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CORPS OF ENGINEERS, U. S. ARMY

REPORT
OF
THAW PENETRATION AND SUBSIDENCE
RUNWAY AND TAXIWAY SECTIONS
THULE AIR FORCE BASE

1953 & 1954 THAWING SEASONS

PREPARED BY

ARCTIC CONSTRUCTION AND FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION
BOSTON, MASSACHUSETTS

FOR

OFFICE OF THE CHIEF OF ENGINEERS
AIRFIELDS BRANCH
ENGINEERING DIVISION
MILITARY CONSTRUCTION

JANUARY 1955

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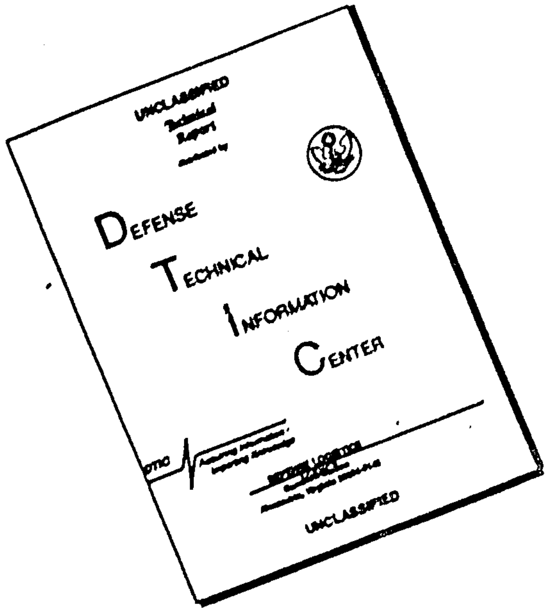

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SYNOPSIS

Construction of the runway at Thule Air Force Base, Greenland, began in the Summer of 1951. By the end of this first summer seven thousand feet of runway with a temporary surface of penetration macadam was operational. During the 1952 construction season the runway was extended to 10,000 feet and associated taxiway and aprons constructed. Hot mix asphalt paving was utilized in this construction and was also placed over the original penetration macadam runway pavement. The subsidence of certain runway pavement sections during the summer of 1952 resulted in the initiation of a program of field investigations at those locations. In the spring of 1953 a number of temperature and ground water wells, as well as vertical movement observation points, were installed under and adjacent to designated buildings, at Crescent Lake Dam, and at selected runway and taxiway locations. Observations were made at desired intervals throughout the 1953 and 1954 thawing seasons.

This report presents an analysis of the data obtained during the 1953 and 1954 thawing seasons at the runway and taxiway test installations. An analysis of the pavement subsidence, which occurred in two areas, is given and a correlation is made between subsidence, depth of thaw and the characteristics of the subgrade soils. The effect of pavement surface color is discussed and tentative conclusions are drawn. The existence of a seasonal ground water table is noted and explained.

Since in some areas the subgrade soils at Thule contain large masses of ice, distributed irregularly throughout the soil mantle and the melting of this ice results in irregular subsidence of the pavement surface, pavement design at Thule should be based on preventing thaw from penetrating into high ice content subgrade soils after the paving materials have been placed. The data thus far obtained indicate that this may best be accomplished at Thule by providing an 8 foot minimum combined thickness of pavement and non-frost susceptible base above the subgrade soils.

In the present subsidence areas the combined thickness of pavement and base course material is in the range of approximately 4 feet to 6 feet. Analyses based on the amounts of pure ice and high ice content soils encountered in test pits in the area indicate that continued localized subsidence will occur at a diminishing rate for the next several thawing seasons and in some locations will continue for more than 20 years. A total future subsidence of 2.0 to 2.5 feet is expected at two of the explorations where high ice content subgrade conditions were revealed.

Recommendations for corrective measures in the areas of subsidence are given.

PART I - INTRODUCTION

1-01. AUTHORIZATION. An "Instructions & Outline for the Development of Design Criteria for Arctic Construction, Thule Air Force Base, Greenland" was prepared by the Chief of Engineers on 17 November 1952. The Permafrost Division, St. Paul District, was the original investigating agency. The Arctic Construction and Frost Effects Laboratory, New England Division, assumed these duties on 1 March 1953 by General Order No. 3, which stipulated transfer of all Permafrost Division functions and responsibilities from the jurisdiction of the District Engineer, St. Paul District, to the jurisdiction of the Division Engineer, New England Division.

1-02. PURPOSE AND SCOPE. The present investigational program at Thule Air Force Base is an outgrowth of a study by the Eastern Ocean District (formerly the Northeast District, East Ocean Division) of the runway pavement subsidence that occurred at two areas, each the full width of the runway and approximately 250 feet in length, during the 1952 thawing season. The program was broadened to include studies of other pavement areas and structures at Thule Air Force Base, with the objective of improving design criteria for airfield pavements, building foundations, and earth dams in arctic regions. As a result a number of temperature wells, ground water wells and vertical movement observation points were installed at selected locations so that fluctuations in ground temperatures and ground water as well as the vertical movement of structures and pavements could be observed.

1-03. ACKNOWLEDGMENTS. The investigational program was initiated by the Chief of Engineers in October 1952. The overall objectives and scope of the investigation were outlined at a conference held at the

Airfields Branch, Military Construction, Office of the Chief of Engineers, on 21 October 1952. This conference was attended by representatives of the Chief of Engineers, East Ocean Division, New England Division, Northeast District and the St. Paul District.

The detailed program was planned cooperatively between the former Permafrost Division, St. Paul District, the former Northeast District and the New England Division. The Permafrost Division designed, procured and shipped the observational equipment to Thule. North Atlantic Constructors performed the necessary test pitting, drilling and trenching operations required to install the thermocouple assemblies and ground water wells under the direction of the Northeast District. Representatives of the Architect-Engineer, Metcalf and Eddy, and Alfred Hopkins and Associates, installed the observational equipment, logged the test pits and borings and performed the necessary supplemental soil testing. During the initial stages of the field installation program, personnel of the Arctic Construction and Frost Effects Laboratory furnished technical assistance to the Northeast District. Following installation, periodic observations were made and will continue to be taken by representatives of the Architect-Engineer, and/or personnel of the Eastern Ocean District.

PART II - INVESTIGATIONS

2-01. GENERAL. Installation of temperature wells in the pavement areas was commenced on 20 March 1953 and completed on 8 May 1953. The installation of the ground water wells was completed on 6 July 1953. Twelve temperature wells, TR-1 through TR-12, were installed at the runway locations shown on Plate 1, to depths of 15 to 24 feet, depending on the thickness of fill. These wells were installed in pairs spaced 13 feet apart and a ground water well was drilled midway between each pair. Locations were chosen so that representative sections through varying thickness of fill could be observed and compared. Three additional ground water wells were drilled in the subsidence area between Stations 57+00 and 60+00.

In an effort to compare thaw progression beneath black and white pavement surfaces, a 125 foot long portion of the south taxiway was painted white. Two temperature wells, TTW-1 and TTW-2, were placed in the white-surfaced area and two temperature wells, TTB-1 and TTB-2, were placed in the adjacent unpainted area of the pavement. Vertical movement grids, as shown on Plate 2, were established at all runway and taxiway locations.

Initial readings of all runway temperature assemblies were taken on 8 May 1953 and of all taxiway temperature assemblies on 9 May 1953 and have continued at weekly intervals. Ground water observations in 1953 began on 6 July and in 1954 on 31 July and were continued at weekly intervals throughout the thawing seasons. Observations of vertical movements have been made at monthly intervals beginning with the initial readings on 14 June 1953, except for the months December 1953 through April 1954 and June and September 1954.

2-02. <u>CLIMATIC DATA</u>. Plate 3 presents a plot of average daily air temperatures taken from Weather Bureau records for 1953 and 1954, from 23 April through 30 September, together with curves of cumulative degree days (°F) of thaw as computed from these average daily air temperatures for the two years. Plate 4 presents cumulative freezing and thawing curves, starting with 1946-1947 freezing season, except for freezing seasons 1950-1951, 1951-1952 and the 1951 thawing season, for which temperature data are not available. Curve for the 1948-1949 thawing season also is not presented. Weather Bureau records show a mean annual temperature for the period 1946-1949 of +12°F. The curves in Plate 4 illustrate the relative severities of the thawing and freezing seasons. Average values for 30 June, 31 July and end of thawing season, for the available years of record, are given below.

Date	Cumulative Degree Days of Thaw
30 June	120
31 July	400
End of Thaw (on or about 14 Sept.)	650

2-03. <u>SOILS DATA</u>. The subgrade soil at Thule is predominantly a glacial till and is classified as a silty, sandy gravel or a silty gravelly sand with 10 to 45 per cent of grains by weight finer than the 200 mesh. The bedrock is a diorite and, in the runway section at least, is relatively shallow varying from 10 to 15 feet below original ground surface. Ice is present in the subgrade soils in large amounts and is found as wedges, lenses, coatings on grains and as irregular masses up to 1.8 feet in thickness. For an example of the massive ice encountered see log of Test Pit S-716, Plate 5 and log of TR-5, Plate A9.

Base course materials vary from poorly graded sandy-gravels and gravelly-sands to quarry rock. Logs of explorations at each temperature well in the runway and taxiway locations are included in Appendix A of this report.

All temperature wells were drilled by the North Atlantic Constructors using a "Joy Heavy Duty Champion", rotary drill. A special carbaloy bit fabricated in the field by the contractor's personnel proved very satisfactory in obtaining frozen core samples of the subgrade soil, except in instances where the subgrade contained a high percentage of large stones. In fill sections where relatively dry frozen granular soils predominated, a 6-3/4" Hughes Tricone Rotary Bit was used. The cuttings from this bit, blown to the surface by compressed air, were collected and the water content determined.

Test pits were dug at three runway locations to depths of from 8 to 12 feet and at two taxiway locations to a depth of 8 feet. Logs of these explorations are included in Appendix A. The water contents of frozen chunk samples obtained from the test pits were compared with the water contents of the cuttings obtained from the drill holes adjacent to each test pit. The results of this correlation indicated that the water contents, as obtained from the cuttings, gave a reliable determination of the actual water contents of the soils encountered.

