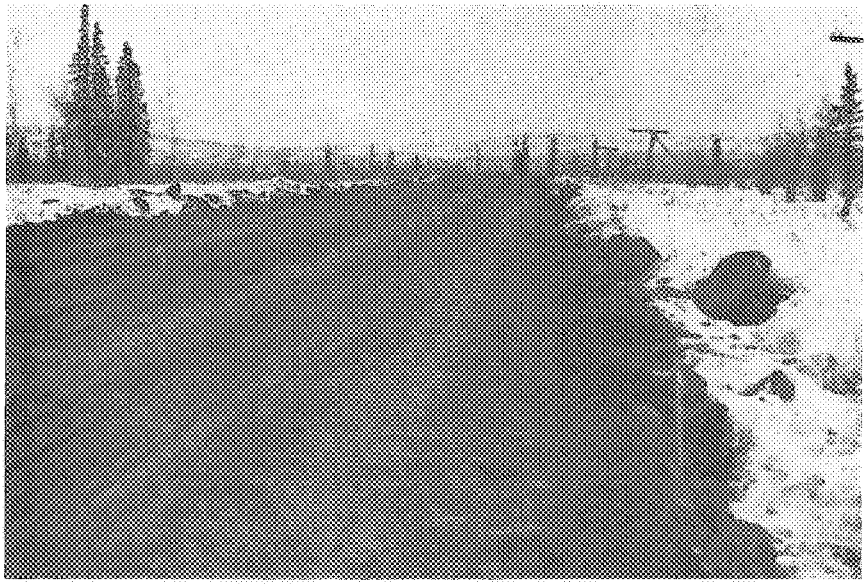


Fig. 10. Winter test site--Prepared bedding layer upon which insulation will be placed.

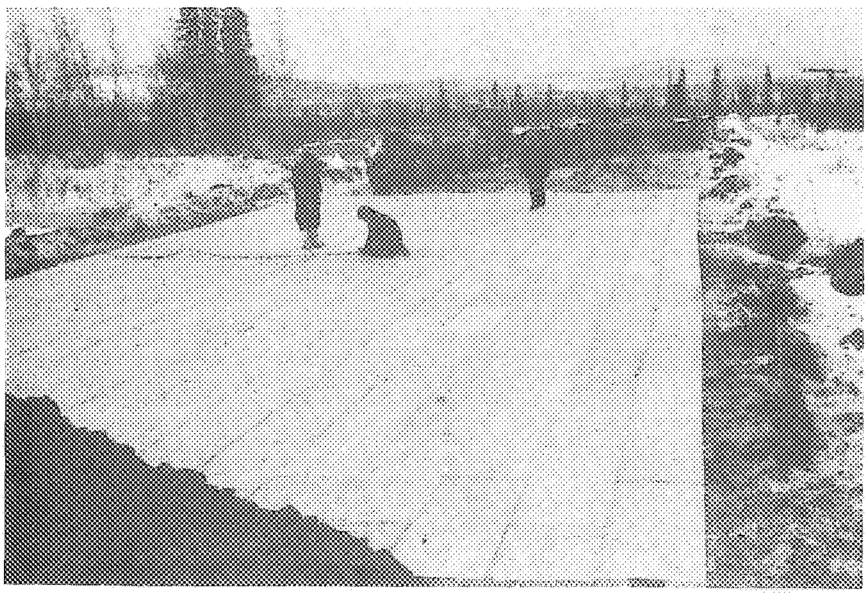


Fig. 11. Winter test site--2" insulation section. Vehicles parked on control section. Completed 3.5" insulation section in background.

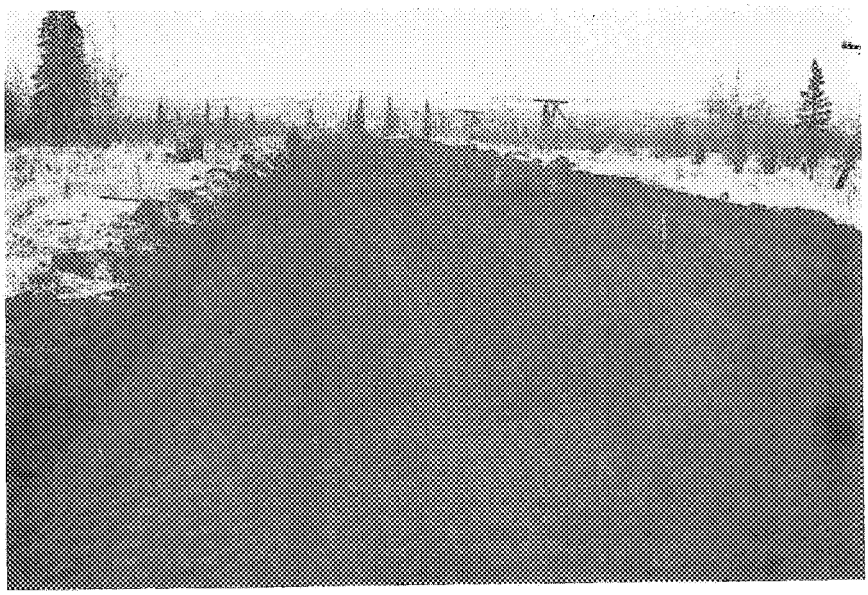


Fig. 12. Completed winter test sections. View to west from east end of 2" insulation section.

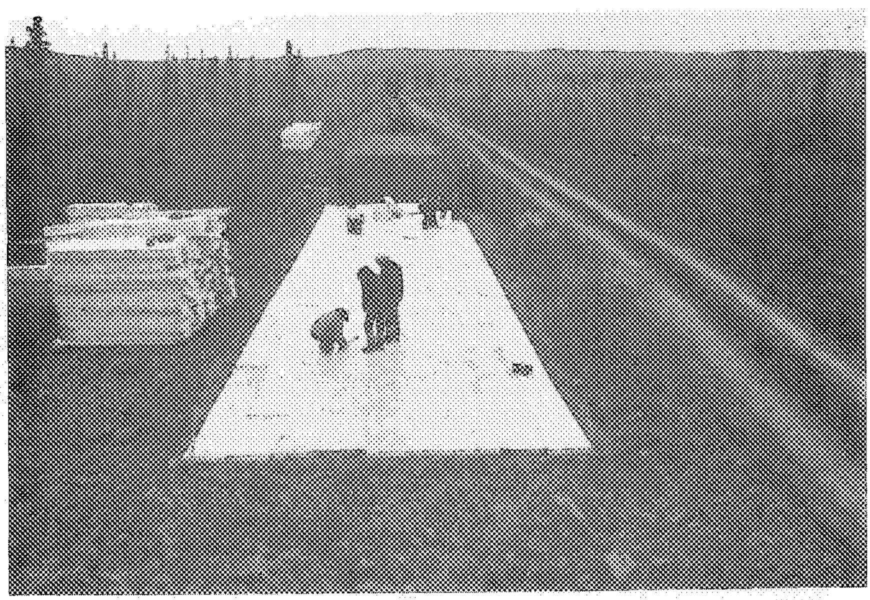


Fig. 13. Summer test site--South half of road. Laying 3" thick boards for bottom layer of 4.5" thick insulation section View to west--winter test site in distant background.

Fig. 14. Summer test site--South half. Laying top layer of boards (1.5" thick) on 4.5" insulated section. Control section and 3.5" section (with crushed rock levelling course) in background.

Fig. 15. Summer test site--South half. Laying insulation for 3.5" section. Note crushed rock levelling course and staggered joints of boards.

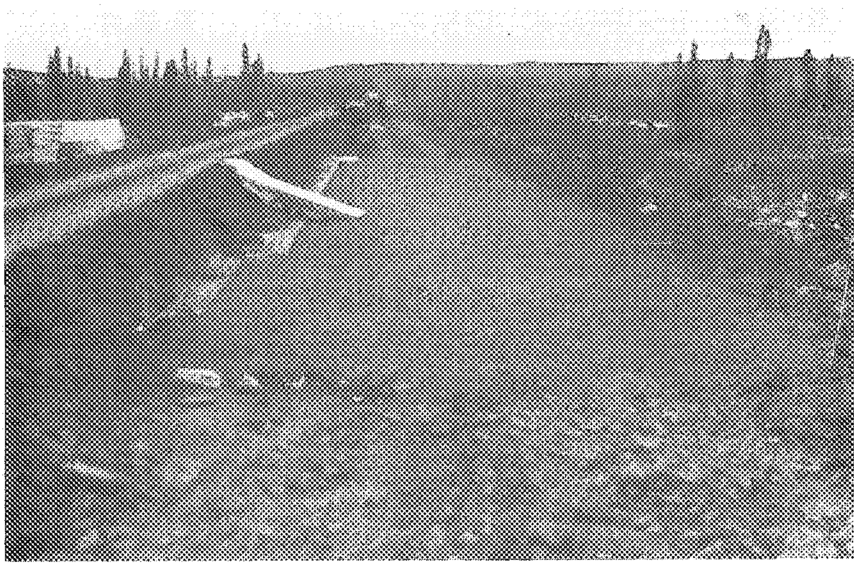


Fig. 16. Summer test site--North half. Crushed rock levelling course laid ready for insulation. Note edge of boards protruding from completed south half. View to west.

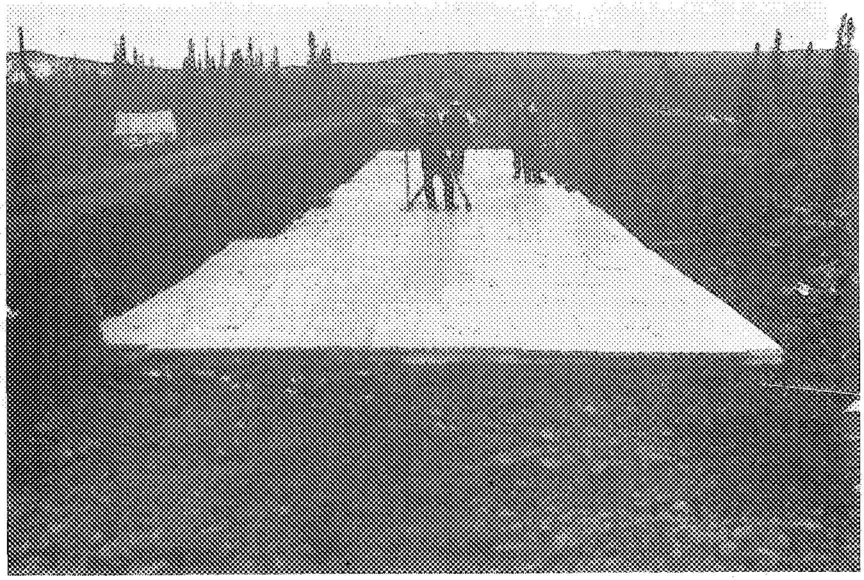


Fig. 17. Summer test site--North half. Insulation laid--4.5" section in foreground, control and 3.5" sections in background.

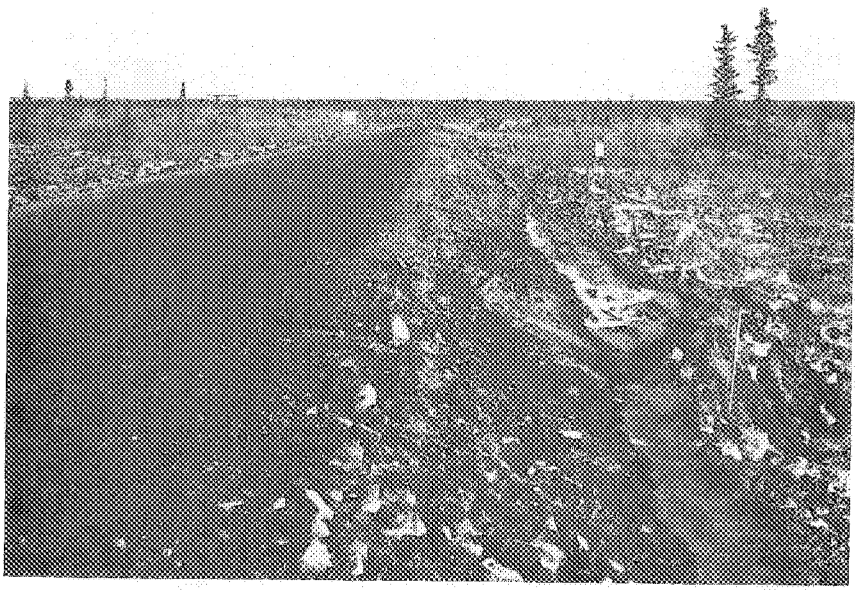


Fig. 18. Completed summer test site. View to east from west end of 3.5" section.