2-04. <u>AS-BUILT PAVEMENT SECTION</u>. To protect subgrade soils from thaw penetration, the pavement design called for a minimum of 6 feet of non-frost susceptible base and subbase materials. Where the difference in elevation between existing ground surface and proposed finished grade exceeded 6 feet, granular or quarry rock fill was placed directly on the natural ground surface; otherwise the subgrade soil was stripped and excavated to produce the required 6-ft. base thickness. The deepest cut, about 13 feet at one location, occurred between Stations 57/00 and 74/00. Plate 1 shows a centerline profile through this cut with an exaggerated vertical scale. All other cuts were relatively shallow.

A generalized cross section of the runway pavement is shown on Plate 6. The original design called for a uniform transverse slope of 1.5 per cent for the full width of the runway. After base course materials had been placed it was decided to construct the pavement with a 1.5 per cent slope on each side of a centerline crown. The crown was formed by stripping base course material from the high side of the slope (south side of runway). This operation reduced the original 6 feet of pavement and base to a minimum of approximately 3 feet at the south edge of pavement. Pronounced subsidence occurred along this edge of the pavement during the summer of 1952. To prevent further subsidence, a 25 foot box was excavated to a minimum depth of 6 feet along this edge from Station 61/00 to Station 75/00 and material replaced with non-frost susceptible fill (see Plate 6).

In the subsidence areas, between Stations 57/00 and 60/00 and between Stations 71/00 and 74/00, resurfacing operations to bring the pavement back to grade have resulted in a thickened surface course. In certain areas the bituminous concrete is now over a foot in thickness.

2-05. SUBSURFACE TEMPERATURES. The progress of thaw below the surface, represented by the 0°C. isotherm and based on subsurface temperatures observed during the 1953 and 1954 thawing seasons at all runway locations, is shown on Plates 7 through 12. Similar temperature plots of the taxiway assemblies are shown on Plates 13 and 14. A summary of thaw and subsidence data at all runway and taxiway installations is given in Table 1. The depth of the 0°C. temperature was interpolated from the geothermal gradients drawn for successive observations. The position of the 0°C. isotherm is assumed to be the boundary between unfrozen and frozen soil. However, it is visualized that the actual boundary between frozen and unfrozen soil as it occurs in nature is a diffuse zone rather than a well defined plane at the interface of frozen and unfrozen soil. Subsurface temperatures obtained by means of thermocouples spaced at intervals of depth in the soil do not clearly define the limits of this zone either during the freezing or thawing cycles.

During the freezing cycle an essentially isothermal zone where a mixture of thawed and frozen soil exists together has been inferred. This inference is based on the shape of temperature-time curves drawn for various specific depths during the period of freeze back. These curves exhibit a marked flattening of slope close to 0°C. and in the vicinity of the maximum depth of thaw. At this depth, based on the thermocouple readings the ground temperature appears to remain constant, for periods ranging from one to three weeks. This essentially isothermal zone is indicated by shading in Plates 7 through 14.

Examination of Plates 7 through 14 also indicates that some small amount of freezing occurs up from the bottom of the thawed zone due to the flow of heat to the underlying frozen soil which exists at several degrees below 0°C. This trend has not generally appeared in available subsurface temperature observations from more southerly arctic and subarctic installations, apparently because the temperature of the underlying permafrost in such areas has been much closer to below 0°C.

TABLE 1

SUMMARY OF THAW AND SUBSIDENCE DATA FOR 1953 AND 1954 THAWING SEASONS

THULE AIR FORCE BASE

	Hole No.	Station	Depth of Fill* in Feet	Max. Depth of Thaw in Feet 1953	Max. Depth of Thaw in Feet 1954	Max. Measured Subsidence in Feet 6/14/53-9/11/53	Max. Measured Subsidence in Feet 5/22/54-8/24/54
	TR-1	25/00	13	7.7	7.7	0.01	0.04
	TR-2	25/13	13	7.4	7.7	-	-
	TR-3	34/00	8.3	6.5	6.8	0.02	0.08
	TR-4	34/13	8.5	6.7	7.0	-	-
	TR-5	58/00	5.3	a 5.8	7.1	b 0.16	0.16
Runway	TR-6	58/13	5.6	a 6.4	7.1	-	-
	TR-7	69/00	5.7	6.0	6.3	0.01	0.02
	TR-8	69/13	5.7	6.8	7.2	-	-
	TR-9	91/00	9.0	7.7	8.0	0.00	0.00
	TR-10	91/13	9.0	7.4	7.7	-	-
	TR-11	93/50	10.5	6.9	7.3	0.00	0.00
	TR-12	93/63	13.0	6.4	6.7	-	-
	TTW-1	94/75	9.0/	6.0	5.4	0.00	0.02
South	TTW-2	94/75	9.0/	5.8	5.5	-	-
Loop	TTB-1	96/00	9.0/	7.8	7.0	0.00	0.02
Taxiway	TTB-2	96/00	9.0/	8.2	7.4	-	-

*Non-frost-susceptible

Notes:

a. Before addition of 6" bituminous at this location during September 1953, making pavement thickness 1'-2".

b. For period 14 June to 17 August 1953 only.
Does not include unknown amount of settlement which may have occured between 17 August and 11 September 1953 when new settlement points were established at this location.

In general, thawing commenced beneath the runway pavement surface around the first week in May in 1953 and toward mid-May in 1954, and refreeze began around 14 September in both years, indicating a thawing period of approximately four months. The entire active zone had cooled to freezing temperatures before 25 September. Thaw penetration in thick base course sections, on the runway, ranged from 6.4 feet to 7.7 feet in 1953 and from 6.7 feet to 8.0 feet in 1954. While it is logical to attribute the variations in thaw depth to local differences in density and water content a correlation of these data did not reveal a consistent relationship. At runway locations with lesser base thicknesses, notably at Station 58+00, 50 feet left of centerline and Station 69+00, 50 feet left of centerline where thaw has penetrated to the subgrade, the maximum depth of thaw has been markedly reduced. This is due principally to the high ice content of the subgrade soils.

At the taxiway locations, notable reduction in the depth of thaw beneath the white-surfaced area was observed. The maximum depth of thaw beneath the white-surfaced pavement averaged 5.9 feet in 1953 and 5.45 feet in 1954, as compared to 8 feet in 1953 and 7.2 feet in 1954 beneath the natural unpainted surface. Surface temperatures in the white surface averaged about 5°C. lower throughout the thawing season than those in the black. In mid-summer the difference was 2 or 3 degrees higher than this average value.

2-06. GROUND WATER (RUNWAY). A free water table had developed above the level of frozen ground by 18 July in 1953 and by 31 July in 1954 between Stations 57+00 75 feet L and 69+00, 50 feet L. The observations from the ground water wells between TR-5 and 6 and TR-7 and 8 are plotted with the temperature data on Plates 9 and 10. In general, the ground water levels in all wells observed in the subgrade cut area rose a maximum of approximately one foot during the thawing season. It is in this cut area, from Stations 57+00 to 60+00, that thawing progressed through the fill material and penetrated the subgrade soil. The rise in water level in the base, as indicated from the ground water wells is believed to be primarily due to the melting of the high ice content soils in the subgrade.

2-07. PAVEMENT SUBSIDENCE. The subsidence during and prior to the 1953 and 1954 thawing season was confined to two areas between Runway Stations 57+00 and 60+00 and between Stations 71+00 and 74+00. These two areas lie at each end of the area of subgrade cut which extends from approximately Stations 55+00 to 74+00. Average subsidence of the remainder of the runway pavement during the 1953 and 1954 thawing seasons was negligible. Plate 1 shows in plan the areas of subsidence and the limits of the cut. Plate 1 also includes a centerline profile showing the level of original ground, top of as-built pavement and bottom of cut.

Vertical movement grids, each covering a small area in the immediate vicinity of each pair of temperature wells, were established in the runway and taxiway, as shown on Plate 2. Initial vertical movement observations on these grids were taken on 14 June 1953. With the exception of the grid around TR-5 and TR-6, settlement of the grid points at all runway and taxiway temperature well locations during the 1953 thawing season was negligible (maximum subsidence 0.02 feet, with an average of 0.003 feet for seven locations). During the 1954 thawing season the vertical movement observations indicate that subsidence averaging as much as 0.05 feet may have taken place in the vicinity of TR-1, TR-3, TR-7 and at the temperature well locations on the South Loop Taxiway. Since observations were not made on the settlement points during September (end of thawing, about 15 September), a more accurate appraisal of possible subsidence cannot be made.

The measured pavement subsidences and heaves in the vicinity of TR-5 and TR-6 are shown in Table 2. The measured maximum subsidence around TR-5 and TR-6 during 1953 was 0.16 feet with an average of 0.13 feet. However, since the pavement at this location was resurfaced to original grade on or about 17 August 1953 and new settlement points were not established until about 11 September, the values of subsidence given in Table 2 are for the period 14 June to 17 August 1953 only. On the basis of the remaining degree-days of thaw after 17 August and the resulting increase in thaw penetration after this date, it is estimated that an additional subsidence of about 0.05 feet could have occurred, for a total seasonal subsidence of about 0.18 feet.

During 1954, the measured maximum subsidence around TR-5 and TR-6 was 0.16 feet with an average of 0.13 feet for the period 22 May to 25 August 1954. The next set of observations was made on 16 October and shows a maximum subsidence of 0.19 feet with an average of 0.16 feet in relation to observations made on 22 May. Thaw reached a maximum on or about 14 September and complete refreeze of the base and subgrade materials had occurred prior to 10 October. If the values given for pavement heave in Table 2 for 11 September to 25 November 1953 may be considered representative of the amount of heaving due to freezing which occurred during fall of 1954, the subsidence around temperature wells TR-5 and TR-6 is estimated to have averaged about 0.21 feet for the

TABLE 2
VERTICAL MOVEMENT OF PAVEMENT
AROUND TEMPERATURE WELLS TR-5 AND TR-6

PT. NO.*	SUBSIDENCE (ft.) 14 June to 17 Aug. 1953	HEAVE (ft.) 11 Sep. to 25 Nov. 1953	SUBSIDENCE (ft.) 22 May to 25 Aug. 1954
1	0.11	0.06	0.11
2	0.13	0.06	0.13
3	0.14	0.06	0.16
4	0.12	0.06	0.16
5	0.12	0.06	0.09
6	0.13	0.06	0.11
7	0.10	0.06	0.12
8	0.13	0.06	0.11
9	0.12	0.06	0.16
10	0.13	0.07	0.14
11	0.13	0.06	0.09
12	0.16	0.06	0.15

*Location of grid points is shown on Plate 2.

summer of 1954. This value added to the average subsidence estimated as occurring in 1953 gives an estimated two-year average subsidence (less the heave in the fall of 1953) at this location of about 0.33 feet.

Figure 1 below illustrates graphically the average movement of the 12-point grid around temperature Wells TR-5 and TR-6 for the period 14 June 1953 through 16 October 1954. The initial level points were established on 14 June 1953 at which time the average depth of thaw at TR-5 and TR-6 was 4 feet. The total thickness of pavement and base at this location averages 5.5 feet.

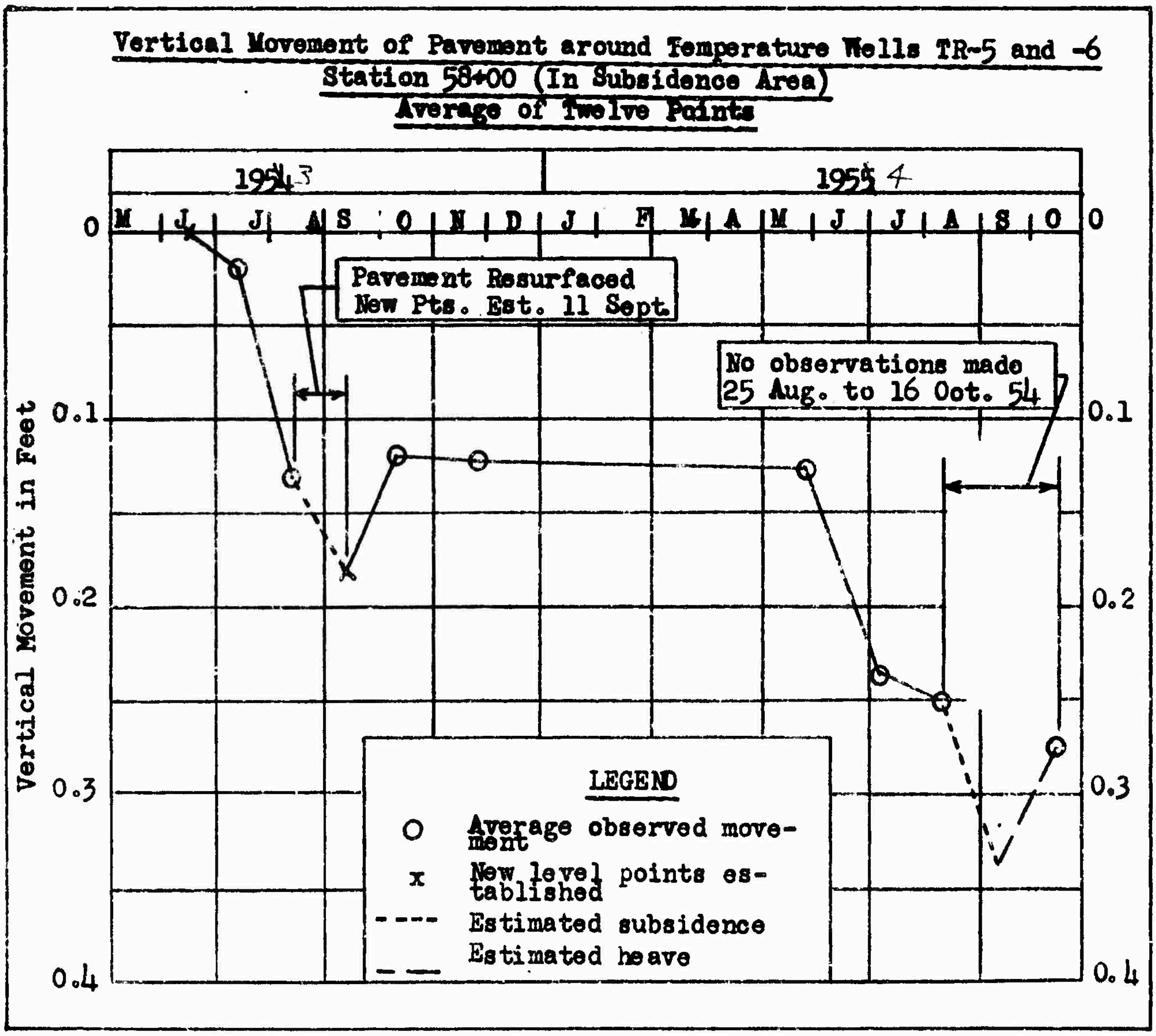


Figure 1

Around TR-7 and TR-8, the maximum subsidence shown by the grid pointswas 0.01 feet during 1953 and 0.02 feet in 1954. This pair of temperature wells, although located well within the area of subgrade cut, was not positioned in an area of previous subsidence as were wells TR-5 and TR-6. These two pairs of wells were located to investigate the reasons for the localization of subsidence in certain sections of the subgrade cut rather than its general occurrence throughout the area. Reference to the boring logs of the test pits at these two runway locations, Plates A-27 and A-28, indicates the subgrade soil at the location of TR-7 and TR-8 contains only minor ice segregation as compared to the subgrade soils at TR-5 and TR-6. In addition the water content of the base course material around TR-7 and TR-8 is somewhat higher than at TR-5 and TR-6, which would tend to reduce the depth of subgrade thaw at this location.

A vertical movement grid was established in the fall of 1952 along the entire length of the runway. Points were spaced at 100-foot intervals along the runway centerline and at 50 feet and 90 feet right and left of the 100-foot interval points in the subgrade cut section between Sta. 57+00 and Sta. 74+00. The total vertical movements between 9 May 1953 and 5 September 1953, and between 9 May 1953 and 19 September 1954, of the points located in this cut section is given in Table 3.

Both above-described sets of grids have shortcomings. In the local grids around the temperature wells, the area covered is only a small part of the total subsidence area, while the grid covering the length of the runway has too great an interval between points. Data from observations of these two grid systems indicate a maximum subsidence of only

0.18 feet during 1953 whereas an average of 0.25 feet of bituminous concrete was required during resurfacing operations in 1953 to bring the subsided areas back to grade. Personnel at the site during the summer of 1953 have indicated, based on the unevenness of the pavement surface, that localized subsidences occurred which were greater than values measured at the grid points.

TABLE 3

VERTICAL MOVEMENT OF RUNWAY PAVEMENT IN SUBGRADE CUT SECTIONS THAW SEASONS 1953 AND 1954

Runway Centerline Stationing	℄ 5-9-53 to 9-5-53	℄ 5-9-53 to 9-19-54	50'R 5-9-53 to 9-5-53	50'R 5-9-53 to 9-19-54	90'R 5-9-53 to 9-5-53	90'R 5-9-53 to 9-19-54	50'L 5-9-53 to 9-5-53	50'L 5-9-53 to 9-19-54	90'L 5-9-53 to 9-5-53	90'L 5-9-53 to 9-9-54
55+00	-.01	+.01	-.03	-.01	-.01	+.01	-.01	+.01	-.03	-.01
56+00	.00	+.01	.00	+.01	+.01	+.03	-.02	-.01	.00	+.01
57+00	.00	.00	-.02	-.01	-.01	+.01	-.01	-.01	-.07	-.13
58+00*	+.02	-.06	-.01	-.10	+.01	-.04	-.07	-	-.11	-.20
59+00*	+.01	-.09	+.04	-.09	+.04	.00	-.10	-.13	+.03	.00
60+00	-.02	-.02	-.01	+.04	-.04	+.01	-.02	-.14	-.02	-.06
61+00	-.02	-.01	-.02	.00	-.01	+.02	-.01	-.01	-.03	-.01
62+00	-.02	-.02	-.02	-.02	-.01	.00	-.04	-.12	-.04	-.02
63+00	-.02	-.02	-.01	-.01	.00	+.01	-.02	-.02	-.03	-.01
64+00	-.03	-.05	-.01	-.01	-.01	+.01	-.01	-.01	-.02	-.01
65+00	-.01	.00	-.03	-.04	-.01	+.01	-.01	+.01	-.03	-.01
66+00	-.01	+.01	-.03	-.05	-.02	.00	-.02	.00	-.03	.00
67+00	.00	+.02	-.02	-.01	-.02	+.05	-.02	.00	-.02	+.02
68+00	-.01	.00	-.02	.00	-.01	+.02	-.01	+.02	.00	+.03
69+00	-.01	-.03	-.04	-.05	-.02	+.01	-	-	.00	+.03
70+00	-.04	-.11	-.02	-.03	-.03	-.03	-.01	-.04	+.01	+.03
71+00	-.04	-.10	-.02	.00	-.02	.00	-.05	-.02	-.01	+.02
72+00	-.02	-.01	-.18	-.30	-.02	+.01	.00	+.03	-.01	+.03
73+00	.00	+.02	-.06	-.08	-.04	+.01	+.04	+.01	.00	+.03
74+00	.00	+.02	-.03	.00	-.02	.00	-.01	+.02	.00	+.03

Note: (+) Denotes heave
(-) Denotes subsidence

*Movement at these two stations for period 9 May 1953 to time of resurfacing on or about 17 Aug. 1953

PART III - ANALYSIS OF DATA

3-01. THAW PENETRATION AND SUBSIDENCE. The maximum depth of thaw under natural colored asphalt pavement sections, where the base course thickness was greater than the thaw depth, ranged from 6.4 feet to 8.2 feet in 1953 and from 6.7 feet to 8.0 feet in 1954. In general the least thaw penetration occurred at locations where the base course contained the greatest amount of water per unit volume with the thaw penetration increasing at locations with less moisture in the base.

In cut sections the total thickness of base course material is 6 feet or less and seasonal thawing of the subgrade occurs. In these sections, thaw progresses at about the same rate as in the deeper fill areas until it reaches the subgrade. At this point, as Plates 7 through 10 indicate, the rate of thaw penetration noticeably lessens. Test pits in the cut area have shown the subgrade to contain large amounts of ice in the form of lenses, pockets, coatings on grains and irregular masses. The substantial amount of heat required to melt this ice is the reason for the reduced rate of subgrade thaw penetration.