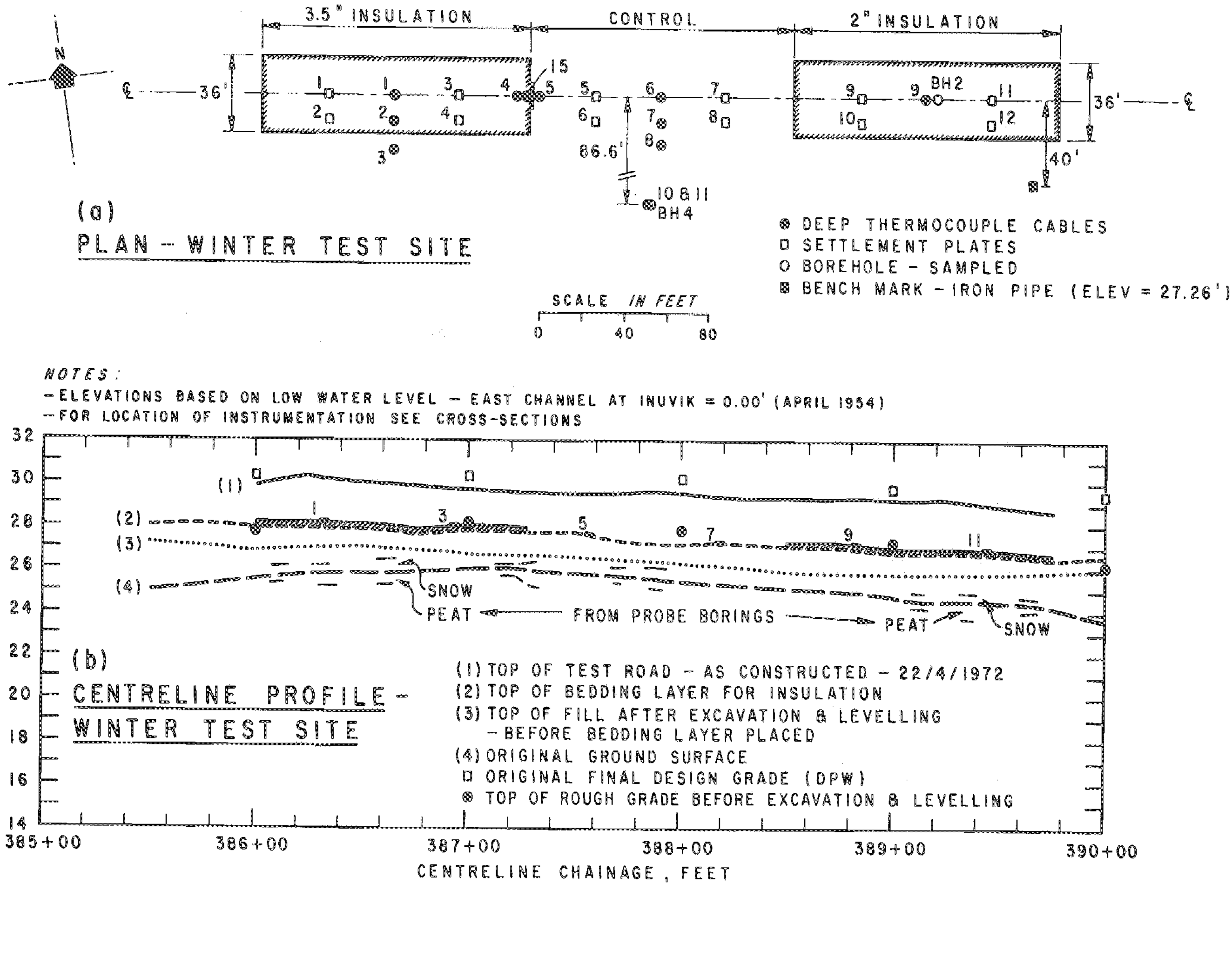


FIGURE 19
WINTER TEST SITE, PLAN AND CENTRELINE PROFILE

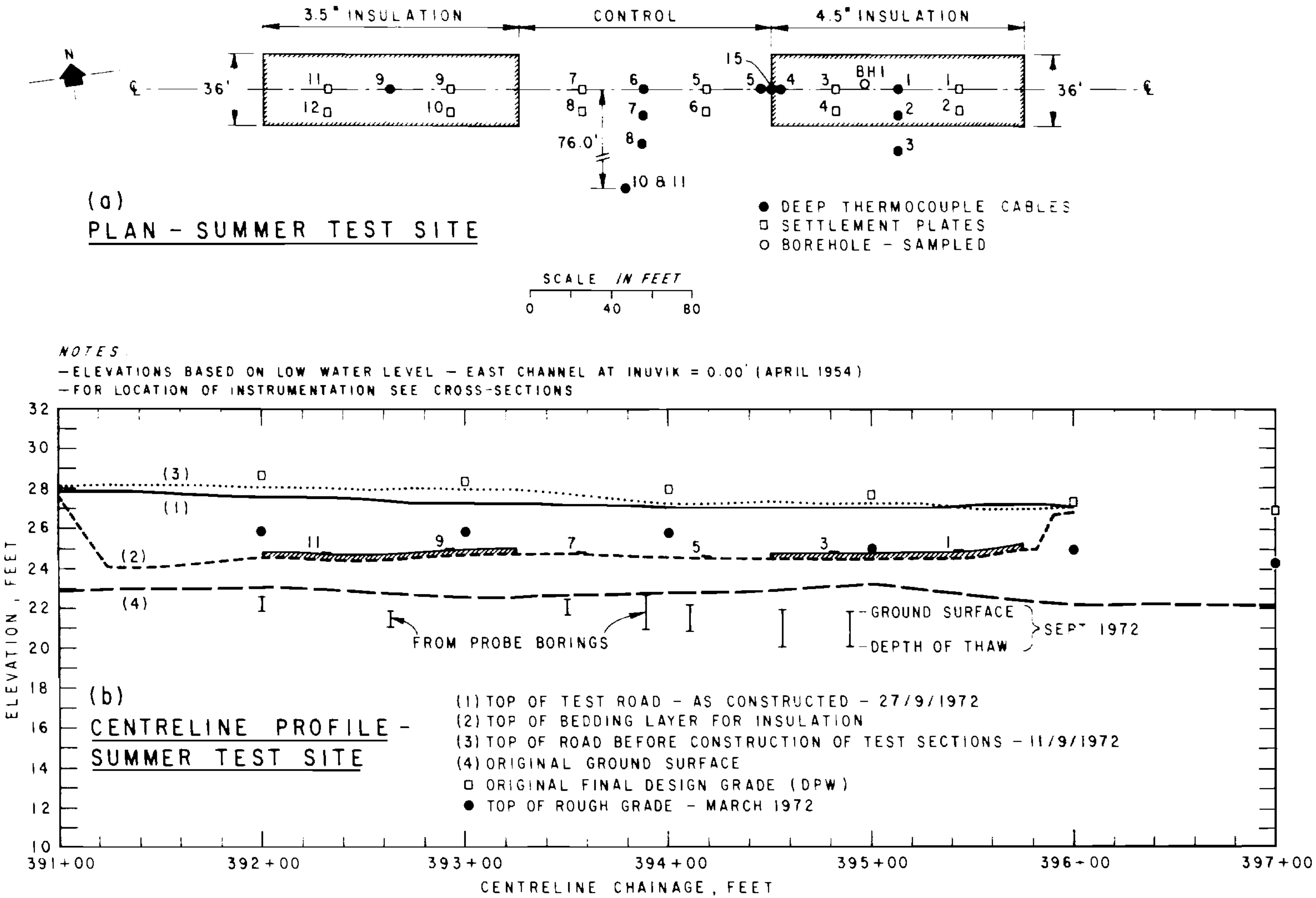
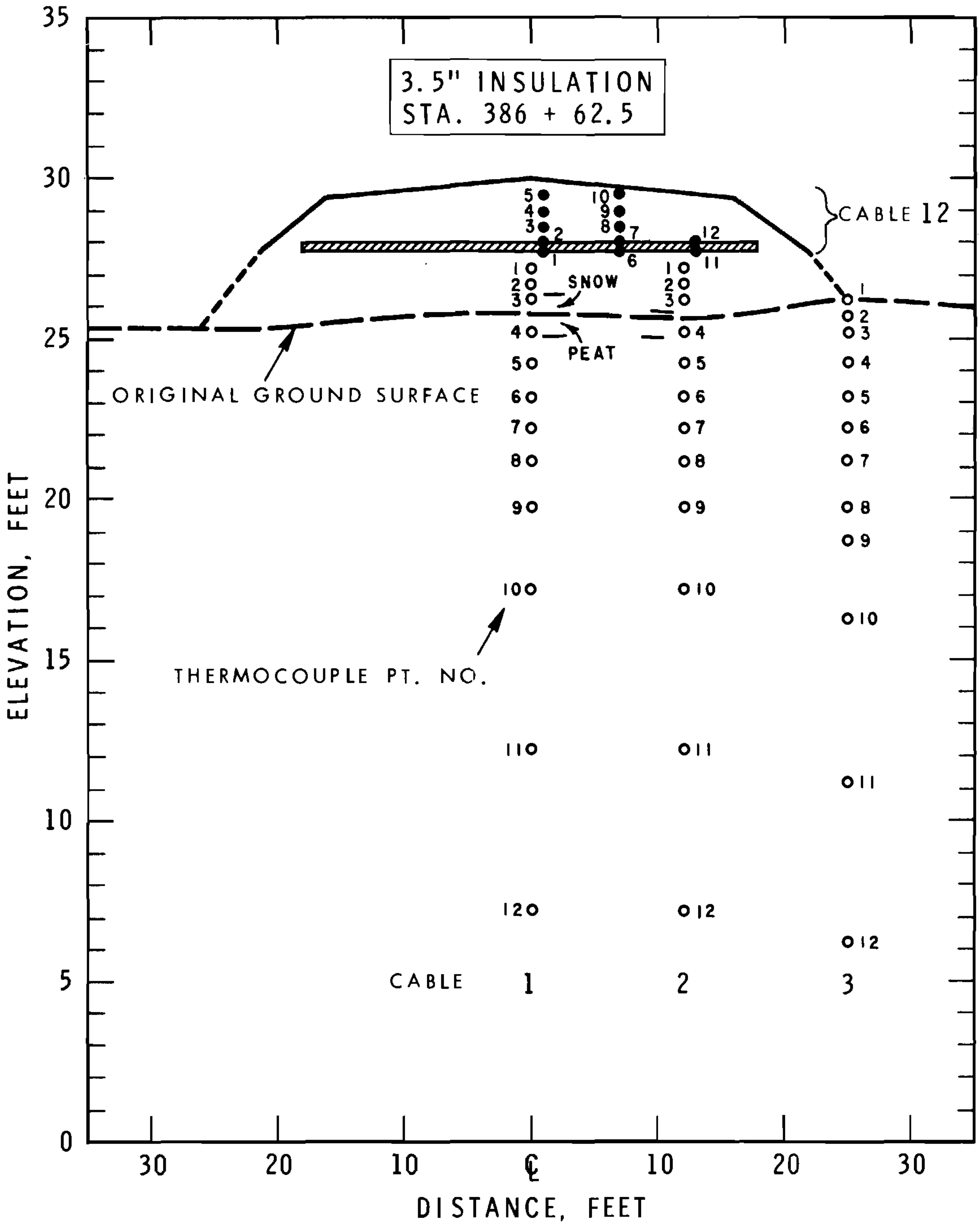


FIGURE 20
SUMMER TEST SITE, PLAN AND CENTRELINE PROFILE

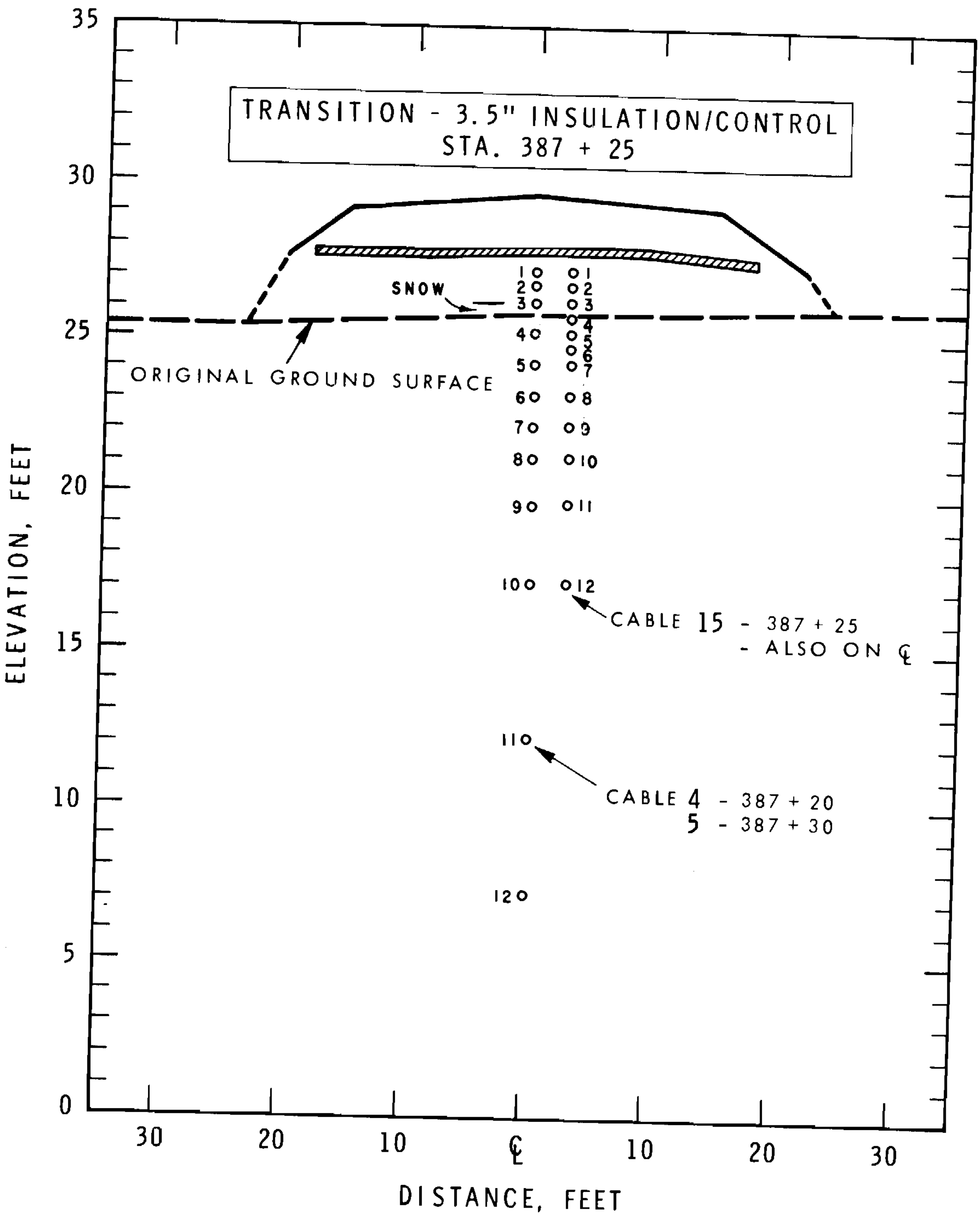


NOTES:

- AS INSTALLED - APRIL 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 21 (a)

WINTER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

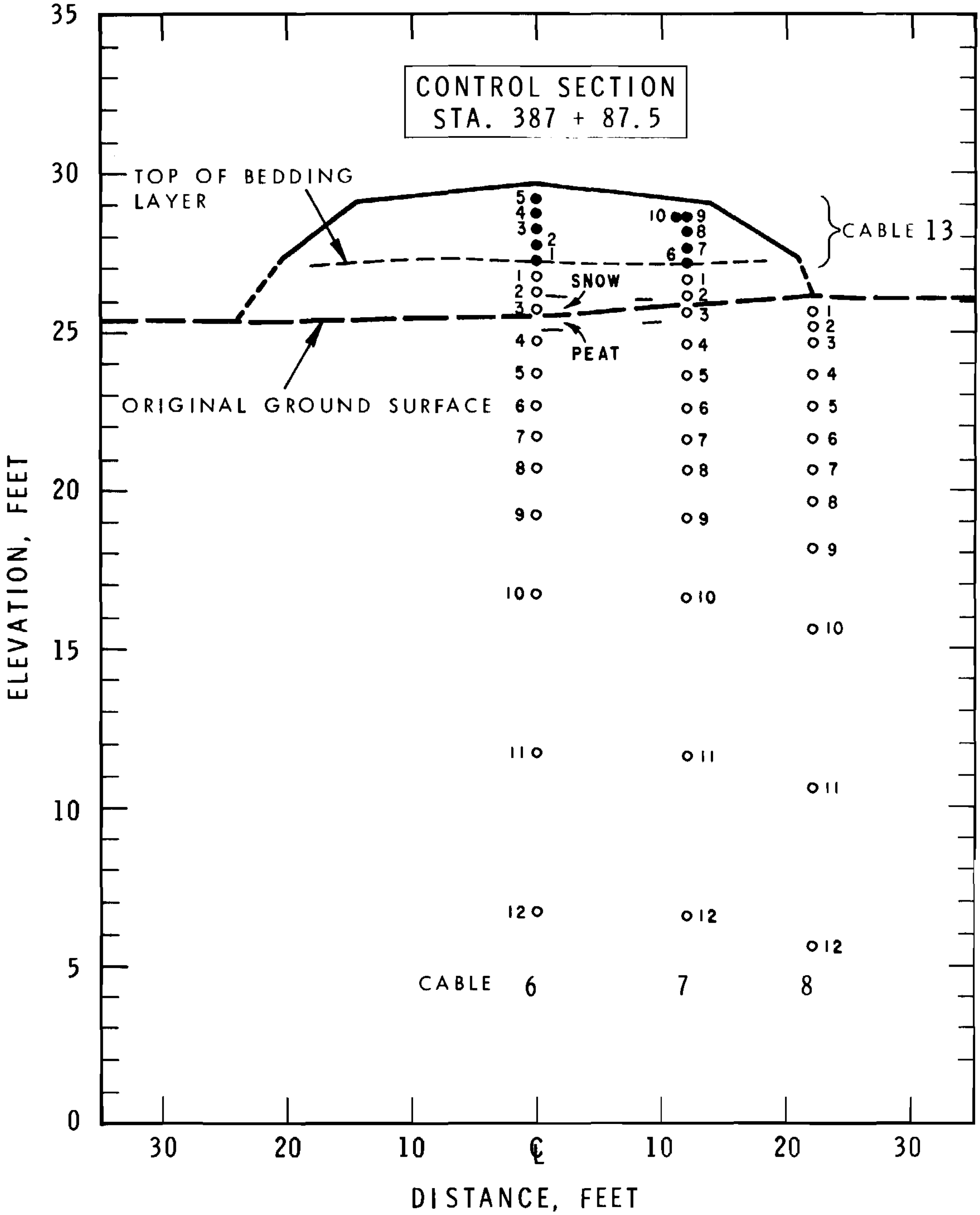


NOTES:

- AS INSTALLED - APRIL 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 21 (b)

WINTER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

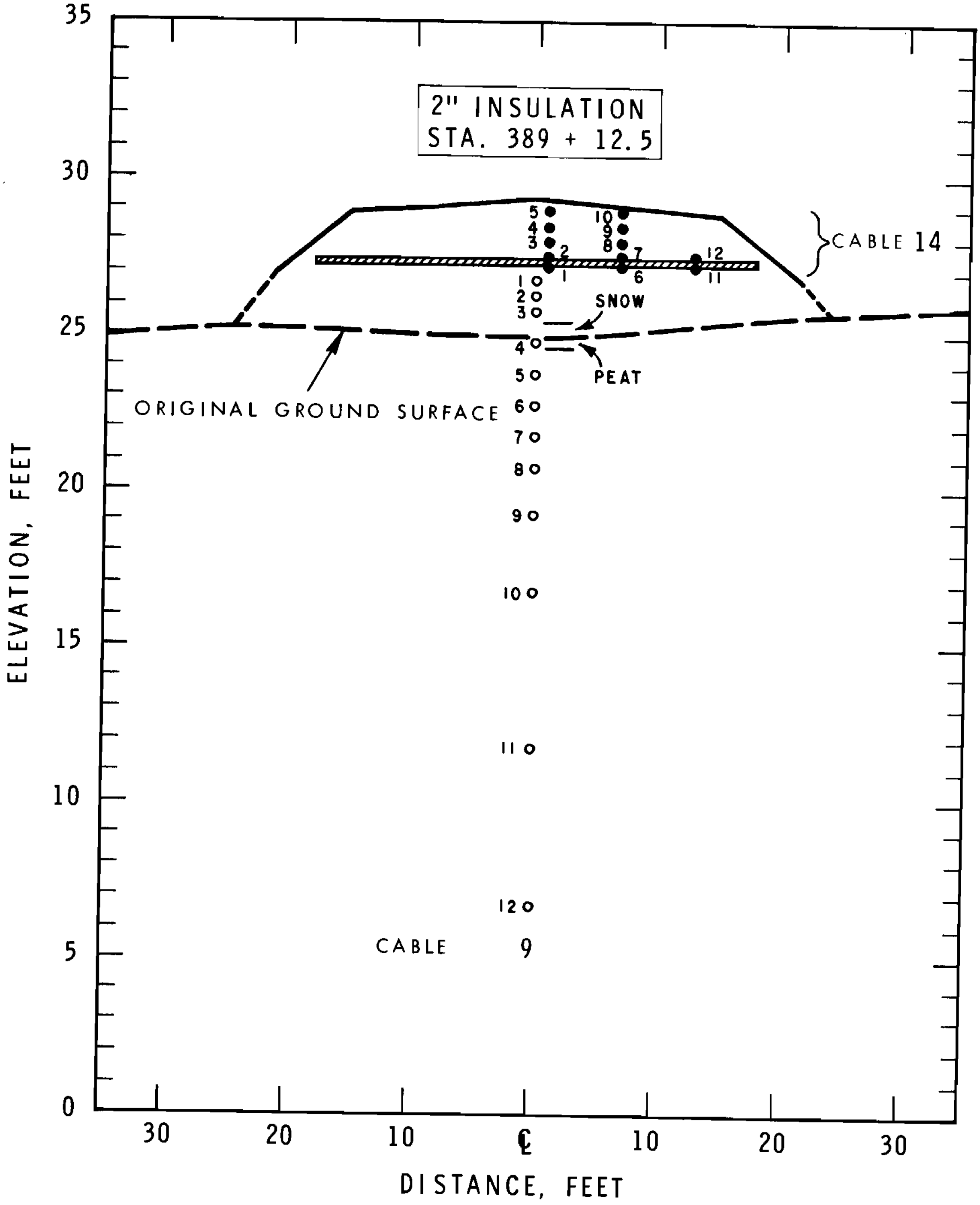


NOTES:

- AS INSTALLED - APRIL 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK= 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 21 (c)

WINTER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

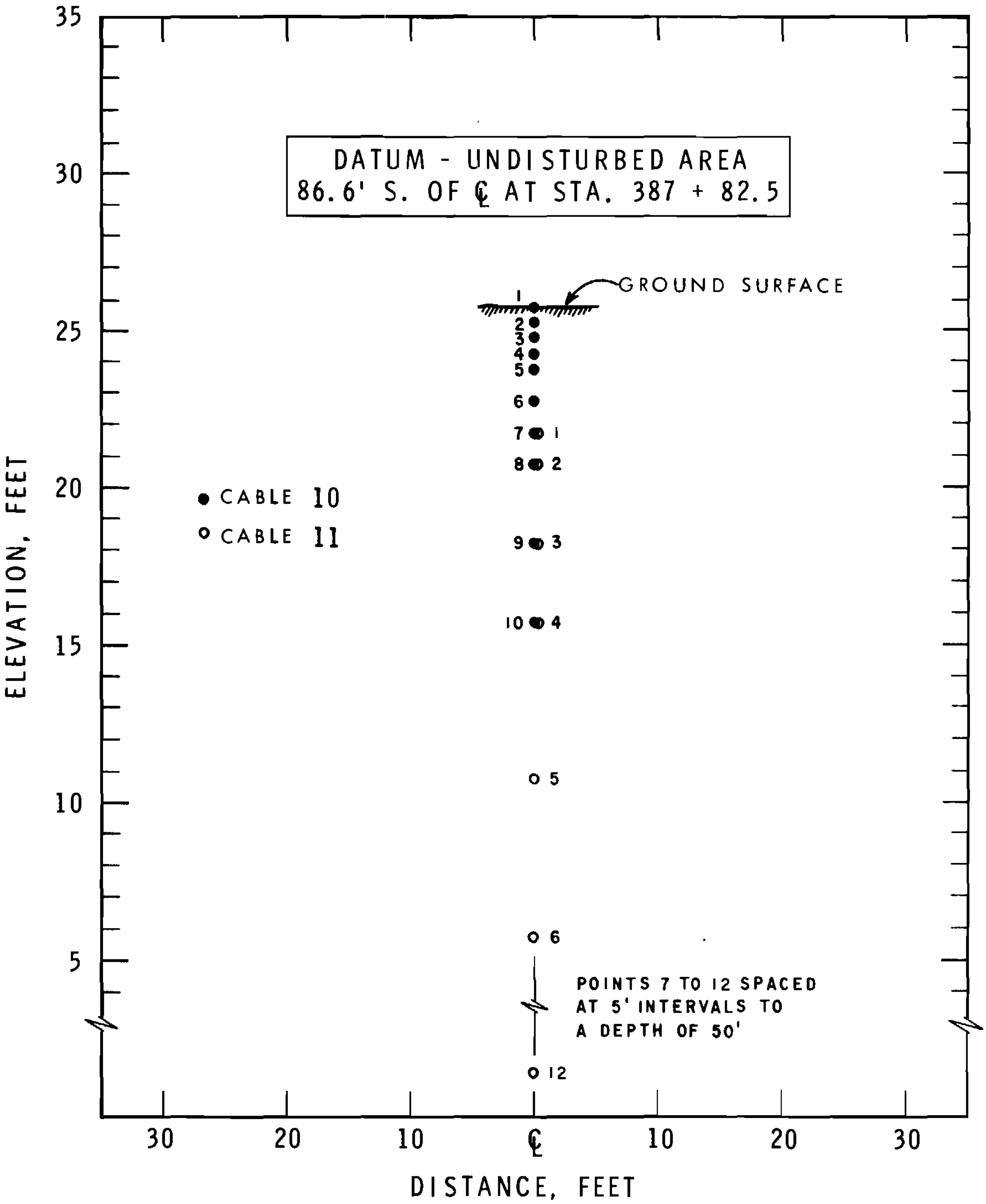


NOTES:

- AS INSTALLED - APRIL 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 21 (d)

WINTER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

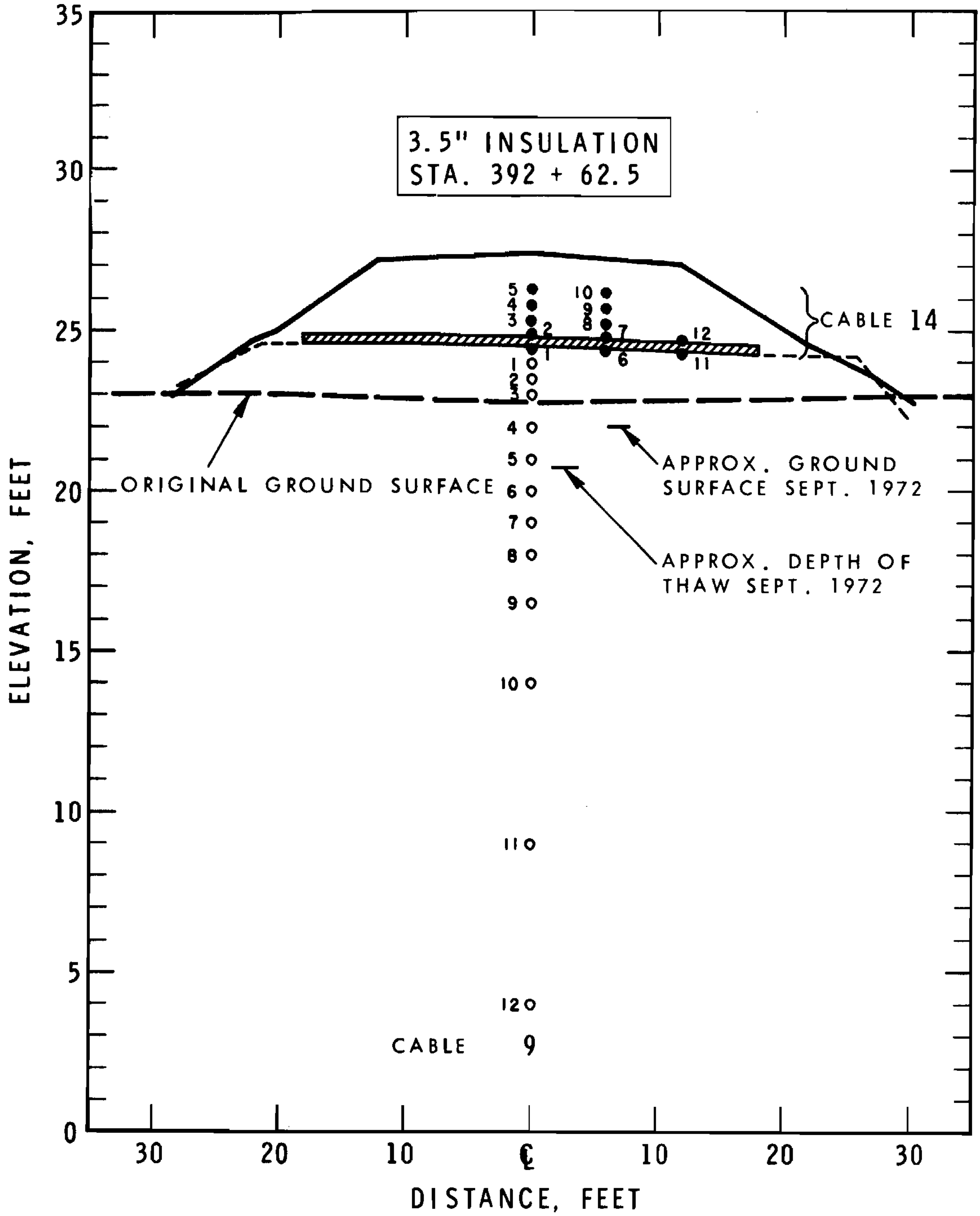


NOTES:

- AS INSTALLED - APRIL 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)

FIGURE 21(e)

WINTER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

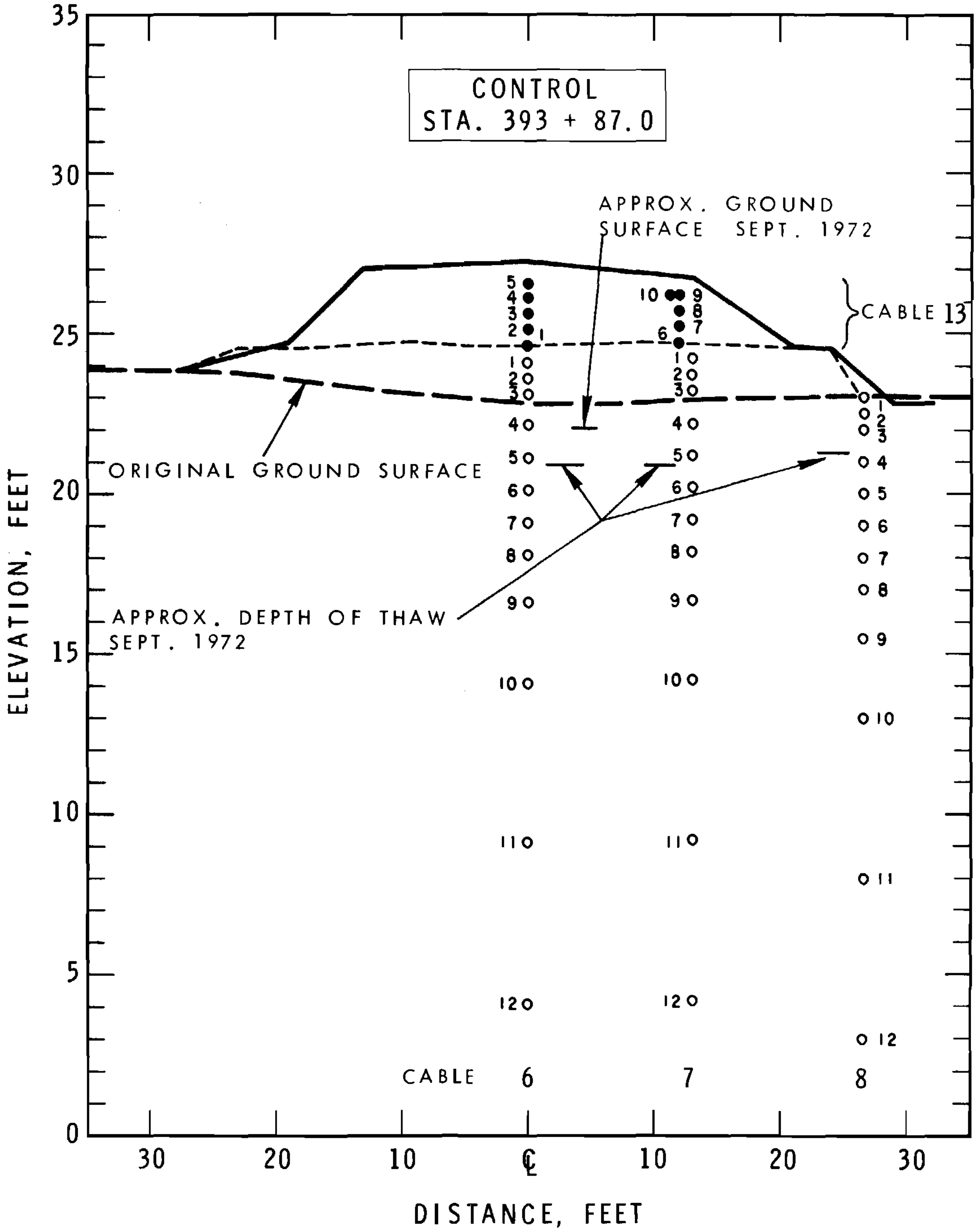


NOTES:

- AS INSTALLED - SEPT. 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 22 (a)

SUMMER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

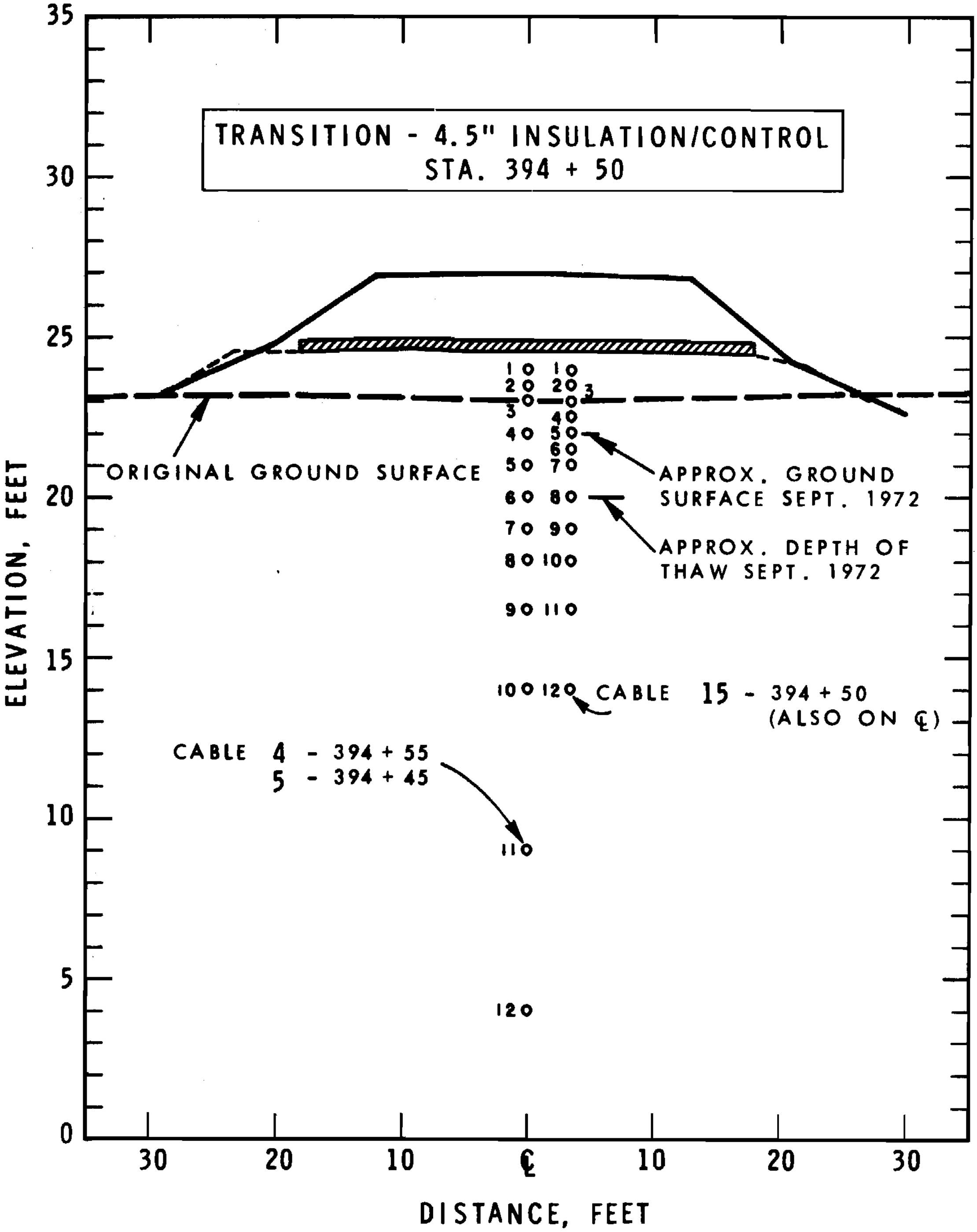


NOTES:

- AS INSTALLED - SEPT. 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 22 (b)