The presence of ice in a soil in excess of that required to fill the natural voids results in the separation of a certain number of the individual soil grains. This separation of particles may be the result of ice lenses and coatings barely discernible to the eye or may result from formation of substantial ice layers and masses. If soil containing such segregated ice is melted, thus restoring the intergranular contacts, vertical subsidence will occur. This is the nature of the settlement taking place in portions of the area of subgrade cut on the Thule runway.

It is possible to estimate the amount of future subsidence that may be expected at a given location if the properties of the underlying soil are known. The relationship between the vertical subsidence, the void ratios of the frozen and thawed soils and the depth of thaw in the frozen soil is shown in the following formula -

$$S = \frac{e_f - e_t}{1 + e_f} \cdot H$$

Where S = estimated vertical subsidence in feet resulting from thawing a frozen soil layer of thickness (H) in feet.

e_f = average void ratio of the frozen soil layer.

e_t = estimated average void ratio of the soil layer after thawing and consolidation.

The void ratio of the frozen soil may be determined using undisturbed frozen soil specimens obtained from test pits or borings. The depth of thaw (H) may be calculated using the equation given in the following paragraph. It is necessary to predict the void ratio of the soil after thawing and consolidation. An estimate of this latter void ratio can be made by utilizing soil density data for thawed soil, existing in the area under approximately the same overburden, of classification and gradation similar to that of the frozen soil.

The depth of thaw penetration into a frozen subgrade soil may be computed by the following formula* -

*Corps of Engineers, Engineering Manual - Military Construction Part XV, Arctic and Subarctic Construction; Chapter 6, Calculation Methods for Determination of Depths of Freeze and Thaw in Soils (Draft) May 1954.

$$H = \sqrt{k^2 \sum R^2 + \frac{48 k I_p \lambda^2}{L}} - k \sum R$$

where

H = depth of thaw penetration into a frozen subgrade in feet. (Note that H is <u>not</u> depth of thaw penetration from pavement surface).

k = arithmetic mean of the thermal conductivities of the frozen soil (k_f) and the thawed soil (k_u) in Btu/hr./sq. ft./°F./ft.

$\sum R$ = thermal resistance of the thawed soil above the frozen subgrade layer, at time (t), Hr-sq.ft.-°F./Btu.

L = latent heat of the frozen subgrade = 1.44 x dry unit weight of soil x water content in per cent, Btu/cu.ft.

I_p = partial thawing index remaining to thaw the subgrade at time (t). (Surface thawing index for entire thawing season minus portion of surface thawing index expended in thawing the soil overlying frozen subgrade layer), deg-days.

λ = dimensionless correction coefficient* (equal to 0.9 for climatic conditions and representative subgrade soil properties at Thule).

By means of the two foregoing equations the depth of thaw penetration during a thawing season and surface subsidence resulting from thawing a frozen soil layer of known ice content may be estimated for one or a series of thawing seasons.

---

* <u>First Interim Report, Analytical Studies of Freezing and Thawing of Soils</u> by H. P. Aldrich, Jr. and H. M. Paynter, dated June 1953. Prepared under contract with Arctic Construction and Frost Effects Laboratory.

appreciable change in soil gradation represents the boundary between the previously unthawed subgrade and the subgrade thawed during the 1952 summer season.

Referring to Plate 15, a total subsidence of 1.63 feet in 20 years is predicted for the soil sequence shown, 0.2 feet of this cumulative total occurring during the 1954 thawing season, 0.18 foot during the 1955 thawing season, and continued subsidence occurring at progressively smaller increments during subsequent thawing seasons. Subsidence will continue until the combined effect of adding pavement to surface and/or a sufficient thickness of thawed and consolidated soil has accumulated, over the high ice content subgrade, to confine maximum seasonal thawing within this accumulated previously thawed soil layer which is relatively free of segregated ice.

If the pavement is kept level by adding bituminous surfacing as subsidence occurs and the subgrade conditions are as depicted on Plate 15, further thawing and subsidence will theoretically be arrested after 0.5 feet of thawed and consolidated subgrade soil has accumulated and 0.7 feet of additional bituminous surfacing has been added to keep the pavement at grade. A stable condition would be approached over a period of several years at a progressively decreasing rate. Assuming for purposes of analysis that surfacing is not added to keep the pavement level and subgrade conditions are as shown in Plate 15, calculations indicate that thawing would continue until a total pavement subsidence of 1.9 feet occurred, and 1.0 feet of thawed and consolidated soil had been built up. The following table is presented as an example of the slow rate of cumulative increase of such a soil layer. The water contents shown are actual values as observed in runway test pits.

Water Content % Dry Wt.	Void Ratio Frozen Subgrade	Assumed Void Ratio After Thaw and Consolidation	Resulting thickness (inches) of thawed and consolidated soil for each one inch of subgrade soil melted
95	2.8	0.25	0.44
300	8.9	0.25	0.14
962	28.6	0.25	0.04

Thus, for a frozen ice-soil mixture having a water content of 300 per cent, each one inch of thaw results in an increase of only 0.14 inch of thawed and consolidated material. To build up the one foot layer of soil necessary to arrest additional thaw penetration into the high ice content material would require thawing approximately 7 feet of subgrade soil. Since the theoretical thaw penetration into the subgrade is in the order of 2 to 3 inches and this rate will continually decrease as the years progress, it may be seen that subsidence in a section where the subgrade soils have water contents of the order of 300 per cent would continue for several years. Where previously unthawed subgrade soil does not contain considerable segregated ice, the seasonal thawing during the next few years will, by thawing and consolidation, tend to build up a sufficient thickness of subgrade free of segregated ice to prevent further degradation and subsidence.

Test Pit S-716, the log of which is shown on Plate 5, reveals the highest ice content or lowest soil content subgrade conditions of any of the explorations. Assuming the water contents shown (318 and 962 per cent) are representative of the two layers at subgrade, only about 3-inches of soil will accumulate by thawing from 4.6 foot depth to 7.5 foot depth. The pavement subsidence resulting from such thawing would occur over a period of several years and would total approximately 2.7 feet. Since the test pit was not of sufficient depth to determine the thickness of the lower ice layer an unknown amount of additional subsidence is possible at this location.

Because of the irregular nature of the distribution and quantity of subgrade ice, it is not known whether Test Pit S-716 reveals an extreme condition or whether similar conditions exist at other locations within the subsidence area. It is believed logical to assume that there are at least a few areas where the subgrade conditions are as severe as at Test Pit S-716. In such areas, subsidence must be anticipated to continue at a rate of 1-1/2 to 2 inches for each of the next several thawing seasons. Resurfacing to keep the pavement level in areas of considerable subsidence may, after a period of years, result in sufficient increase in the thermal resistance of the pavement and base to prevent further subgrade thawing. Theoretically a pavement thickness of 2.5 feet over 5 feet of gravel base of the type used at Thule will protect the subgrade from thawing. For conditions at Test Pit S-716 where the base is 4.6 feet, the required asphaltic pavement thickness to arrest thawing would be approximately 3.0 feet. Since the annual accumulation of subgrade soil by thawing will be negligible at this location, the thermal resistance of the resurfacing material must play a major role in arresting future thawing and subsidence.

3-02. PAVEMENT HEAVE. As shown in Table 2, the measured pavement heave resulting from refreezing of the base and subgrade materials in the area of subsidence in the vicinity of TR-5 and TR-6 averaged 0.06 feet. The pavement heave indicated elsewhere in the subsidence area was of similar magnitude. Although some of the water released by thawing probably drained away before refreezing started, the distinct water table existing in this area throughout the summer undoubtedly resulted in increased moisture availability and increased heave on freeze-up in the fall.

3-03. SURFACE COLOR. Plates 13 and 14 show that the depth of thaw beneath the white painted surface is significantly less than that beneath the adjacent natural colored asphaltic concrete surface. The fact that pavements in arctic regions receive solar radiation 24 hours a day during the summer months coupled with the much lower absorptivity of the white-colored surface has resulted in surface temperatures in the painted pavement averaging about 5°C lower than those in the adjacent unpainted pavement. The net effect of this lowered surface temperature is a marked reduction in total heat transfer between the pavement and the underlying soils and a corresponding reduction in the maximum thaw depth.

The surface around TTW-1 was painted white on 9 May 1953. At this time thaw had penetrated to about 0.7 feet below the top of the pavement. It is of interest to note that this 0.7 feet had completely refrozen by 14 May and rethawing did not commence again until 1 June. Thaw beneath the adjacent unpainted surfaces continued to progress uniformly throughout this period.

During the spring of 1954, the presence of a layer of compact snow up to two inches in thickness on the pavement surface in the vicinity of the taxiway temperature installations resulted in delaying penetration of the thaw beneath the surface until the snow disappeared on about 22 May. Thaw beneath both the white-painted and natural surfaces began on this date.

Referring to Plates 13 and 14, it will be noted that from 22 May to 9 June 1954 thaw penetrated almost three feet below the natural asphaltic concrete surface as compared to less than 1.5 feet below the white-painted surface.

The effect of surface color on rate and total depth of thaw was about the same for both the 1953 and 1954 thawing seasons. The greater depth of thaw penetration under TTB-1 and -2 and TT -1 and -2 during 1953, despite the greater thawing index of 1954, is attributed to introduction of heat into the ground by excavations made on approximately 4 July 1953 when all four thermocouple strings were removed and re-installed so as to move terminal boxes from one side of the taxiway to the other. The depths of thaw in 1954 are therefore considered more nearly representative.

3-04. <u>GROUND WATER</u>. The existence of a ground water table in the cut section between Sta. 57+00, 75 feet left, and Sta. 69+00, 50 feet left, during the latter half of the thawing season is believed to be due to the melting of the ice in the subgrade soils. Its appearance in the second half of July coincides approximately with the penetration of thaw into the subgrade. As thaw began melting the ice in the top layer of the subgrade, the ground water table rose rapidly to a level 1/2 to 2-1/2 feet above the level of frozen ground. Here an equilibrium between the supply of water due to continued melting and the loss of water due to drainage was apparently established. The volumetric heat capacity of the newly released water may have exerted some control by reducing the potential rate of melting of the underlying still-frozen soil. At TR-5 and TR-6 the water table remained relatively constant with only minor fluctuations until early September, when some lowering of the table began. This lowering of the water table paralleled closely the decreasing rate of thaw penetration and consequent decrease in the rate of supply of water. At TR-7 and TR-8 the water table held a fairly steady level, or dropped slightly, from late July until freeze-up.

PART IV - SUMMARY OF RESULTS AND CONCLUSIONS

4-01. SUMMARY OF RESULTS AND CONCLUSIONS. Based on the foregoing analysis of the observational data obtained at the test areas on the runway and south loop taxiway at Thule AFB during the 1953 and 1954 thawing seasons* the following conclusions are reached:

a. Where the total thickness of pavement and base course exceeded the depth of thaw, the maximum depth of thaw penetration beneath the natural color asphalt pavement at six runway temperature well locations averaged 7.1 feet and ranged from 6.4 feet to 7.7 feet during 1953, and averaged 7.4 feet and ranged from 6.7 to 8.0 feet in 1954. For similar conditions on the south loop taxiway, observations in 1953 showed an average maximum thaw penetration at two locations under natural color asphalt pavement of 8.0 feet and a corresponding average value for two locations under pavement painted white of 5.9 feet; in 1954 average maximum depths of thaw for these locations were 7.2 feet for black pavement and 5.45 feet for white pavement. The 1954 taxiway observations are considered probably more representative than the 1953 values because of disturbance of the thermocouple installations during the summer of 1953; however, the 1954 values may also be smaller because a layer of snow remained on the taxiway during approximately 3 weeks in May 1954, delaying thaw, whereas the pavement was bare in the same period in 1954.

b. Pavement subsidence was confined to two areas, each approximately 200 feet in length, lying at either end of the area of subgrade cut, which extends from approximately Sta. 55+00 to Sta. 74+00 and has thicknesses of pavement and base course less than the depth of seasonal thawing.

*The Air Thawing Index during 1954 was the maximum value for the six years of temperature record available, and 20 per cent greater than the mean value. During 1953, the Index was equal to the mean value.

c. Localized subsidences during a single thawing season of as much as 2-1/2 inches have been reported by field engineers in each of the two subsidence areas.

d. Explorations in the subsidence areas reveal that at some locations virtually pure ice masses and high ice content soils exist at or near the subgrade surface. Analyses indicate that where such conditions were found, continued subsidence will occur for several thawing seasons and in some instances may continue for more than 20 years.

e. Maximum estimated rates of future subsidence in the zones near the ends of the subgrade cut will be of the order of 0.2 feet per year, with this rate progressively decreasing until subsidence is complete.

f. It is estimated that a total ultimate subsidence of as much as 2.0 to 2.5 feet may occur at some locations.

g. Because of the irregular nature of the occurrence of the ice masses and high ice content soils in the subgrade, future subsidence will result in uneven pavement surface conditions and possibly abrupt changes in grade. Continued resurfacing of pavement in areas of subsidence to keep the pavement properly smooth for operation of aircraft with high landing and take-off speeds should be anticipated for each of the next several thawing seasons. The area of pavement requiring resurfacing will decrease with succeeding thawing periods.

PART V - RECOMMENDATIONS

5-01. RECOMMENDATIONS. Based on the results of the investigation of the pavement sections at Thule Air Force Base during the 1953 and 1954 thawing seasons, the following recommendations are made:

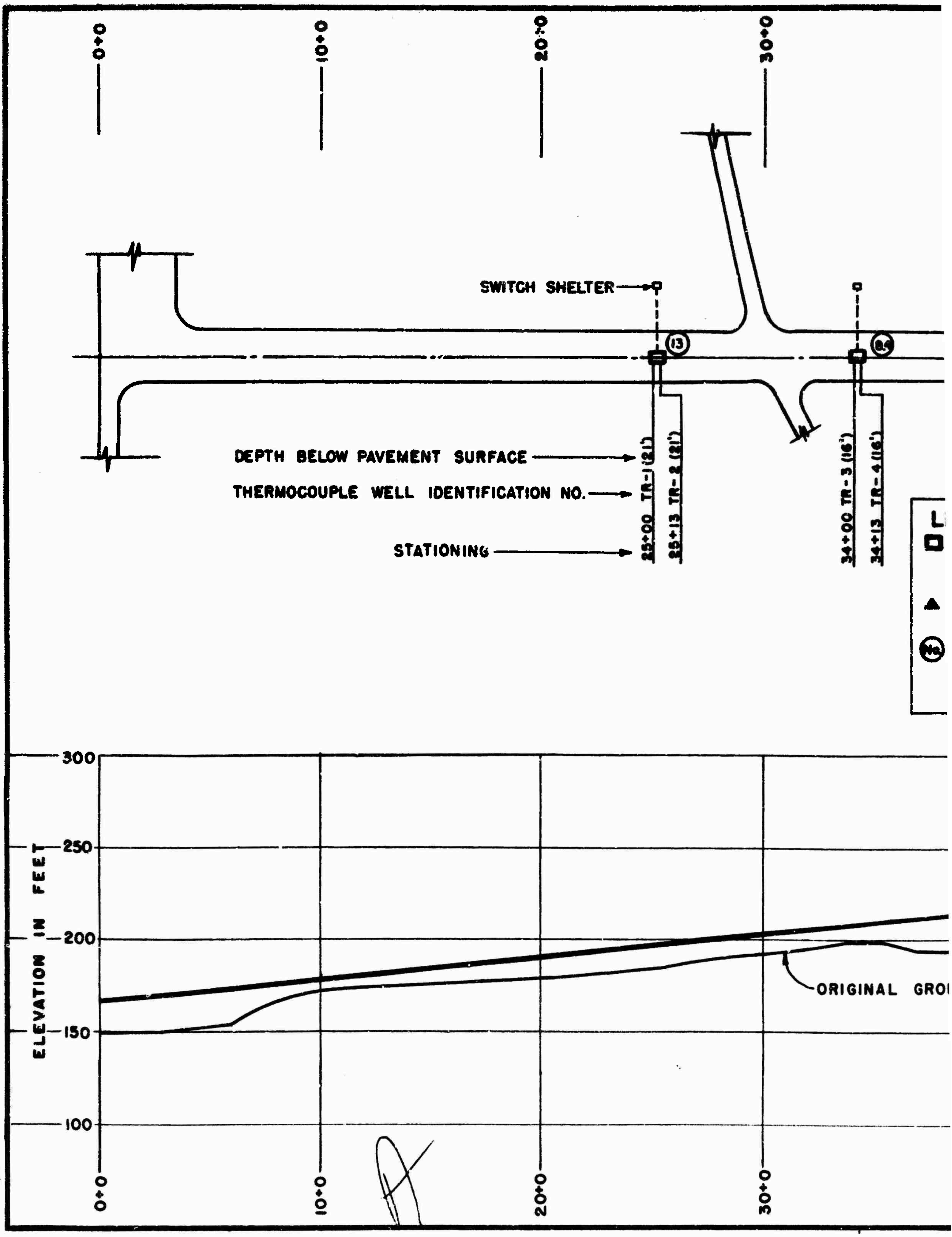
a. Maintenance of Existing Pavement. In the subsidence areas it is recommended that one of the two following courses of action be adopted. The selection of course of action will undoubtedly be dictated by runway operational considerations and by the degree to which periodic levelling operations may prove undesirable with time:

(1) Resurface affected sections of pavement periodically when noticeable or objectionable unevenness develops in the subsidence areas.

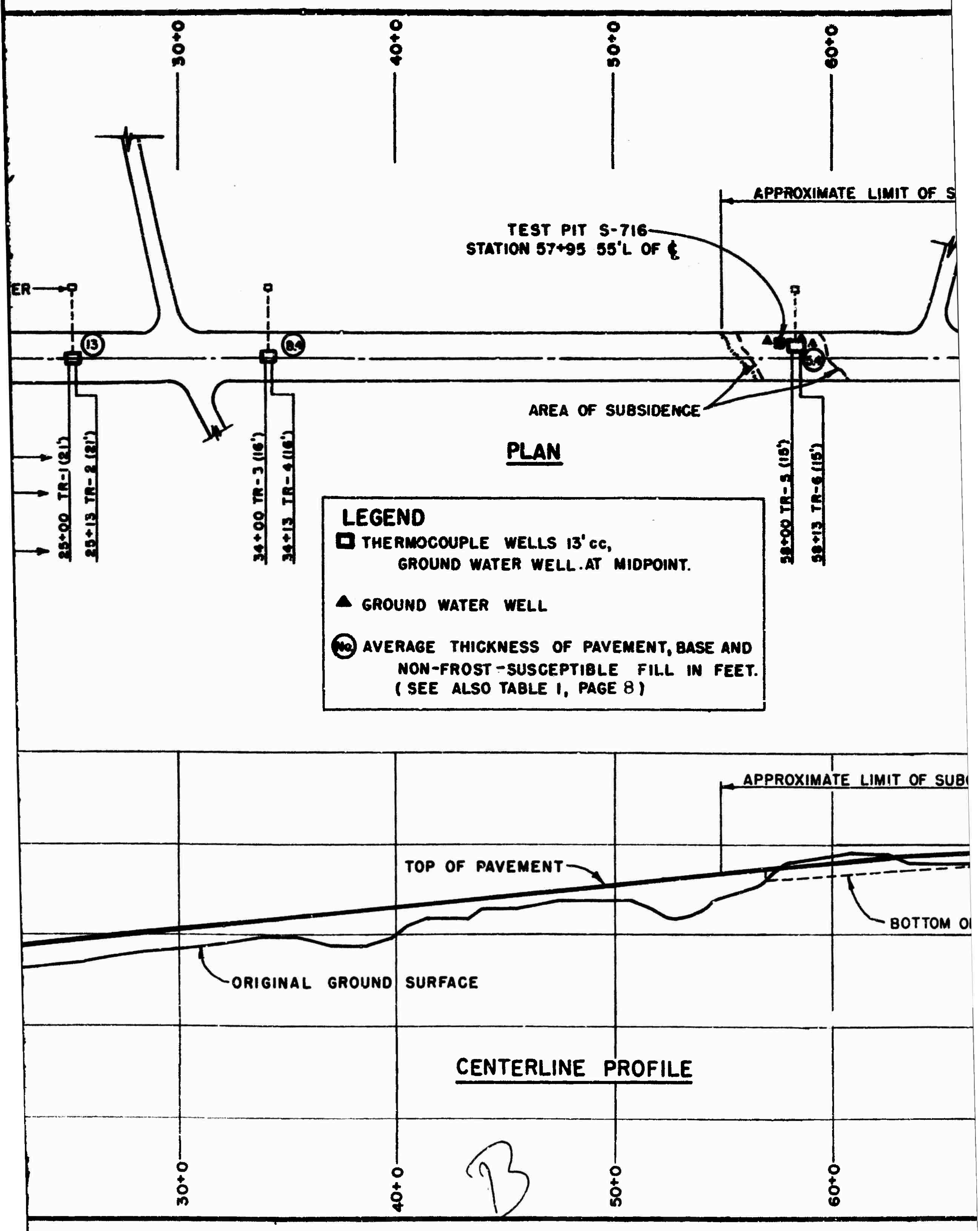
(2) Paint the surface of the pavement white in the subsidence areas so as to reduce depth of thaw penetration, which for the conditions observed would eliminate further subsidence except for possibly a few isolated small areas.