SUMMER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

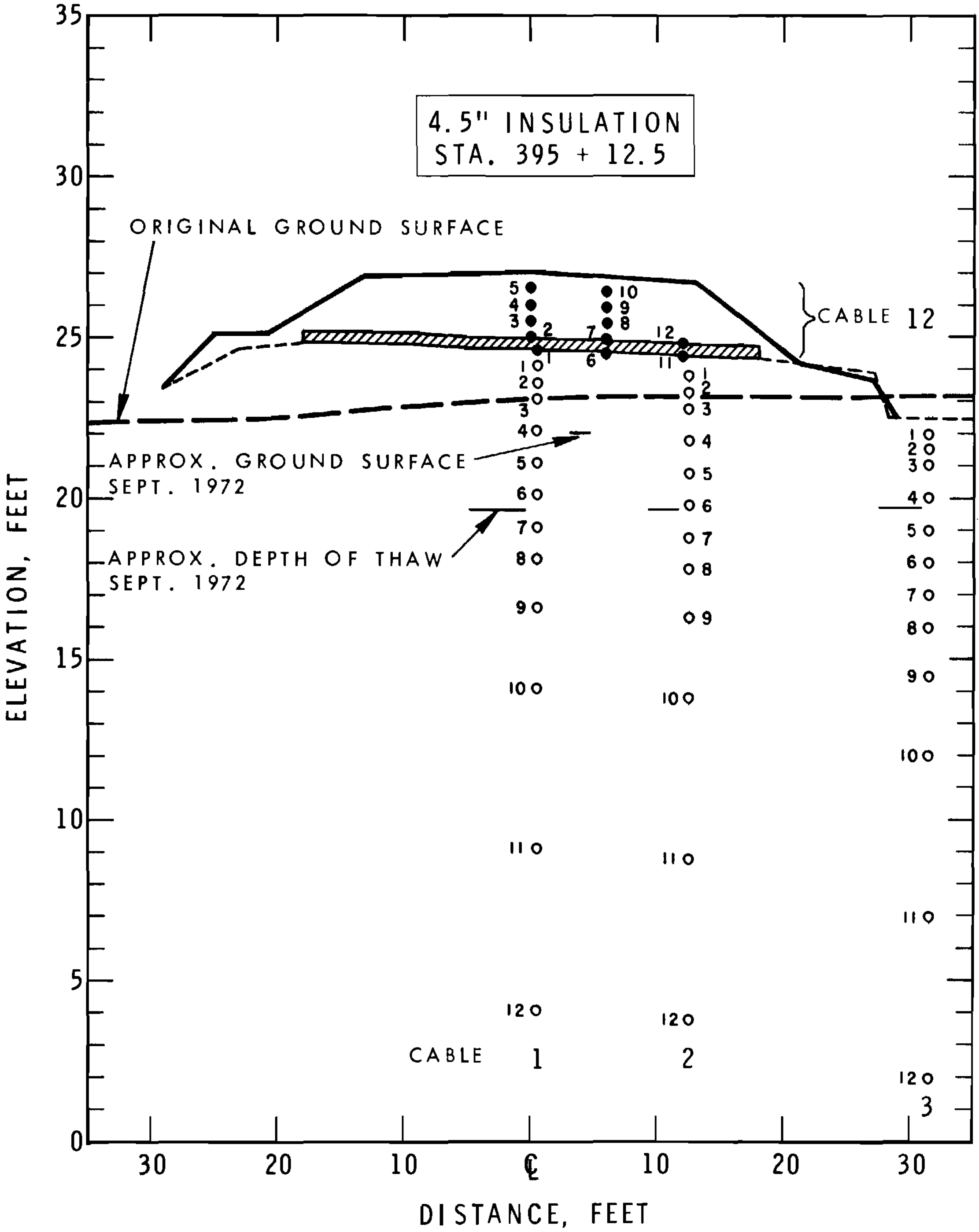


NOTES:

- AS INSTALLED - SEPT. 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 22 (c)

SUMMER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

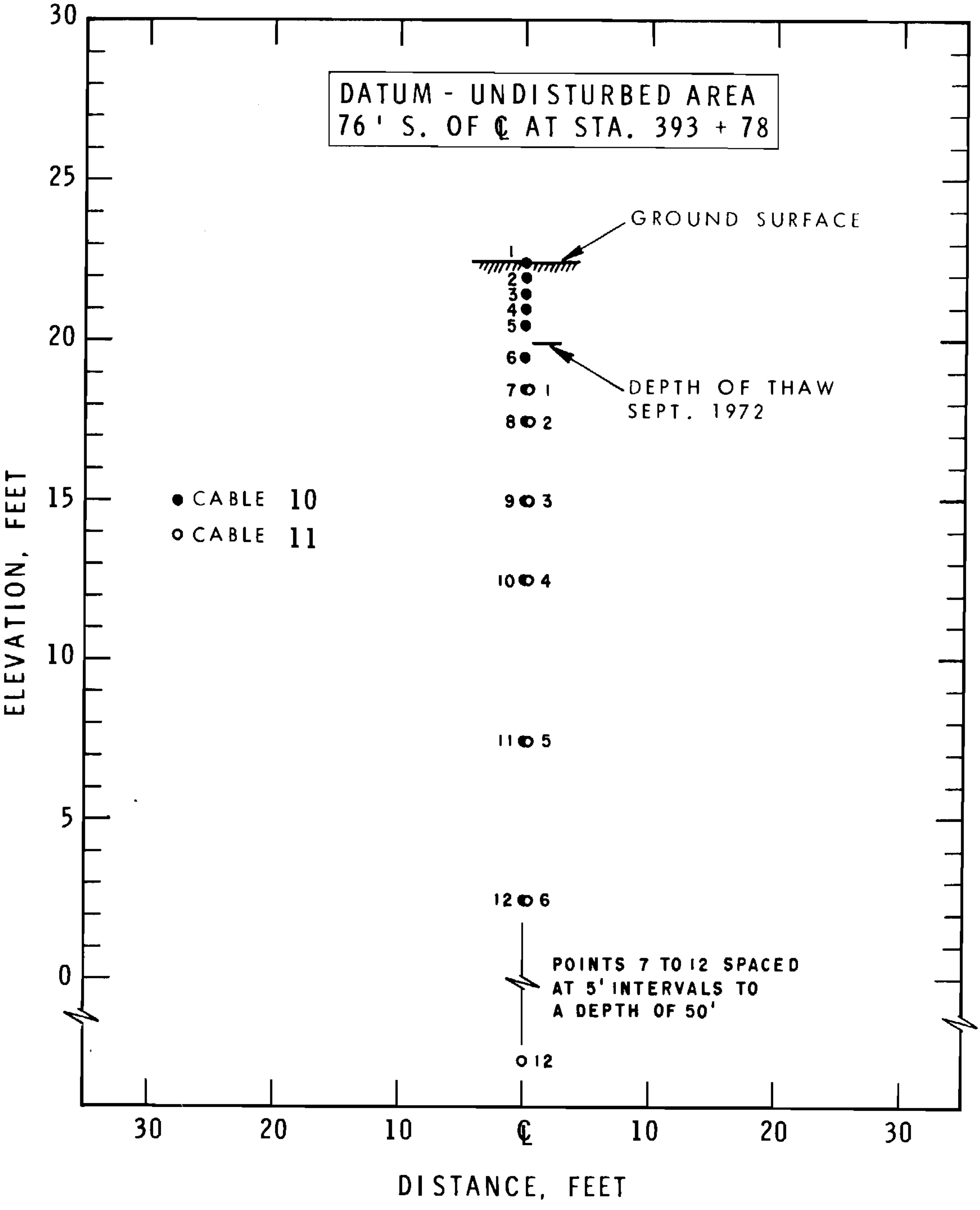


NOTES:

- AS INSTALLED - SEPT. 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS PRIOR TO CONSTRUCTION

FIGURE 22(d)

SUMMER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS



NOTES:

- AS INSTALLED - SEPT. 1972
- THERMOCOUPLE POINT NO. = SWITCH POINT NO.
- ELEVATIONS BASED ON L.W.L. EAST CHANNEL AT INUVIK = 0.00' (APRIL 1954)
- ORIGINAL GROUND SURFACE APPROXIMATE ONLY - INTERPOLATED FROM DPW SURVEYS

FIGURE 22(e)

SUMMER TEST SITE, CROSS-SECTION AND THERMOCOUPLE LOCATIONS

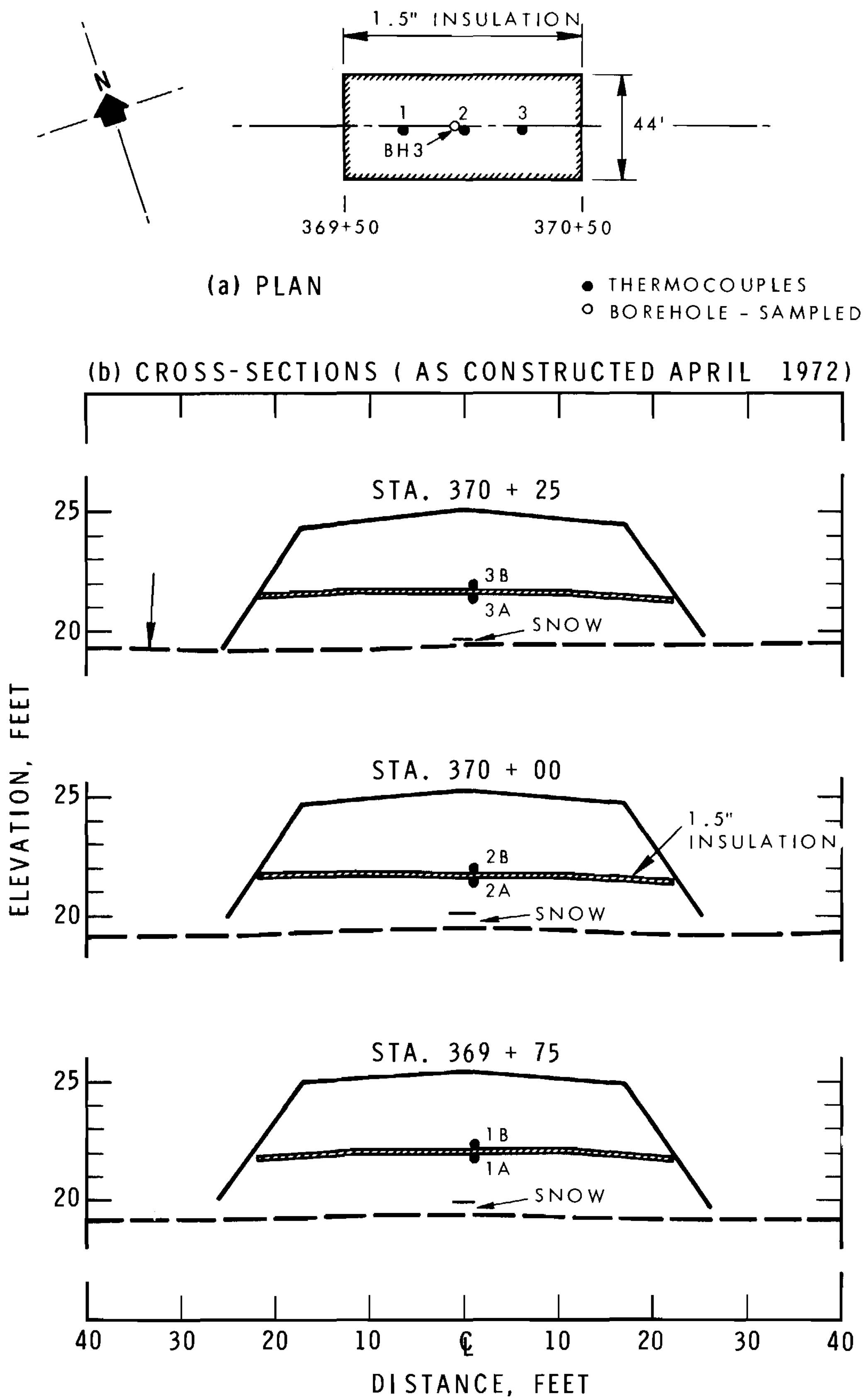
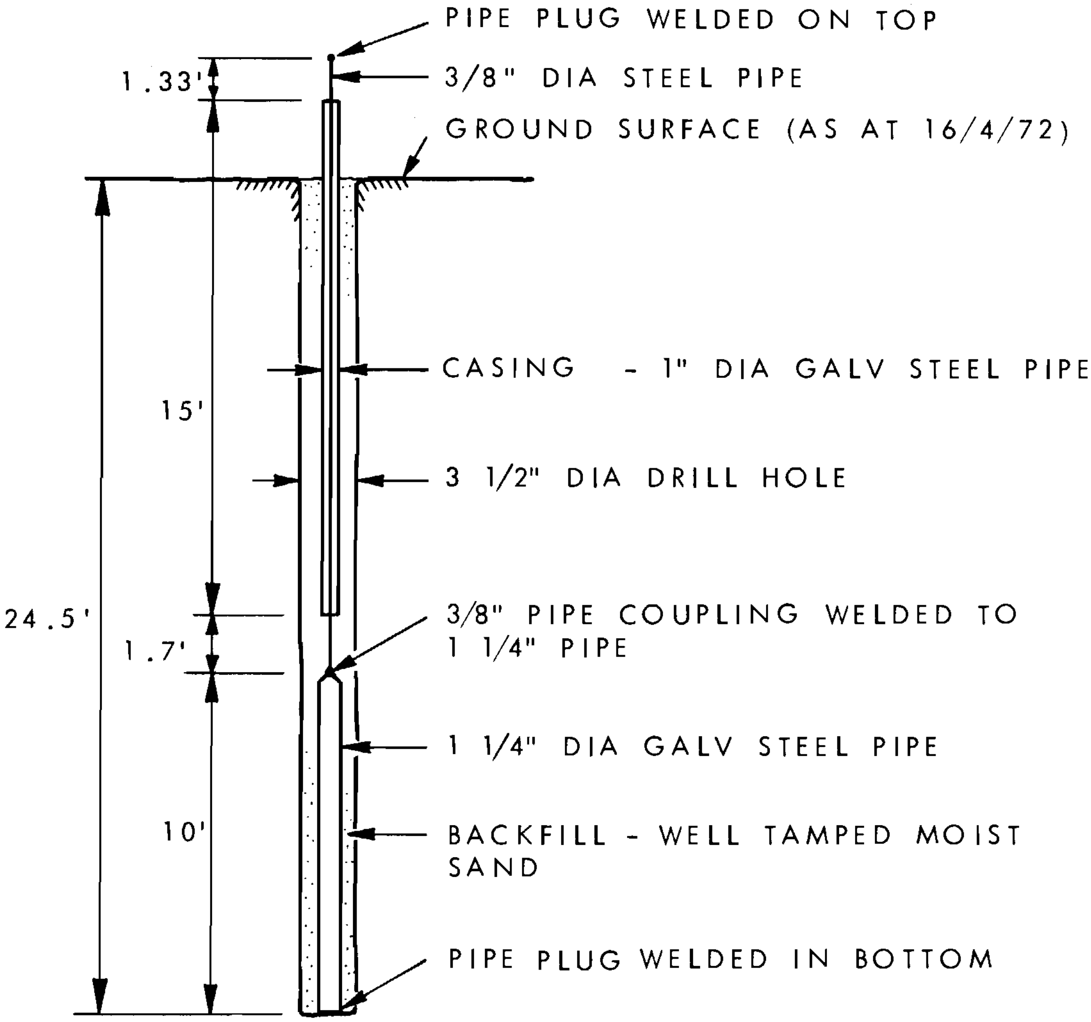


FIGURE 23

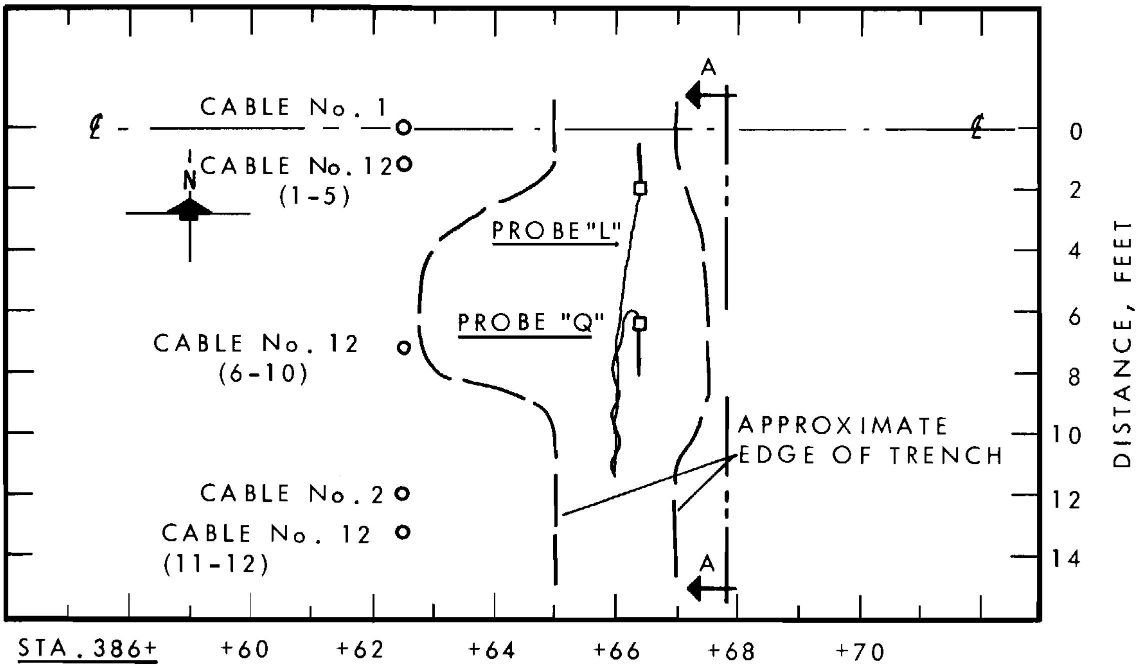
POLYGON TEST SITE, PLAN AND CROSS-SECTIONS