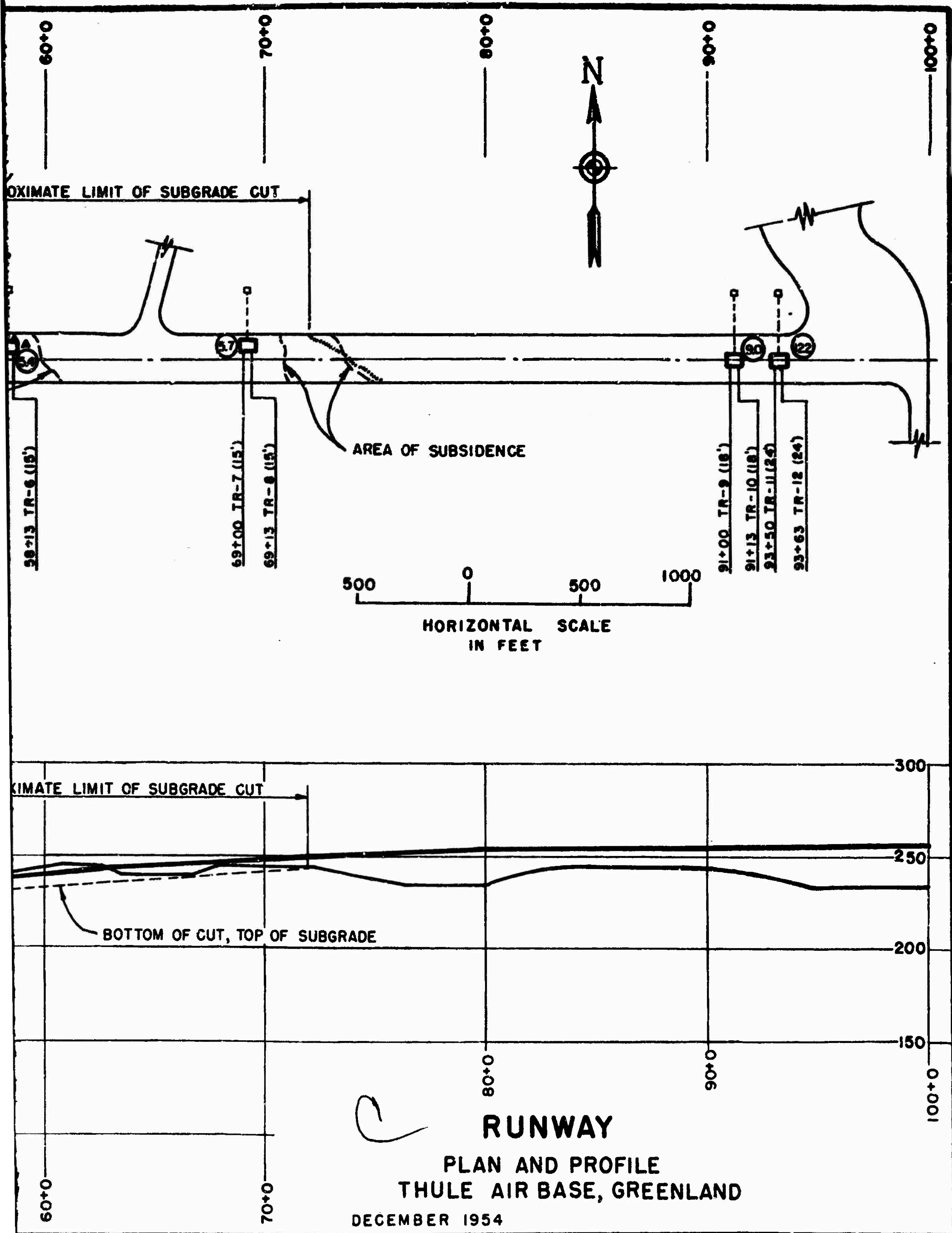
b. Future Construction. In additional airfield pavement construction at Thule Air Force Base over subgrade soils containing segregated ice, it is recommended a minimum total thickness of 8 feet of non-frost-susceptible pavement and base, of the type used for past construction at Thule, be provided over the ice-containing materials. Somewhat less than 8 feet of base would be required if non-frost-susceptible material with higher moisture retention characteristics, such as sand, were included in the lower portion of the base course. In fill sections over non-frost-susceptible soils having a naturally ice-free active zone, advantage may be taken of the latter stratum to minimize the height of embankment required.

c. Additional Investigations. It is recommended that the field investigations and observations at the runway and taxiway test areas be continued during the 1955 thawing season. It is recommended that personnel of the Arctic Construction and Frost Effects Laboratory visit Thule prior to the start of the thawing period and at time of maximum thaw to determine the surface elevation of the pavement in the subsidence areas. It is recommended that the Eastern Ocean District obtain elevations immediately prior to and immediately following any resurfacing that is done during the thawing period.



0+0
10+0
20+0
30+0
SWITCH SHELTER
13
84
DEPTH BELOW PAVEMENT SURFACE
THERMOCOUPLE WELL IDENTIFICATION NO.
STATIONING
25+00 TR-1 (21')
25+13 TR-2 (21')
34+00 TR-3 (16')
34+13 TR-4 (16')
No.
300
250
200
150
100
ELEVATION IN FEET
ORIGINAL GROU


30+0
40+0
50+0
60+0
APPROXIMATE LIMIT OF S
TEST PIT S-716
STATION 57+95 55'L OF ℄
ER
13
8.4
5.4
25+00 TR-1 (21')
25+13 TR-2 (21')
34+00 TR-3 (16')
34+13 TR-4 (16')
58+00 TR-5 (15')
58+13 TR-6 (15')
AREA OF SUBSIDENCE
PLAN
LEGEND
THERMOCOUPLE WELLS 13' cc, GROUND WATER WELL AT MIDPOINT.
GROUND WATER WELL
AVERAGE THICKNESS OF PAVEMENT, BASE AND NON-FROST-SUSCEPTIBLE FILL IN FEET. (SEE ALSO TABLE I, PAGE 8)
APPROXIMATE LIMIT OF SUB
TOP OF PAVEMENT
BOTTOM O
ORIGINAL GROUND SURFACE
CENTERLINE PROFILE
30+0
40+0
50+0
60+0
B

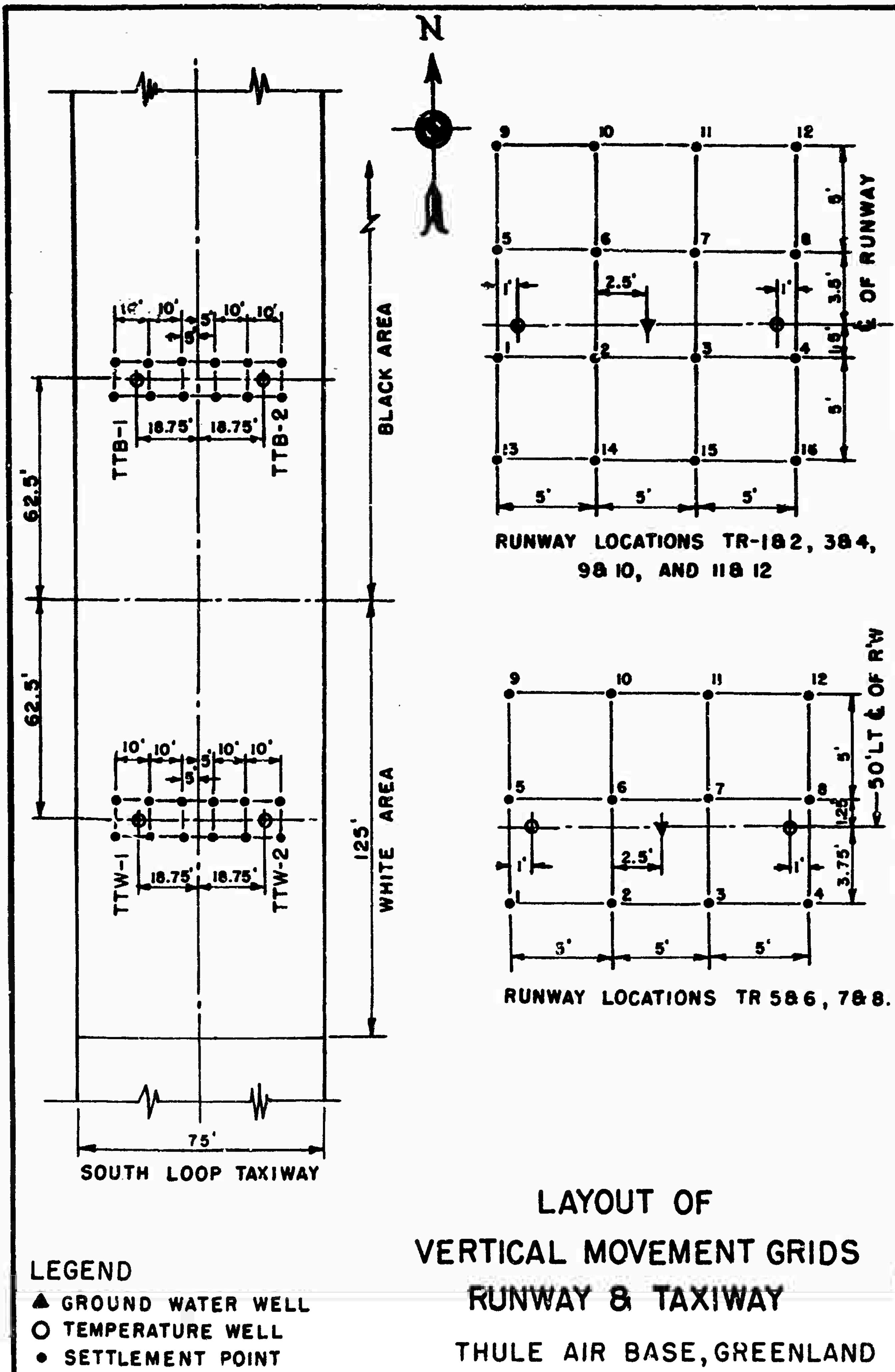


RUNWAY

PLAN AND PROFILE
THULE AIR BASE, GREENLAND

DECEMBER 1954

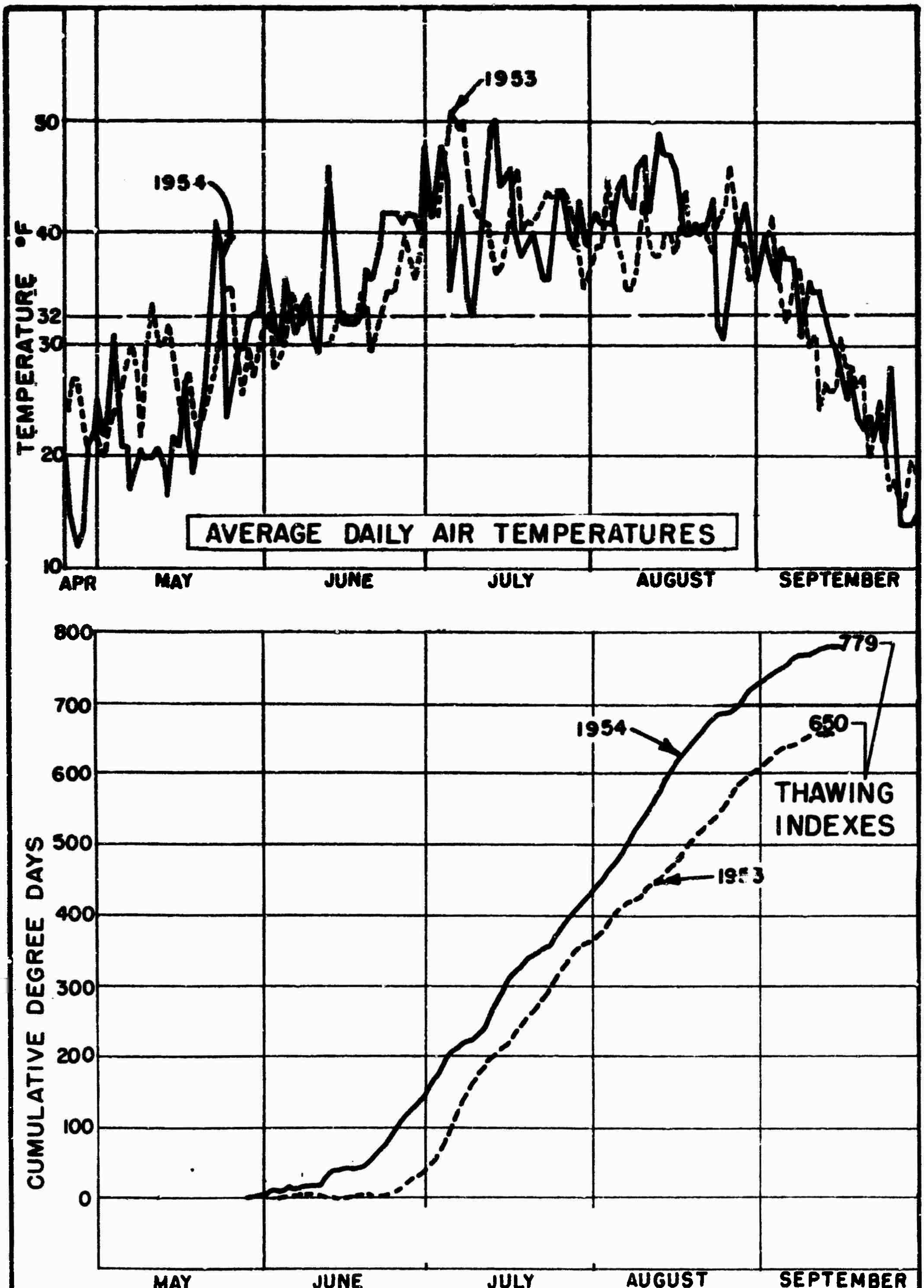
PLATE 1



LAYOUT OF VERTICAL MOVEMENT GRIDS RUNWAY & TAXIWAY

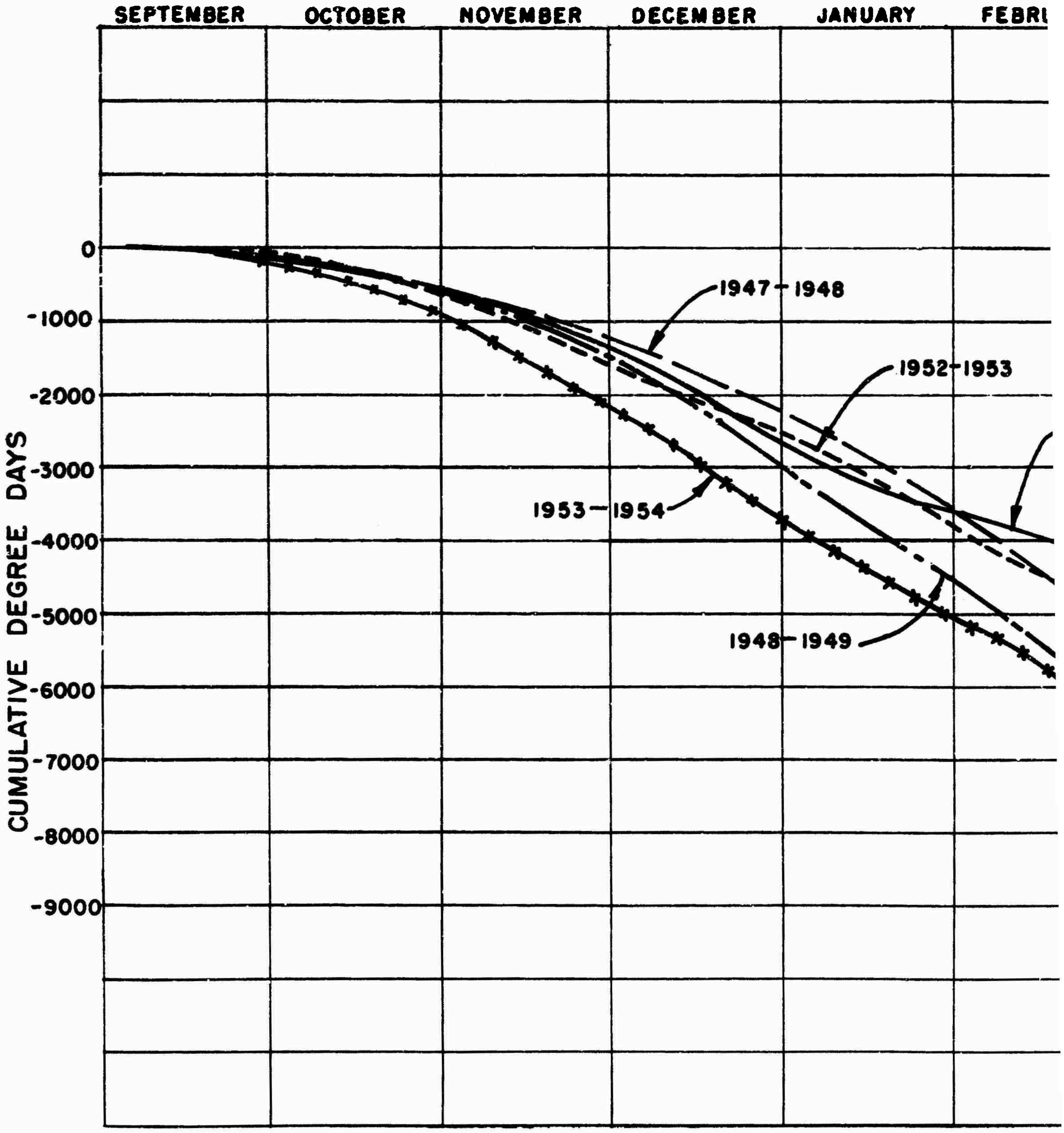
THULE AIR BASE, GREENLAND

PLATE 2

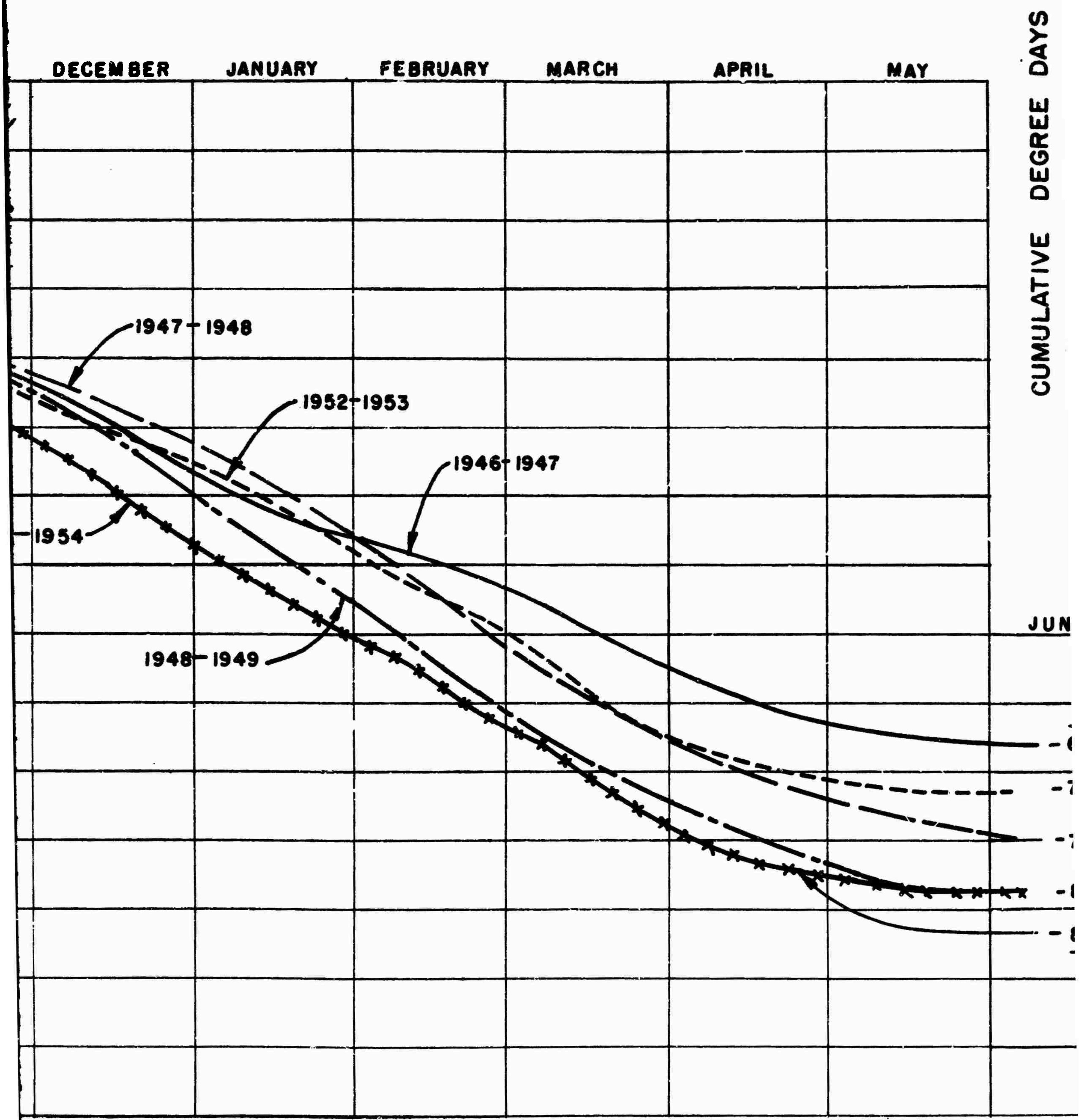