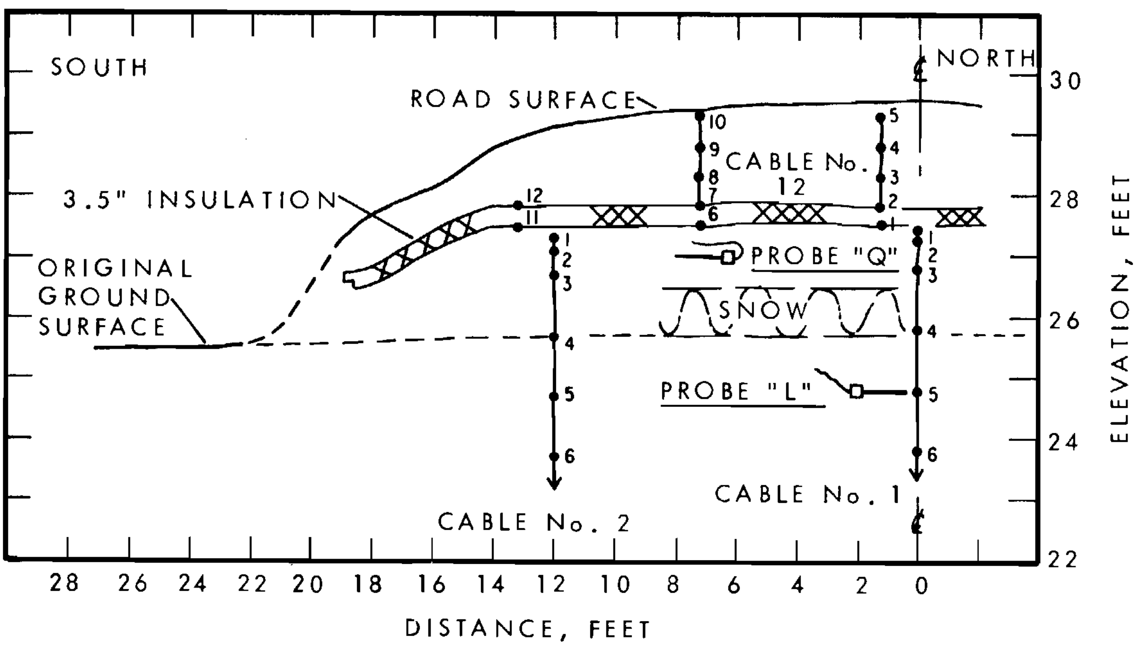
B.M. INSTALLED 40' RIGHT (SOUTH) OF ℄ AT STA. 389+63

FIGURE 24

BENCH MARK DETAILS



(a) PLAN VIEW



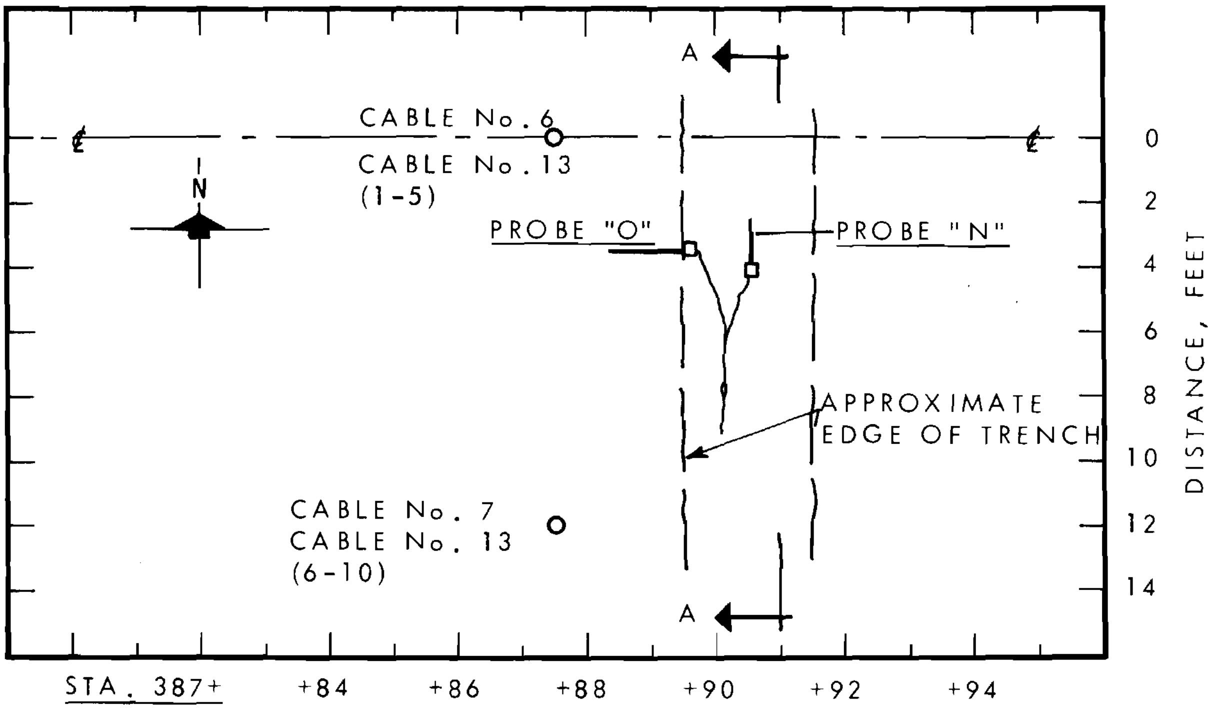
(b) SECTION A-A

PROBES INSTALLED 17-9-73

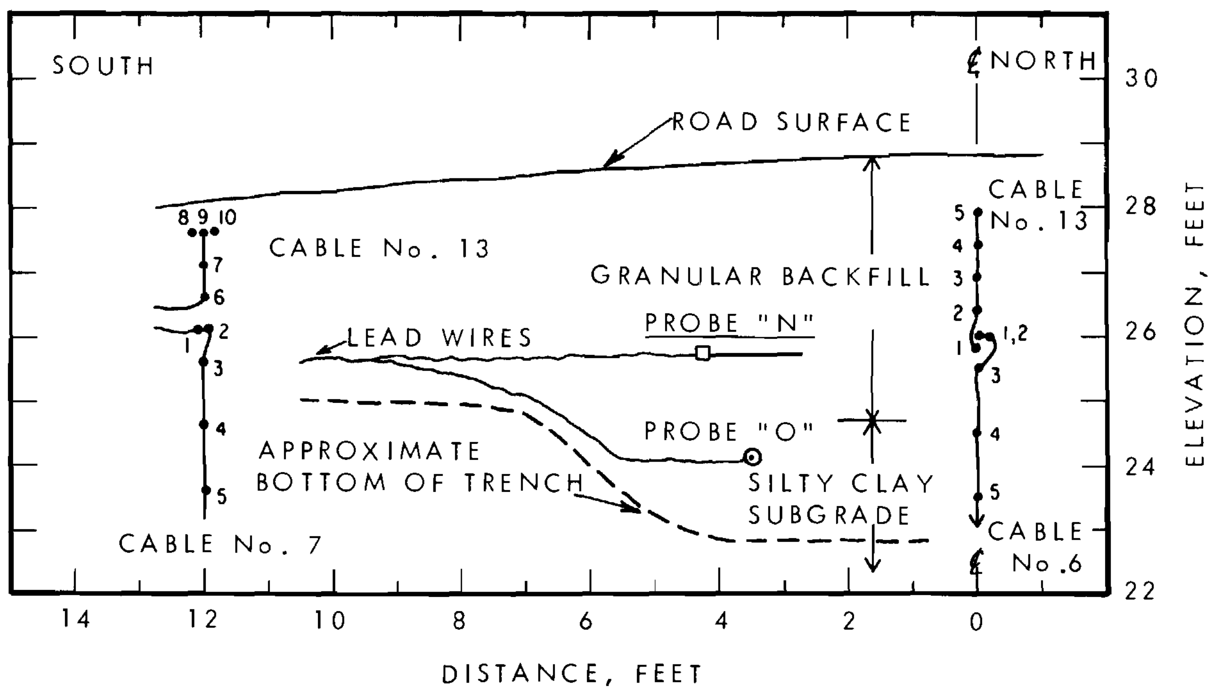
STA. 386+66.5

FIGURE 25

LOCATION OF THERMAL CONDUCTIVITY PROBES
3.5" INSULATED SECTION-WINTER TEST SITE



(a) PLAN VIEW



(b) SECTION A-A

PROBES INSTALLED 18-9-73
STA. 387+90

FIGURE 26

LOCATION OF THERMAL CONDUCTIVITY PROBES
CONTROL SECTION - WINTER TEST SITE

INSULATED ROAD STUDY

MACKENZIE HIGHWAY

INUVIK, N.W.T.

APPENDIX I

EXPLORATORY BOREHOLE LOGS AND

SOIL TEST RESULTS

a. DPW HOLES

b. MVPRL/NRC HOLES

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING	TECHNICIAN.	PROJECT.	STATION.	HOLE NO.
March 1972		Inuvik, Test Section		1 & 2

LAB No.	BAG No	DEPTH	SOIL DESCRIPTION.	W %	CONS LIMITS W_L %	W_P %	I_P	#4 % PASSING SIEVE	#10	#40	#200	SILT %	CLAY %	Gs	ESTIMATED PROCTOR COMPACTION MAX. DENS.	OPT. MOIST	GROUP INDEX	AASHO	UNIFIED
HOLE #1																			
11906	1	0-2	Brown - Fill Sand - pebbles SM	22.8		N.P.		93	90	68	19				Ice from 6'- 11'				
11907	2	2-4	Grey - Sandy silty clay some org. material Cl	22.9	45.0	19.8	25.2	100	99	98	88				Thick ice from 8'-9'				
11908	3	4-6	Grey-brown Silty clay Cl	33.4				-	100	98	90				Ice lense at 15'				
11909	4	6-8	Brown Silty clay Cl	47.0				-	100	99	96								
11910	5	8-10	Brown - Silty clay Free water Cl	81.0				-	100	98	93								
11911	6	10-12	Grey Sandy silty clay Cl	34.3				-	100	95	78								
11912	7	12-14	Grey Sandy silty clay Cl	13.5				99	99	94	84								
11913	8	14-16	Grey Sandy silty clay Cl	41.2	37.3	16.3	21.0		100	97	89								
HOLE #2																			
11914	1	0-2	Brown - Fill - pebbles Silty sandy - org. material SM	55.9		N.P.		94	91	70	31								
11915	2	2-4	Brown - Fill Pebbles - silty sand some clay SC	40.6	N.P. Low	to p.i.		93	92	70	35								
11916	3	4-6	Brown Silty clay Cl	39.0					100	98	93								
11917	4	6-8	Brown - silty clay Free water Cl	49.6					100	98	92				Ice Lenses				

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING.			TECHNICIAN.	PROJECT.								STATION.			HOLE NO.				
M[illegible] 4 1972				Inuvik Test Section											2 & 3				
IDENTIFYING INFORMATION.			SOIL DESCRIPTION.	PHYSICAL PROPERTIES.											ESTIMATED PROCTOR COMPACTION		SOILS CLASSIFICATION.		
				W	CONS LIMITS.			MECHANICAL ANALYSIS.						Gs					
LAB. No.	BAG No.	DEPTH.		%	W_L %	W_P %	I_P	# 4 % PASSING SIEVE.	# 10	# 40	# 200	SILT %	CLAY %		MAX. DENS.	OPT. MOIST	GROUP INDEX	AASHO.	UNIFIED
11918	5	8–10	Brown – silty clay free water CI	50.6	40.9	18.8	22.1	100	99	97	92				From	6' –	12'		
11919	6	10–12	Brown – sandy silty clay free water CI	68.4					100	94	84								
11920	7	12–14	Brown – Grey Silty sandy clay CI	25.7				100	98	76	61								
11921	8	14–16	Grey Silty sandy clay CI	16.0				100	98	80	62								
11922	9	16–18	Grey Silty sandy clay CI	13.3					100	84	65								
11923	10	18–20	Grey Silty sandy clay CI	12.7	42.4	18.4	24.0		100	85	66								
HOLE # 3																			
11924	[illegible]	0–2	Brown Silty clay – org. mat. CI – CH	36.9	50.3	23.1	27.2			100	99								
11925	2	2–4	Brown Silty clay – free water CI-CH	77.1						100	99								
11926	3	6–8	Brown Silty clay – free water CH	79.8						100	98				Ice Lenses				
11927	4	8–10	Brown Silty clay – free water CI	70.8				100	99	98	95				From	4' –	15'		
11928	5	10–12	Brown Silty clay – free water CI	84.3						100	98				Thick	ice	from		
11929	6	12–14	Grey Silty clay CI	41.8				100	99	99	96				10'	– 12'			

I-4

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING	TECHNICIAN	PROJECT	STATION	HOLE NO.
March 1972		Inuvik Test Section		3 & 4

LAB. No.	BAG No	DEPTH	SOIL DESCRIPTION	W %	CONS. LIMITS W_L %	W_P %	I_P	MECHANICAL ANALYSIS #4 (% passing sieve)	#10	#40	#200	SILT %	CLAY %	Gs	EST. PROCTOR MAX. DENS.	OPT. MOIST	GROUP INDEX	AASHO	UNIFIED
11930	7	14–16	Grey Sandy silty clay CL	25.6	28.3	14.2	14.1	100	99	92	78								
11931	8	16–18	Grey pebbles – silty sandy clay CL	11.8	22.4	13.1	9.3	96	90	79	66								
11932	9	18–20	Grey – silty sandy clay shale chips CL	10.8				92	85	74	61								
HOLE #4																			
11933	1	0–2	Brown – free water Fill – sand & sandstone SM	26.9		N.P.		79	74	55	17								
11934	2	2–4	Brown – sandy silty clay source org. material CI	37.7				95	95	94	89								
11935	3	4–6	Brown Silty clay CI	43.3					100	97	90								
11936	4	6–8	Grey Silty clay – free water CI	64.8						100	99				Ice lenses from				
11937	5	8–10	Grey – silty clay free water CI	74.2	48.2	19.9	28.3			100	98				$5^{5'}$ –	13'			
11938	6	10–12	Grey Silty clay – free water CI	111.9					100	99	95								
11939	7	12–14	Grey Silty clay – free water CI	62.2				100	99	96	90								
11940	8	14–16	Grey – sandy silty clay shale chips CI	24.3	36.5	16.2	20.3	99	97	94	85								
11941	9	16–18	Grey – sandy silty clay shale chips CI	23.3	31.4	11.6	19.8	99	95	85	74								

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING	TECHNICIAN.	PROJECT.	STATION.	HOLE NO.
MARCH 1972		Inuvik Test Section		4 & 5

LAB. No.	BAG No.	DEPTH.	SOIL DESCRIPTION.	W %	CONS LIMITS W_L %	W_P %	I_P	MECHANICAL ANALYSIS # 4 (% PASSING SIEVE)	# 10	# 40	# 200	SILT %	CLAY %	Gs	ESTIMATED PROCTOR COMPACTION MAX. DENS.	OPT. MOIST	SOILS CLASSIFICATION GROUP INDEX	AASHO.	UNIFIED.
11942	10	18–20	Grey – sandy silty clay shale chips CL	13.2				95	87	75	64								
HOLE # 5																			
19943	1	0–2	Brown Fill clayey sand some sandstone Sc	27.2	20.8	12.9	7.9	98	96	79	38								
11944	2	2–4	Brown – sandy silty clay org. mat. & some sandstone Cl	45.5	42.2	19.7	22.5	97	97	91	67								
11945	3	4–6	Brown Silty clay Cl	41.6	46.7	20.4	26.3	99	99	98	92								
11946	4	6–8	Brown silty clay Cl	47.1					100	98	91				Ice lenses from				
11947	5	8–10	Grey silty clay – free water Cl	85.6					100	99	98				5' – 12'				
11948	6	10–12	Grey – silty clay free water Cl	69.7					100	97	92				Thick ice at 9'				
11949	7	12–14	Grey Silty sandy clay Cl	27.8	32.7	16.4	16.3	98	91	72	57								
11950	8	14–16	Grey silty clay Cl	35.0	45.1	17.6	27.5		100	97	92								
11951	9	16–18	Grey silty sandy clay Cl	33.5					100	96	88								

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING	TECHNICIAN.	PROJECT.	STATION.	HOLE NO.
March 1972		Inuvik Test Section		6 & 7

IDENTIFYING INFORMATION.			SOIL DESCRIPTION.	PHYSICAL PROPERTIES.											ESTIMATED PROCTOR COMPACTION		SOILS CLASSIFICATION.		
				W	CONS LIMITS.			MECHANICAL ANALYSIS.						Gs					
LAB. No.	BAG No.	DEPTH.		%	W_L %	W_P %	I_P	# 4 % PASSING SIEVE.	# 10	# 40	# 200	SILT %	CLAY %		MAX. DENS.	OPT. MOIST	GROUP INDEX.	AASHO	UNIFIED.
HOLE #6																			
11952	1	0-2	Brown - mixture of sand and clay - free water - Fill CL	47.8	27.6	15.7	11.9	100	99	92	60								
11953	2	2-4	Brown Silty sandy - org. mat. CI	40.4					100	99	95				Ice lenses from				
11954	3	4-6	Brown - silty clay source org. material CI	41.3					100	99	97				45' to bottom of				
11955	4	6-8	Brown silty clay - free water CI-CH	66.1	54.8	24.5	30.3			100	99				Hole.				
11956	5	8-10	Grey silty clay - ~~source~~ some free water CI-CH	58.6						100	100								
11957	6	10-12	Grey silty clay - small shale chips CI	54.4					100	98	90								
11958	7	12-14	Grey Silty clay CI	40.5	45.5	19.1	26.4	100	99	96	90								
11959	8	14-16	Grey Silty clay CI	46.4				100	99	97	92								
HOLE #7																			
11960	1	0-2	Brown - free water - silty sandy clay & sandstone - Fill CL	30.2	25.1	13.3	11.8	95	93	84	63								
11961	2	2-4	Brown - silty clay some org. material CI	25.9					100	99	96				Ice lenses from				
11962	3	4-6	Brown silty clay CH	29.8					100	99	98				6' - 15'				
11963	4	6-8	Brown silty clay CH	38.7						100	99				Thick ice from				

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING	TECHNICIAN.	PROJECT.	STATION.	HOLE NO
March 1972		Inuvik Test Section		7 & 8

LAB. No.	BAG No	DEPTH.	SOIL DESCRIPTION.	W %	CONS. LIMITS W_L %	W_P %	I_P	MECHANICAL ANALYSIS # 4 % PASSING SIEVE	# 10	# 40	# 200	SILT %	CLAY %	Gs	ESTIMATED PROCTOR COMPACTION MAX. DENS.	OPT. MOIST	SOILS CLASSIFICATION GROUP INDEX.	AASHO	UNIFIED
11964	5	8-10	Brown silty clay CI-CH	50.0	53.0	23.0	30.0			100	99				12' –	14'			
11965	6	10-12	Grey silty clay CI-CH	48.3						100	99								
11966	7	12-14	Grey silty clay – free water CI	83.4				100	99	99	97								
11967	8	14-16	Grey silty clay CI	46.7				100	99	98	95								
HOLE # 8																			
11968	1	0-2	Brown – silty clay org. mat. – free water CH	74.9						100	98								
11969	2	2-4	Brown silty clay – org. material CI	43.5	50.9	25.6	25.3			100	99				Ice lenses from				
11970	3	4-6	Brown silty clay – free water CI-CH	66.2						100	100				approximately 2' – 13'				
11971	4	6-8	Grey silty clay – free water CI	74.5						100	98								
11972	5	8-10	Grey silty clay – free water CI	69.3				100	99	97	95								
11973	6	10-12	Grey silty clay CI	47.6					100	99	97								
11974	7	12-14	Grey silty clay CI	36.7				100	99	95	91								
11975	8	14-16	Grey silty clay CI	47.0					100	99	97								

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS. – OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING			TECHNICIAN	PROJECT							STATION				HOLE NO.				
March 1972				Inuvik, Test Section															
IDENTIFYING INFORMATION			SOIL DESCRIPTION	PHYSICAL PROPERTIES											ESTIMATED PROCTOR COMPACTION		SOILS CLASSIFICATION		
				W	CONS. LIMITS			MECHANICAL ANALYSIS						Gs					
LAB. No.	BAG No	DEPTH		W %	W_L %	W_P %	I_P	# 4 % PASSING SIEVE	# 10	# 40	# 200	SILT %	CLAY %	Gs	MAX. DENS.	OPT. MOIST	GROUP INDEX	AASHO	UNIFIED
HOLE #9																			
11976	1	0-2	Brown - Fill Sand & sandstone SM	24.4	N	P.		92	88	71	28								
11977	2	2-4	Brown (free water) clayey sand - org. mat. some sandstone SC	92.2	25.3	19.4	5.9	97	96	88	54				Snow layer @ 2'				
11978	3	4-6	Brown Sandy silty clay CI	35.9				99	99	97	88				Ice lenses from				
11979	4	6-8	Brown Silty clay CI	31.7				-	100	98	92				7' to bottom				
11980	5	8-10	Brown Silty clay - some sand Free water CI	135.8	40.6	17.8	22.8	100	99	96	88				of hole				
11981	6	10-12	Grey Silty clay CI	53.1	-			-	100	96	94								
HOLE #9A																			
11982	1	0-2	Brown Silty clay - org. mat. CH	35.5				-	-	100	94								
11983	2	2-4	Brown Silty clay CH	39.1				-	-	100	99								
11984	3	4-6	Brown Silty clay - free water CH	60.7	53.0	24.0	29.0	-	-	100	99								
11095	4	6-8	Brown Silty clay - free water CI	152.8				100	99	97	95								
11986	5	8-10	Grey Silty clay CI	34.4				99	98	97	92				Ice lenses from				
11987	6	10-12	Grey Silty sandy clay CL	19.7	25.2	13.8	11.4	99	94	81	62				2^{5}' - 10'				

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING			TECHNICIAN	PROJECT				STATION							HOLE NO.				
March 1972				INUVIK - Test Section															
IDENTIFYING INFORMATION			SOIL DESCRIPTION	PHYSICAL PROPERTIES											ESTIMATED PROCTOR COMPACTION		SOILS CLASSIFICATION		
				W	CONS. LIMITS			MECHANICAL ANALYSIS						Gs					
LAB. No.	BAG No	DEPTH		W %	W_L %	W_P %	I_P	#4 % PASSING SIEVE	#10	#40	#200	SILT %	CLAY %	Gs	MAX. DENS.	OPT. MOIST.	GROUP INDEX	AASHO	UNIFIED
HOLE #9A																			
11988	7	12-14	Grey Mixture of shale+sand+clay CL	10.8				94	81	54	30								
11989	8	14-16	Grey Mixture of shale+sand+clay CL	13.1				98	89	65	37								
11990	9	16-18	Grey Mixture of shale+sand+clay CL	9.7	23.1	12.4	10.7	95	84	56	34								
11991	10	18-20	Grey Mixture of shale+sand+clay CL	9.0				95	84	63	42								
HOLE #10																			
11992	1	0-2	Brown Org. mat. - silty clay CI	33.1	48.0	27.1	20.9	-	-	100	96								
11993	2	2-4	Brown Silty sandy clay Pebbles CI	27.3	33.1	15.7	17.4	93	86	74	62								
11994	3	4-6	Brown Pebbles Sandy silty clay CI	31.3				95	89	81	70								
11995	4	6-8	Grey Pebbles Silty sandy clay CL	15.7	24.3	12.9	11.4	97	88	67	49								
11996	5	8-10	Grey Pebbles Clayey silty sand CL	13.1				93	84	66	44				Thin	ice	lenses		
11997	6	10-12	Grey Pebbles Clayey sand SC	12.2				91	80	55	28				from	25'	-	8'	
11998	7	12-14	Grey Pebbles Clayey sand SC	9.8	17.8	11.8	6.0	88	75	51	26								
11999	8	14-16	Grey Mixture of shale & clay CL	10.5				92	81	64	48								

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.- OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING.			TECHNICIAN.	PROJECT.							STATION.				HOLE NO.				
March 1972				INUVIK - Test Section															
IDENTIFYING INFORMATION.			SOIL DESCRIPTION.	PHYSICAL PROPERTIES.											ESTIMATED PROCTOR COMPACTION		SOILS CLASSIFICATION.		
				W	CONS. LIMITS.			MECHANICAL ANALYSIS.						Gs					
LAB. No.	BAG No.	DEPTH.		%	W_L %	W_P %	I_P	#4 % PASSING SIEVE.	#10	#40	#200	SILT %	CLAY %		MAX. DENS.	OPT. MOIST.	GROUP INDEX.	AASHO.	UNIFIED.
HOLE #10																			
12000	9	16-18	Grey Mixture of clay & shale CL	8.1				84	71	56	39								
12001	10	18-20	Grey Mixture of clay & shale CL	10.9	28.8	13.9	14.9	95	89	78	63								
HOLE #11																			
12002	1	0-2	Brown Silty clay - org. mat. CI	55.1				-	-	100	99								
12003	4	6-8	Brownish grey Silty clay CI	42.2				-	-	-	100				Ice	lenses		from	
12004	5	8-10	Grey Silty clay Free water CI	69.8	49.1	14.7	34.4	-	100	99	99				4^{5}'	- 12'			
12005	6	10-12	Grey Silty clay CI	37.2				99	99	98	96								
12006	7	12-14	Grey Silty clay CI	19.9				100	99	98	95								
12007	8	14-16	Grey Sandy silty clay CI	26.7	35.8	15.7	18.1	99	95	87	77								
12008	9	16-18	Grey Pebbles Sandy silty clay CI	26.1				94	91	87	82								
HOLE #12																			
12009	1	0-2	Brown Silty clay - org. mat. CH	40.4	51.2	25.8	25.4	-	-	100	98								
12010	2	2-4	Brown Silty clay CH	42.3				-	-	100	100				Ice	lenses		from	
12011	3	4-6	Brown Silty clay CI-CH	41.6				-	-	-	100				3'	-	17'		

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING.	TECHNICIAN.	PROJECT.	STATION.	HOLE NO.
March 1972		INUVIK - Test Section		

IDENTIFYING INFORMATION. LAB. No.	BAG No	DEPTH.	SOIL DESCRIPTION.	W %	CONS. LIMITS. W_L %	W_P %	I_P	MECHANICAL ANALYSIS. # 4 % PASSING SIEVE	# 10	# 40	# 200	SILT %	CLAY %	Gs	ESTIMATED PROCTOR COMPACTION MAX. DENS.	OPT. MOIST	SOILS CLASSIFICATION. GROUP INDEX.	AASHO.	UNIFIED
HOLE #12																			
12012	4	6-8	Brown Silty clay CI	48.3				99	99	98	97								
12013	5	8-10	Grey Silty clay CI	36.7				100	99	98	94								
12014	6	10-12	Grey Silty clay CI-CH	25.0	48.8	18.9	29.9	100	100	100	98								
12015	7	12-14	Grey Sandy silty clay CI-CH	28.8	50.0	19.9	30.1	-	100	99	88								
12016	8	14-16	Grey Silty clay CI	33.4	45.7	18.1	27.6	-	-	100	99								
12017	9	16-18	Grey Sandy silty clay CI	28.6	40.9	18.2	22.7	97	91	84	78								
HOLE #13																			
12018	1	0-2	Brown Silty clay CI	108.7				-	-	100	98								
12019	2	2-4	Brown Silty clay CH-CI	34.2				-	-	-	100				Ice lenses from				
12020	3	4-6	Brown Silty clay CH-CI	36.9				-	-	100	100				2' - 12'				
12021	4	6-8	Brown Silty clay CI-CH	47.2	50.9	19.4	31.5	-	-	-	100								
12022	5	8-10	Brown Silty clay CI-CH	46.2				-	-	-	100								
12023	6	10-12	Grey Silty clay CI	29.4				-	100	98	93								

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.— OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING	TECHNICIAN	PROJECT	STATION	HOLE NO.
March 1972		INUVIK - Test Section		

LAB. No.	BAG No.	DEPTH	SOIL DESCRIPTION		W %	CONS. LIMITS W_L %	W_P %	I_P	MECHANICAL ANALYSIS # 4 (% PASSING SIEVE)	# 10	# 40	# 200	SILT %	CLAY %	Gs	ESTIMATED PROCTOR COMPACTION MAX. DENS.	OPT. MOIST	GROUP INDEX	AASHO	UNIFIED
HOLE #13																				
12024	7	12-14	Grey Sandy silty clay Shale chips	Cl	22.5				98	92	81	72								
12025	8	14-16	Grey Sandy silty clay Shale chips	CL	18.0				96	90	85	59								
12026	9	16-18	Grey Silty sandy clay Shale chips	CL	17.3	21.8	12.0	9.8	99	90	74	56								
12027	10	18-20	Grey Sandy silty clay Shale chips	CL	14.8				95	89	80	65								
HOLE #14																				
12028	1	0-2	Brown Silty clay	Cl	30.6				-	-	100	99								
12029	2	2-4	Brown Silty clay Free water	Cl	175.7				-	-	-	100				Ice lenses from				
12030	3	4-6	Brown Silty clay Free water	Cl	56.8				-	-	-	100				2.5' - 8'				
12031	4	6-8	Brown Silty clay	Cl	35.3	50.0	23.0	27.0	-	-	-	100				Thick ice to 6'				
12032	5	8-10	Brown Silty clay	Cl	29.7				-	-	-	100								
12033	6	10-12	Grey Silty clay	Cl	31.2				-	-	-	100								
12034	7	12-14	Grey Silty clay	Cl	26.6				100	99	97	93								
12035	8	14-16	Grey Silty clay	Cl	31.2	43.0	18.9	24.1	-	100	99	93								

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING.	TECHNICIAN.	PROJECT.	STATION.	HOLE NO.
MARCH 1972		INUVIK - Test Section		

LAB. No.	BAG No.	DEPTH.	SOIL DESCRIPTION.	W %	CONS. LIMITS W_L %	W_P %	I_P	MECHANICAL ANALYSIS # 4 (% PASSING SIEVE)	# 10	# 40	# 200	SILT %	CLAY %	Gs	ESTIMATED PROCTOR COMPACTION MAX. DENS.	OPT. MOIST	GROUP INDEX	AASHO	UNIFIED
HOLE # 15																			
12036	1	0-2	Brown Silty clay CI	40.3				-	-	-	100								
12037	2	2-4	Brown Silty clay CI	52.8				-	-	-	100				Ice lenses from				
12038	3	4-6	Brown Silty clay CI	37.8				-	-	100	99				3^5' - 6^5'				
12039	4	6-8	Brown Silty clay CI	33.5	49.1	22.0	27.1	-	-	-	100				Thin ice lenses				
12040	5	8-10	Grey Silty clay CH-CI	27.4				-	-	-	100				to bottom of				
12041	6	10-12	Grey Silty clay CH	58.3	56.7	21.0	35.7	-	-	-	100				hole				
12042	7	12-14	Grey Silty clay CI-CH	33.3				-	-	100	99								
12043	8	14-16	Grey Sandy silty clay CI	32.7	37.2	16.1	21.1	100	99	92	78								
12044	9	16-18	Grey Silty clay CI	45.8				100	99	98	95								
12045	10	18-20	Grey Sandy silty clay CI	34.2	41.3	23.0	18.3	100	98	93	88								
HOLE #16																			
12046	1	0-2	Brown Silty clay CI	25.1				-	-	100	99								
12047	2	2-4	Brown Silty clay - org. mat. CI	39.2	47.1	26.0	21.1	-	-	-	100				Ice lenses from				

TESTING LAB. DEV. ENGINEERING BRANCH, DEPT. OF PUBLIC WORKS.– OTTAWA, ONTARIO. BANFF, ALBERTA.

DATE OF SAMPLING.	TECHNICIAN.	PROJECT.	STATION.	HOLE NO.
MARCH 1972		INUVIK - Test Section		

IDENTIFYING INFORMATION.			SOIL DESCRIPTION.	PHYSICAL PROPERTIES											ESTIMATED PROCTOR COMPACTION		SOILS CLASSIFICATION.		
				W	CONS. LIMITS.			MECHANICAL ANALYSIS.						Gs					
LAB. No.	BAG No	DEPTH.		W %	W_L %	W_P %	I_P	# 4 % PASSING SIEVE.	# 10	# 40	# 200	SILT %	CLAY %	Gs	MAX. DENS.	OPT. MOIST	GROUP INDEX.	AASHO	UNIFIED.
HOLE #16																			
12048	3	4-6	Brown Silty clay CI	49.2	49.8	21.7	28.1	-	-	-	100				3' -	8^{5}'			
12049	4	6-8	Brown Silty clay CI	39.9				-	100	98	97				Thin	ice		lenses	
12050	5	8-10	Grey Sandy silty clay Pebbles CI	21.5				97	92	75	62				from	11'	-	18'	
12051	6	10-12	Grey Silty sandy clay CL	17.1	25.2	13.2	12.0	99	97	74	53								
12052	7	12-14	Grey Sandy silty clay CI	35.2	35.6	16.5	19.1	-	100	90	74								
12053	8	14-16	Grey Sandy silty clay CI	24.8				-	100	96	85								
12054	9	16-18	Grey Silty clay CI	47.0	43.3	18.0	25.3	-	100	99	96								
12055	10	18-20	Grey Sandy silty clay CI	25.9	35.1	15.0	20.1	98	90	77	68								

TEST HOLE LOG - 1-16

PROJECT: INSULATED ROAD SITE: MACKENZIE HWY—INUVIK DATE:

HOLE NO. D-1 LOCATION: 2.7' L. of ℄ - STA. 394 + 96 DEPTH: 25.0'

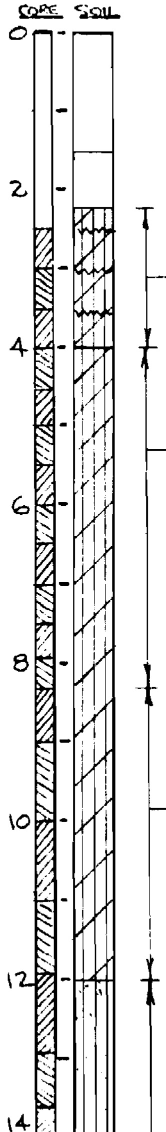
ELEVATION OF GROUND SURFACE (ZERO DEPTH): ROAD SURFACE

METHOD OF ADVANCING HOLE: FAILING DRILL - 4" Ø GAS ARCTIC BARREL

REMARKS: SUMMER TEST SITE

LOG | DESCRIPTION

CORE SOIL



ROAD FILL

SNOW

BROWN ORGANIC SILT
- RANDOM 1/16" ICE LENSES & CRYSTALS
~ 15 % ICE BY VOLUME

- HORIZONTAL ICE LENSES TO 1/8"
30 - 50 % ICE.

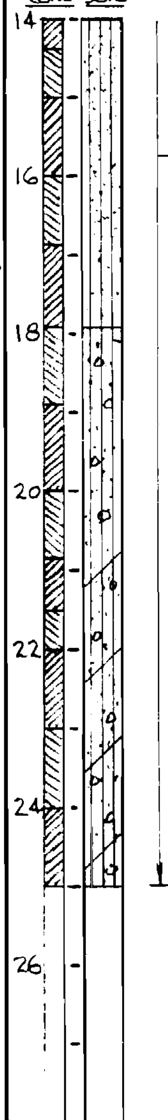
GREY SILTY CLAY

- IRREGULAR ICE LENSES TO 3/8"
30 - 50 % ICE

30 - 50 % ICE

LOG | DESCRIPTION

CORE SOIL



GREY SANDY SILT (TILL)

- ICE CRYSTALS
OCCASIONAL ICE LENSES
1/8" - 1/2"

GREY SANDY SILT, LITTLE CLAY, OCCASIONAL STONES (TILL)

< 5 % ICE

BOTTOM - 25.0'

BORING BY: MVPRL DATE: 30-3-72
PLOTTED BY: NRC DATE:
CHECKED BY: DATE:

SOIL MECHANICS LABORATORY
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

SOIL TEST SUMMARY - 1-17

PROJECT INSULATED ROAD SITE MACKENZIE HWY. - INUVIK DATE

HOLE NO. D-1 LOCATION 27' L. of ℄ - STA 394+96 DEPTH 25.0'

ELEVATION OF GROUND SURFACE (zero depth) ROAD SURFACE

METHOD OF ADVANCING HOLE FAILING DRILL - 4" ϕ GAS ARCTIC BARREL

REMARKS: SUMMER TEST SITE

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/P.I.	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
D1-1	2.5 - 3.5	28.4								
2	3.5 - 4.0	26.2								
3	4.0 - 4.5	35.6	48.5/26.3	58	42	0	0	2.76		
4	4.5 - 5.0	41.5								
5	5.0 - 5.5	43.5								
6	5.5 - 6.0	36.8							103.4	75.9
7	6.0 - 6.5	34.6							112.7	83.9
8	6.5 - 7.0	52.2								
9	7.0 - 7.5	51.0								
10	7.5 - 7.9	66.0								
11	7.9 - 8.3	43.2								
12	8.3 - 9.0	31.7								
12	"	46.1							104.6	71.5
13	9.0 - 10.0	43.7	30.6/15.1	30	44	26	0	2.75		
13	"	31.9							111.2	84.3
14	10.0 - 11.0	48.0								
14	"	38.8							108.9	78.7
15	11.0 - 11.9	34.5								
15	"	20.9	21.5/7.1	13	44	43	0	2.72	129.0	106.8
16	11.9 - 12.8	25.0								
16	"	19.6	N.P.	5	42	53	0	2.74	125.7	105.1
17	12.8 - 13.6	25.3								
17	"	24.3							116.2	93.7
18	13.6 - 14.5	23.5								
18	"	22.2							120.4	98.7
19	14.5 - 16.8	29.6								
19	"	21.7							119.2	96.3
19	"	24.6							119.6	95.8

BORING BY: MVPRL DATE: 30-3-72
TESTING BY: MVPRL / DPW DATE: 4-6-72
CHECKED: ________ DATE: ________

SOIL MECHANICS LABORATORY
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

SOIL TEST SUMMARY - I - 18 HOLE No. D-1

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/PI	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
D1 - 20	16.8 - 17.9	15.9								
21	17.9 - 18.9	14.9								
21	"	13.2	17.3/3.5	8	34	46	12	2.72	138.9	122.3
22	18.9 - 20.0	11.1								
23	20.0 - 20.8	12.5								
24	20.8 - 21.5	11.4								
25	21.5 - 23.0	17.9	26.2/12.7	20	38	34	8	2.76		
26	23.0 - 24.0	14.2								
27	24.0 - 25.0	14.9								

BORING BY: MVPRL DATE: 30-3-72

TESTING BY: MVPRL/DPW DATE: 4-6/72

CHECKED: DATE:

SOIL MECHANICS LABORATORY

DIVISION OF BUILDING RESEARCH

NATIONAL RESEARCH COUNCIL

OTTAWA CANADA

TEST HOLE LOG - 1 - 19

PROJECT: INSULATED ROAD SITE: MACKENZIE HWY - INUVIK DATE:

HOLE NO. D-1A LOCATION: 27' L. of ℄ - STA. 394 + 94.0 DEPTH: 9.3'

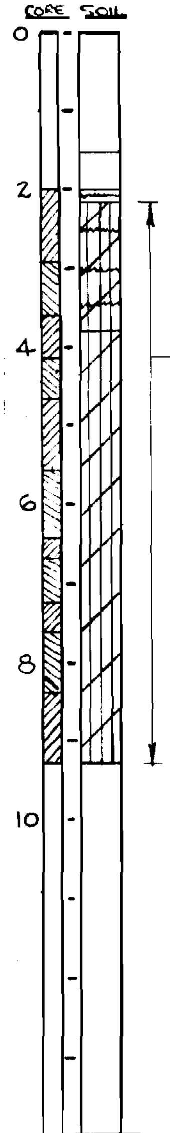
ELEVATION OF GROUND SURFACE (ZERO DEPTH): ROAD SURFACE

METHOD OF ADVANCING HOLE: FAILING DRILL - 4" ø GAS ARCTIC BARREL

REMARKS: SUMMER TEST SITE

LOG — DESCRIPTION

CORE SOIL



ROAD FILL

SNOW

MOSS & PEAT

BROWN ORGANIC SILT

IRREGULAR & HORIZONTAL ICE LENSES TO 1/8" AND ICE CRYSTALS 30 - 50 % ICE

GREY SILTY CLAY

BOTTOM - 9.3'

LOG — DESCRIPTION

CORE SOIL

BORING BY: MVPRL	DATE: 30-3-72	SOIL MECHANICS LABORATORY
PLOTTED BY: HRC	DATE:	DIVISION OF BUILDING RESEARCH
CHECKED BY:	DATE:	NATIONAL RESEARCH COUNCIL
		OTTAWA CANADA

SOIL TEST SUMMARY - 1-20

PROJECT INSULATED ROAD SITE MACKENZIE HWY - INUVIK DATE

HOLE NO. D-1A LOCATION 2.7' L. of ℄ - STA. 394+94 DEPTH 9.3'

ELEVATION OF GROUND SURFACE (zero depth) ROAD SURFACE

METHOD OF ADVANCING HOLE FAILING DRILL - 4"ϕ GAS ARCTIC BARREL

REMARKS: SUMMER TEST SITE

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/P.I.	GRAIN SIZE - %				SPEC. GRAV.	DENSITY - #/FT³	
				CLAY	SILT	SAND	GRAVEL		BULK	DRY
D1A-1	2.0 - 2.8	22.2								
-2	2.8 - 3.7	23.5	40.6/16.5	55	43	2	0	2.73	115.4	93.4
-3	3.7 - 4.2	41.0								
-4	4.2 - 4.7	29.5								
-5	4.7 - 5.7	46.1								
-5	"	54.9							99.6	64.3
-6	5.7 - 6.3	32.3							101.1	76.5
-7	6.3 - 6.7	36.6								
-8	6.7 - 7.2	73.6							92.7	53.4
-9	7.2 - 7.6	50.2	45.9/24.4	55	45	0	0	2.76		
-10	7.6 - 8.3	41.3								
-10	"	72.8							92.7	53.7
-11	8.3 - 9.0	39.2								
-12	9.0 - 9.3	29.7								

BORING BY: MVPRL DATE: 30-3-72

TESTING BY: MVPRL/DPW DATE: 4-6/72

CHECKED: DATE:

SOIL MECHANICS LABORATORY
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

TEST HOLE LOG - I-21

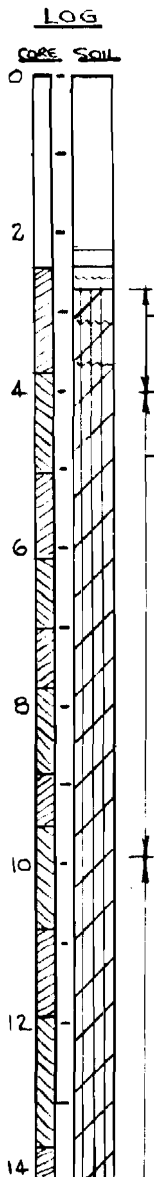
PROJECT: INSULATED ROAD **SITE:** MACKENZIE HWY – INUVIK **DATE:**

HOLE NO. D-2 **LOCATION:** 1.0' L. of ℄ – STA. 389 + 17.7 **DEPTH:** 31.2'

ELEVATION OF GROUND SURFACE (ZERO DEPTH): ROAD SURFACE

METHOD OF ADVANCING HOLE: FAILING DRILL – 4" ϕ GAS ARCTIC BARREL

REMARKS: WINTER TEST SITE



DESCRIPTION

ROAD FILL

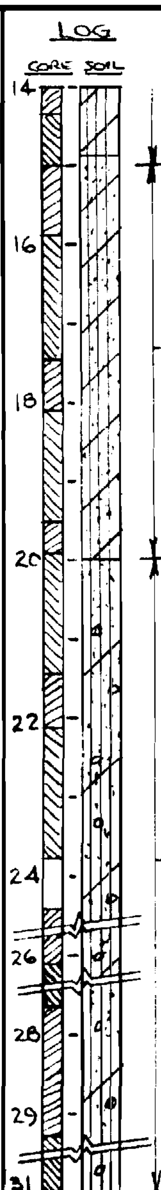
SNOW/ MOSS

RANDOM ICE LENSES TO 1/16" @ 2"-4" 5-10 % ICE

IRREGULAR HORIZONTAL LENSES & RANDOM INCLUSIONS TO 1" @ 1"-4" - 30-40 % ICE

GREY SILTY CLAY

20-30 % ICE



DESCRIPTION

GREY SILTY CLAY WITH SAND (TILL)

RANDOM 1/2"-3/4" ICE LENSES ~ 20 % ICE

GREY CLAYEY SANDY SILT WITH GRAVEL (TILL)

GENERALLY WELL BONDED, VISIBLE ICE RARE OCCASIONAL COATINGS & CRYSTALS

BOTTOM – 31.2'

BORING BY: MVPRL **DATE:** 30-3-72

PLOTTED BY: NRC **DATE:**

CHECKED BY: **DATE:**

SOIL MECHANICS LABORATORY
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

SOIL TEST SUMMARY - I - 22

PROJECT INSULATED ROAD SITE MACKENZIE HWY - INUVIK DATE

HOLE NO. D-2 LOCATION 1.0' L. of ℄ - STA. 389 + 17.7 DEPTH 31.2'

ELEVATION OF GROUND SURFACE (zero depth) ROAD SURFACE

METHOD OF ADVANCING HOLE FAILING DRILL - 4" ϕ CRS ARCTIC BARREL

REMARKS: SUMMER TEST SITE

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/P.I.	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
DZ-1	2.8 - 3.8	26.9	45.0/22.0	58	41	1	0	2.75		
2	3.8 - 5.1	32.3								
3	5.1 - 6.2	42.4	43.9/23.1	57	43	0	0	2.74		
3	"	47.7							102.0	69.3
4	6.2 - 7.0	45.1								
4	"	49.0							105.2	70.6
5	7.0 - 7.7	73.3								
6	7.7 - 8.8	59.2								
6	"	77.5							95.2	52.8
7	8.8 - 9.6	72.0								
7	"	91.2							88.7	46.7
8	9.6 - 10.8	56.1								
9	10.8 - 11.9	52.0								
10	11.9 - 13.7	40.0	42.7/23.3	42	54	3	1	2.77		
11	13.7 - 14.3	50.8								
12	14.3 - 15.0	29.6								
13	15.0 - 15.8	37.2								
14	15.8 - 17.4	34.4								
14	"	24.0	35.8/19.3	36	51	13	0	2.76	121.6	98.3
15	17.4 - 18.1	41.0								
16	18.1 - 18.8	27.2								
16	18.8 - 19.4	15.3								
17	19.4 - 19.8	13.7								
18	19.8 - 21.3	13.4								
18	"	16.2							134.7	115.8
19	21.3 - 22.2	14.4	26.6/12.8	17	37	32	14	2.74		
19	"	13.0							138.5	122.6
20	22.2 - 23.8	15.5								

BORING BY: MVPRL DATE: 30-3-72

TESTING BY: MVPRL / DPW DATE: 4-6-72

CHECKED: ______ DATE: ______

SOIL MECHANICS LABORATORY
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

SOIL TEST SUMMARY - 1-23 HOLE No. D-2

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY w_L/PI	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
D2-21	24.3-26.2	10.1								
22	26.2-27.7	10.4								
22	"	12.7							140.3	124.7
23	27.7-29.3	10.8								
24	29.3-31.2	10.9								

BORING BY: MVPRL DATE: 30-3-72
TESTING BY: MVPRL/DPW DATE: 4-6/72
CHECKED: DATE:

SOIL MECHANICS LABORATORY
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

TEST HOLE LOG - 1-24

PROJECT: INSULATED ROAD **SITE:** MACKENZIE HWY - INUVIK **DATE:**

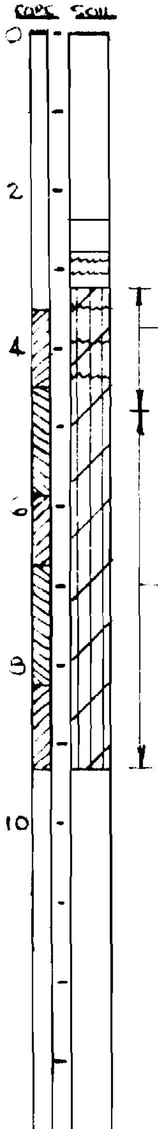
HOLE NO. D-2A **LOCATION:** 1.0' L of ℄ - STA. 389+15 **DEPTH:** 9.3'

ELEVATION OF GROUND SURFACE (ZERO DEPTH): ROAD SURFACE

METHOD OF ADVANCING HOLE: FAILING DRILL - 4" ø GAS ARCTIC BARREL

REMARKS: WINTER TEST SITE

LOG	DESCRIPTION	LOG	DESCRIPTION
CORE SOIL		CORE SOIL	



ROAD FILL

SNOW

MOSS & PEAT

IRREGULAR < 1/16" ICE LENSES & INCLUSIONS 5-10 % ICE

BROWN TO GREY SILTY CLAY

HORIZONTAL ICE LENSES, TO 1/4" @ 1/4"-1/2" 35-50 % ICE

BOTTOM - 9.3'

BORING BY: MVPRL **DATE:** 30-3-72

PLOTTED BY: NRC. **DATE:**

CHECKED BY: **DATE:**

SOIL MECHANICS LABORATORY
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NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

SOIL TEST SUMMARY - I - 25

PROJECT INSULATED ROAD SITE MACKENZIE HWY - INUVIK DATE

HOLE NO. D-2A LOCATION 1.0' L. of ℄ - STA. 389 + 15 DEPTH 9.3'

ELEVATION OF GROUND SURFACE (zero depth) ROAD SURFACE

METHOD OF ADVANCING HOLE FAILING DRILL - 4" ϕ GAS ARCTIC BARREL

REMARKS: WINTER TEST SITE

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY WL/P.I.	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
D2A-1	3.6 - 4.5	31.3								
1	"	27.5	47.9/24.2	60	39	1	0	2.74	120.4	94.5
2	4.7 - 5.9	48.4								
2	"	44.1							107.7	74.8
3	5.9 - 6.8	41.7								
4	6.8 - 8.3	63.2	52.8/30.4	56	44	0	0	2.77		
4	"	65.2							94.7	57.3
5	8.3 - 9.3	74.6								
5	"	57.4							97.0	61.6

BORING BY: MVPRL DATE: 30-3-72

TESTING BY: MVPRL / DPW DATE: 4-6/72

CHECKED: DATE:

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TEST HOLE LOG - 1-26

PROJECT: INSULATED ROAD SITE: MACKENZIE HWY - INUVIK DATE:

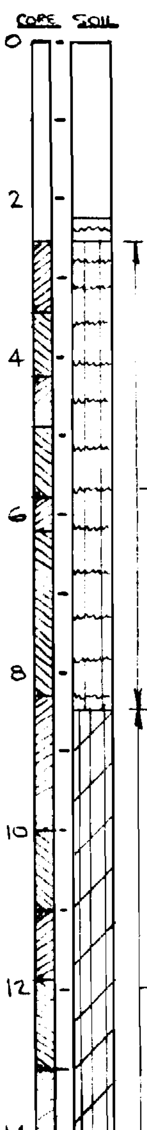
HOLE NO. D-3 LOCATION: ON ℄ - STA. 369 + 98.7 DEPTH: 27.9'

ELEVATION OF GROUND SURFACE (ZERO DEPTH): ROAD SURFACE

METHOD OF ADVANCING HOLE: FAILING DRILL - 4" ø GAS ARCTIC BARREL

REMARKS: POLYGON TEST SITE

LOG (CORE, SOIL) — DESCRIPTION



ROAD FILL

MOSS & PEAT

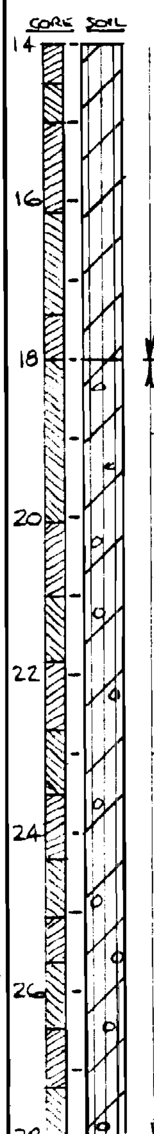
PEAT WITH SOME SILT

IRREGULAR ICE LENSES & INCLUSIONS TO ½"
30 - 50 % ICE

GREY SILTY CLAY

HORIZONTAL ICE LENSES TO ¼" @ ½" - 1"
15 - 20 % ICE

LOG (CORE, SOIL) — DESCRIPTION



RANDOM ICE LENSES TO ½"
10 - 20 % ICE

GREY SILTY CLAY WITH OCCASIONAL STONES (TILL)

OCCASIONAL ICE COATINGS & INCLUSIONS; VISIBLE ICE RARE, GENERALLY WELL BONDED

VERY DENSE

BOTTOM - 27.9'

BORING BY: MVPRL DATE: 30/31 - 3 - 72

PLOTTED BY: NRC. DATE:

CHECKED BY: DATE:

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OTTAWA CANADA

SOIL TEST SUMMARY - 1 - 27

PROJECT: INSULATED ROAD SITE: MACKENZIE HWY - INUVIK DATE:

HOLE NO.: D-3 LOCATION: ON ℄ - STA. 369 + 98.7 DEPTH: 27.9'

ELEVATION OF GROUND SURFACE (zero depth): ROAD SURFACE

METHOD OF ADVANCING HOLE: FAILING DRILL - 4" ϕ GAS ARCTIC BARREL

REMARKS: POLYGON TEST SITE

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/P.I.	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
D3-1	2.5 - 3.3	78.2								
2	3.3 - 4.2	194.6							69.2	23.4
3	4.2 - 4.8	171.0							69.9	25.8
4	4.8 - 5.7	263.0								
5	5.7 - 6.2	174.7								
5B	6.2 - 8.2	94.5	48.0/8.3	24	73	3	0	2.35		
5B	"	519.0							64.6	10.5
6	8.2 - 10.0	77.7								
6	"	39.9							108.2	77.5
7	10.0 - 11.0	39.3								
8	11.0 - 11.7	32.4								
9	11.7 - 13.0	34.1								
9	"	29.2	44.8/24.4	45	53	2	0	2.78	118.7	92.0
10	13.0 - 14.4	44.0								
11	14.4 - 15.0	40.2								
12	15.0 - 16.2	32.4								
13	16.2 - 17.3	31.8	48.1/25.5	61	39	0	0	2.75		
14	17.3 - 18.0	26.2							123.8	98.1
15	18.0 - 20.1	14.5								
15	"	15.5							135.0	117.0
16	20.1 - 21.0	16.5								
17	21.0 - 21.7	14.8								
18	21.7 - 22.6	12.6								
19	22.6 - 23.4	12.5								
20	23.4 - 24.3	15.0	39.4/17.5	54	46	0	0	2.76	137.9	120.0
21	24.3 - 25.1	12.2								
22	25.1 - 25.6	13.3								
23	25.6 - 26.3	12.7								

BORING BY: MVPRL DATE: 30/31-3-72

TESTING BY: MVPRL / DPW DATE: 4-6/72

CHECKED: DATE:

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SOIL TEST SUMMARY - I - 28 HOLE No. D-3

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/PI	GRAIN SIZE - %				SPEC. GRAV.	DENSITY - #/FT³	
				CLAY	SILT	SAND	GRAVEL		BULK	DRY
D3-24	26.3 - 27.2	11.7								
25	27.2 - 27.8	10.4								

BORING BY: MVPRL DATE: 30/31-3-72
TESTING BY: MVPRL/DPW DATE: 4-6/72
CHECKED: DATE:

SOIL MECHANICS LABORATORY
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TEST HOLE LOG - 1-29 (1) OF (2)

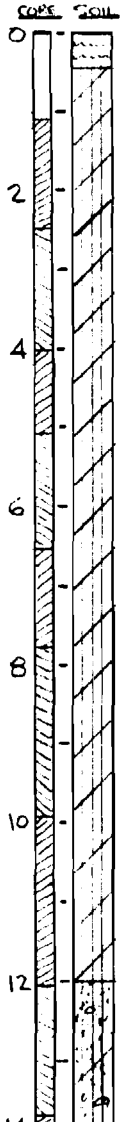
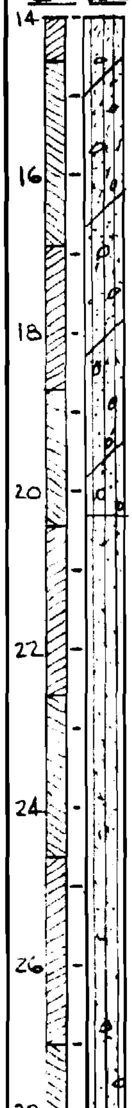
PROJECT: INSULATED ROAD **SITE:** MACKENZIE HWY - INUVIK **DATE:**

HOLE NO. D-4 **LOCATION:** 86.6' R. of ℄ - STA. 387 + 82.5 **DEPTH:** 58.5'

ELEVATION OF GROUND SURFACE (ZERO DEPTH):

METHOD OF ADVANCING HOLE: FAILING DRILL - 4" ϕ GAS ARCTIC BARREL

REMARKS: WINTER TEST SITE - UNDISTURBED AREA

LOG (CORE, SOIL)	DESCRIPTION
	MOSS & PEAT IRREGULAR HORIZONTAL ICE LENSES TO 1" 20-30 % ICE GREY SILTY CLAY ICE LENSES TO 2" 30 % ICE IRREGULAR RANDOM ICE INCLUSIONS TO 2" 20-30 % ICE GREY SILTY SAND, SOME CLAY & GRAVEL (TILL)
	VISIBLE ICE RARE, WELL BONDED OCCASIONAL ICE CRYSTALS & COATINGS GREY SANDY SILT (TILL) RANDOM ICE LENSES & INCLUSIONS TO 1/2" 5-15 % ICE OCCASIONAL COBBLES

BORING BY: MVPRL **DATE:** 30/31-3-72

PLOTTED BY: NRC **DATE:**

CHECKED BY: **DATE:**

SOIL MECHANICS LABORATORY
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TEST HOLE LOG - 1-30 (2) OF (2)

PROJECT: INSULATED ROAD **SITE:** MACKENZIE HWY. - INUVIK **DATE:**

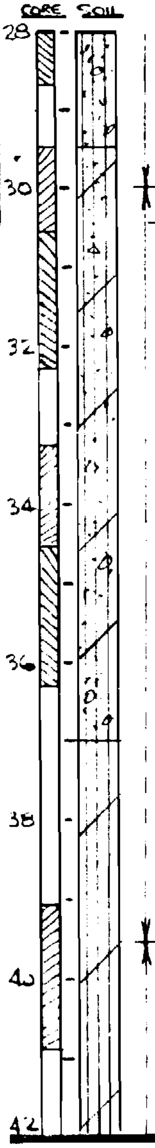
HOLE NO. D-4 **LOCATION:** 86.6' R of ℄ - STA. 387+82.5 **DEPTH:** 58.5

ELEVATION OF GROUND SURFACE (ZERO DEPTH):

METHOD OF ADVANCING HOLE: FAILING DRILL - 4" ⌀ GAS ARCTIC BARREL

REMARKS: WINTER TEST SITE - UNDISTURBED AREA

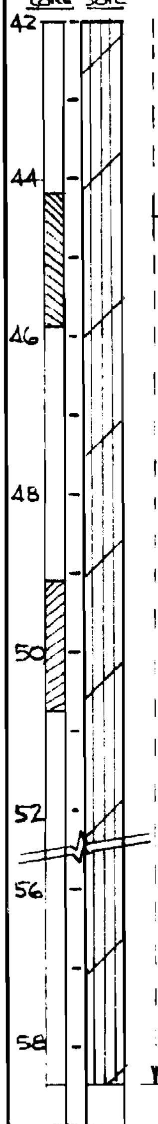
LOG CORE SOIL — **DESCRIPTION**



VISIBLE ICE RARE, WELL BONDED

CLAYEY, SANDY SILT, OCCASIONAL GRAVEL (TILL)

LOG CORE SOIL — **DESCRIPTION**



RANDOM ICE LENSES & INCLUSIONS TO 1"
5-15% ICE

CLAYEY SILT, SOME SAND, LITTLE GRAVEL

BOTTOM - 58.5'

BORING BY: MVPRL **DATE:** 30/31-3-72
PLOTTED BY: NRC **DATE:**
CHECKED BY: **DATE:**

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SOIL TEST SUMMARY - I - 31

PROJECT: INSULATED ROAD SITE: MACKENZIE HWY. - INUVIK DATE:

HOLE NO. D-4 LOCATION: 86.6' R. OF ℄ - STA. 387 + 82.5 DEPTH: 58.5'

ELEVATION OF GROUND SURFACE (zero depth)

METHOD OF ADVANCING HOLE: FAILING DRILL - 4"⌀ GAS ARCTIC BARREL

REMARKS: WINTER TEST SITE

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/P.I.	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
D4 - 1	1.2 - 2.3	63.3	48.1/24.5	50	50	0	0	2.78		
1	"	71.1							91.2	53.2
2	2.3 - 4.0	59.2								
2	"	61.3							95.7	59.3
3	4.0 - 5.2	88.6								
3	"	57.5	45.0/25.8	44	48	8	0	2.75	100.5	63.9
4	5.2 - 6.5	59.3								
5	6.5 - 7.8	50.6								
6	7.8 - 9.9	40.0								
7	9.9 - 12.1	42.0								
8	12.1 - 13.8	30.5	24.9/11.0	11	22	53	14	2.77		
9	13.8 - 14.6	18.0								
10	14.6 - 16.9	16.0								
11	16.9 - 18.7	13.2								
12	18.7 - 20.6	9.8	N.P.	7	68	25	0	2.71		
13	20.6 - 22.6	9.7								
14	22.8 - 24.6	12.4								
15	24.6 - 27.0	22.4								
15	"	15.7							124.0	107.2
16	27.0 - 26.7	9.5								
17	29.5 - 30.6	11.1								
18	30.6 - 33.2	13.4								
19	33.3 - 34.5	16.5								
20	34.5 - 36.3	15.8	25.3/11.4	19	52	24	5	2.76		
20	"	15.0							131.2	114.3
21	39.2 - 40.8	16.5								
21	"	16.2							130.5	112.3
22	44.2 - 45.8	24.8								

BORING BY: MVPRL DATE: 30/31-3-72
TESTING BY: MVPRL / DPW DATE: 4-6/72
CHECKED: ______ DATE: ______

SOIL MECHANICS LABORATORY
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NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

SOIL TEST SUMMARY - 1-32 HOLE No. D-4

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/PI	GRAIN SIZE - %				SPEC. GRAV.	DENSITY - #/FT³	
				CLAY	SILT	SAND	GRAVEL		BULK	DRY
D4-22	44.2-45.8	23.2							126.3	102.8
23	49.1-50.7	12.9	38.7/21.5	38	48	13	1	2.74		
23	"	13.8							138.5	121.7

BORING BY: MVPRL DATE: 30/31-3-72
TESTING BY: MVPRL/DPW DATE: 4-6/72
CHECKED: DATE:

SOIL MECHANICS LABORATORY
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OTTAWA CANADA

INSULATED ROAD STUDY

MACKENZIE HIGHWAY

INUVIK, N.W.T.

APPENDIX II

BOREHOLE LOGS AND SOIL TEST RESULTS

BEDDING AND BACKFILL MATERIAL

TEST HOLE LOG - 11-3

PROJECT: INSULATED ROAD **SITE:** MACKENZIE HWY – INUVIK **DATE:**

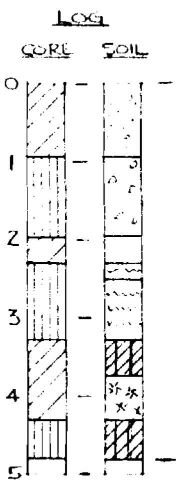
HOLE NO. VARIOUS **LOCATION:** WINTER & POLYGON SITES **DEPTH:**

ELEVATION OF GROUND SURFACE (ZERO DEPTH): TOP OF BEDDING LAYER

METHOD OF ADVANCING HOLE: FAILING DRILL – 4" ⌀ GAS ARCTIC BARREL

REMARKS:

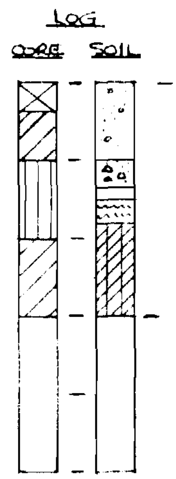
HOLE #1 – 3.7' L. of ℄ – 389+35.5



DESCRIPTION

- TOP OF BEDDING
- BEDDING
- ORIGINAL FILL
- SNOW
- LIVING MOSS COVER.
- PEAT
- SILTY CLAY
- ICE
- SILTY CLAY
- BOTTOM – 4.8'

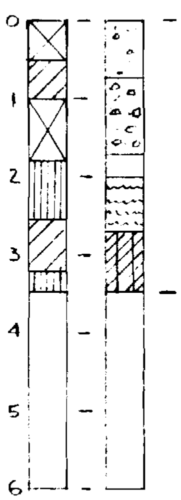
HOLE #2 – 2.9' L. of ℄ – 387+70



DESCRIPTION

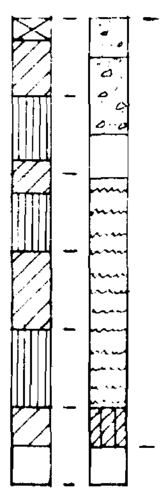
- TOP OF BEDDING
- BEDDING
- ORIGINAL FILL
- SNOW
- PEAT
- SILTY CLAY
- BOTTOM – 3.0'

HOLE #3 – ON ℄ – 386+32



- TOP OF BEDDING
- BEDDING
- ORIGINAL FILL
- SNOW
- PEAT
- SILTY CLAY
- BOTTOM – 3.4'

HOLE #4 – 4' R. of ℄ – 370+04



- TOP OF BEDDING
- BEDDING
- ORIGINAL FILL
- SNOW
- PEAT
- SILTY CLAY
- BOTTOM – 5.5'

BORING BY: NRC	**DATE:** 19-4-72	**SOIL MECHANICS LABORATORY**
PLOTTED BY: NRC	**DATE:**	**DIVISION OF BUILDING RESEARCH**
CHECKED BY:	**DATE:**	**NATIONAL RESEARCH COUNCIL OTTAWA CANADA**

SOIL TEST SUMMARY - II - 4

PROJECT INSULATED ROAD SITE MACKENZIE HWY- INUVIK DATE

HOLE NO. VARIOUS LOCATION WINTER & POLYGON SITES DEPTH

ELEVATION OF GROUND SURFACE (zero depth) TOP OF BEDDING LAYER

METHOD OF ADVANCING HOLE FAILING DRILL - 4"φ GAS ARCTIC BARREL

REMARKS:

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L/P.I.	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT³ BULK	DRY
HOLE #1 - 3.7' L of ℄ - STA 389 +35.5 (2" INSULATED SECTION)										
1-1	0.3 - 0.9	29.3								
-2	1.4 - 1.8	21.5								
-3	2.3 - 3.3	99.5							67.0	33.7
-5	4.3 - 4.8	83.2							86.3	47.0
HOLE #2 - 2.9' L. of ℄ - STA. 387 + 70 (CONTROL SECTION)										
2-1A	0.3 - 0.8	17.0								
-1	1.5 - 2.0	65.4							73.9	44.7
-2	2.0 - 3.0	24.8							112.8	90.5
HOLE #3 - ON ℄ - STA. 386 + 32 (3.5" INSULATED SECTION)										
3-1A	0.5 - 1.0	9.3								
-1	0.8 - 1.0	32.5								
-3	2.0 - 2.6	118.1							70.7	32.4
-4	2.8 - 3.2	35.1							102.3	75.6
-5	3.2 - 3.4	26.5								
HOLE #4 - 4' R. of ℄ - STA 370 + 04 (POLYGON SITE)										
4-2	2.2 - 3.0	486.2							50.4	8.6
-4	4.0 - 5.0	185.0							68.0	23.8
-5	5.0 - 5.5	234.0							66.9	20.0
REPRESENTATIVE BULK SAMPLES - WINTER TEST SITE										
(a) ORIGINAL FILL (UNDER BEDDING)										
				2	6	66	26	2.71		
(b) BEDDING MATERIAL										
				9	20	32	39	2.71		
(c) BACK FILL - OVER INSULATION										
		7.2		5	6	46	43	2.74		

BORING BY: NRC DATE: 19-4-72

TESTING BY: NRC DATE: APRIL, 1972

CHECKED: DATE:

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OTTAWA, ONTARIO, CANADA

SOIL TEST SUMMARY - II - 5

PROJECT INSULATED ROAD SITE MACKENZIE HWY. - INUVIK DATE

HOLE NO. LOCATION SUMMER TEST SITE DEPTH

ELEVATION OF GROUND SURFACE (zero depth)

METHOD OF ADVANCING HOLE

REMARKS: DENSITIES DETERMINED BY SAND CONE METHOD.

SAMPLE No.	DEPTH FT.	M/C %	PLASTICITY W_L / P.I.	GRAIN SIZE - % CLAY	SILT	SAND	GRAVEL	SPEC. GRAV.	DENSITY - #/FT^3 BULK	DRY
BEDDING LAYER = ORIGINAL FILL										
(a) SOUTH HALF OF ROAD										
32/33	391 + 87.5	10.6		8	15	44	33		135.4	122.4
31		6.6		6	11	31	52		135.4	127.0
29		5.0		5	12	23	60		143.1	136.3
30		6.3							147.7	138.9
(b) NORTH HALF OF ROAD										
25	392 + 75	6.7		3	11	19	67		103.3	96.8
24	393 + 75	10.6							117.7	106.4
26	394 + 55	5.8		4	9	18	69		100.3	94.8
REPRESENTATIVE BULK SAMPLES - BACK FILL (OVER INSULATION)										
1				–	7	47	46			
2				–	8	48	44			
6				–	9	47	44			

BORING BY: NRC DATE: SEPT. 1972

TESTING BY: NRC DATE: SEPT. 1972

CHECKED: DATE:

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