AIR TEMPERATURES & THAWING INDEXES
1953 & 1954 THAWING SEASONS
THULE A. F. B.

PLATE 3

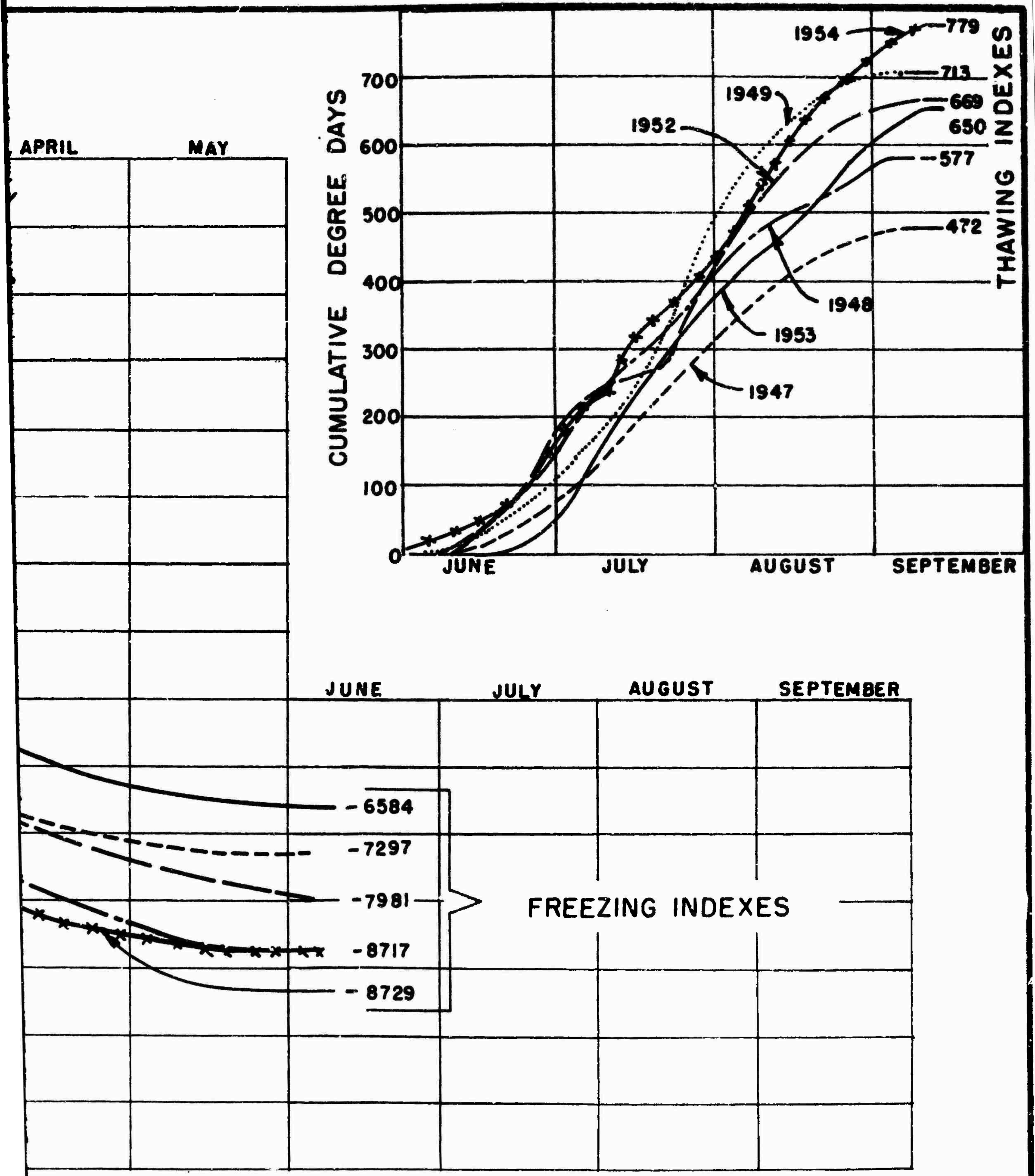


NOTE: THE 1949-1950 FREEZING SEASON FOLLOWED CLOSELY THE RESULTS OF THE 1948 — 1949 SEASON. THE TOTAL CUMULATIVE DEGREE DAYS WERE 8701.



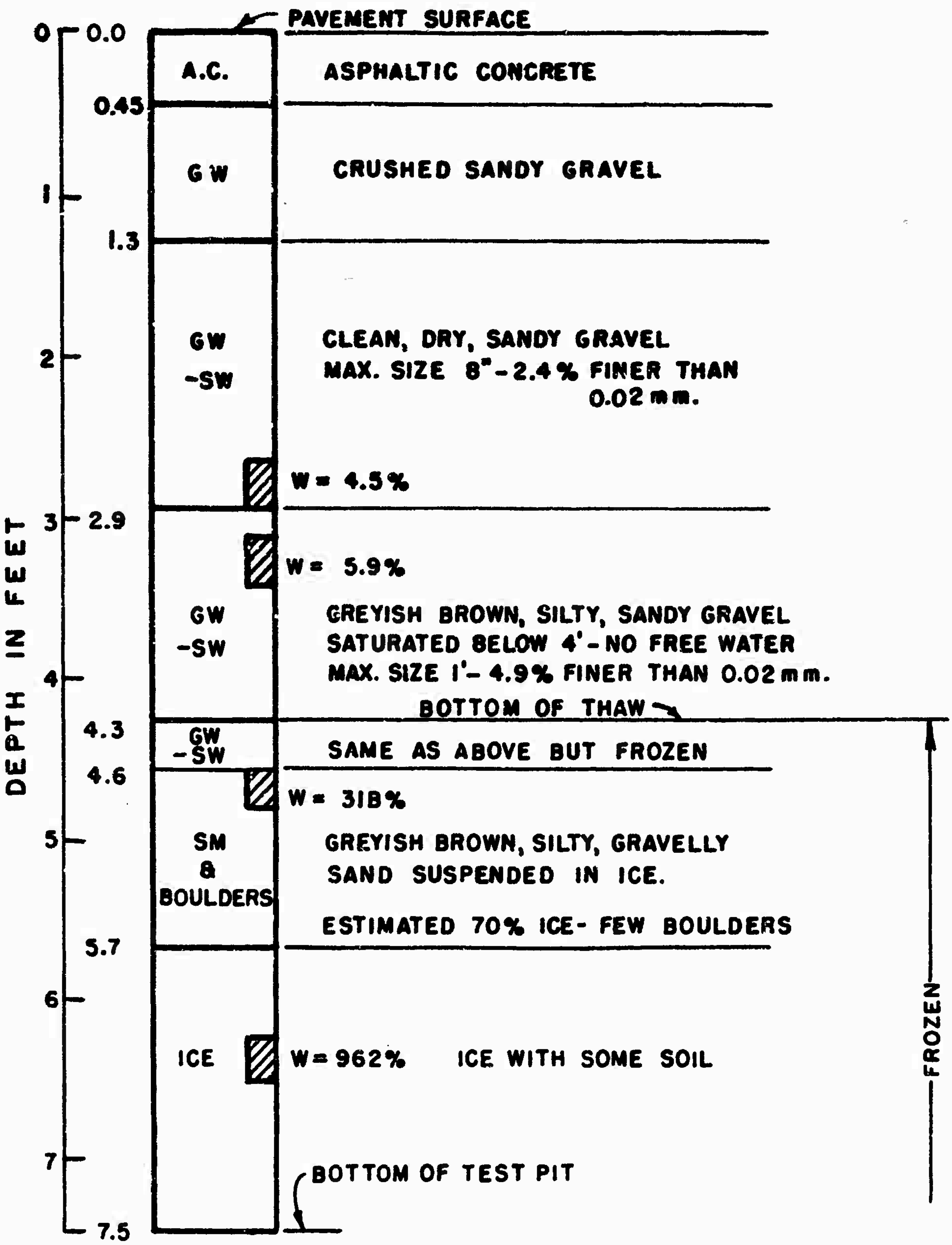
9-1950 FREEZING SEASON FOLLOWED
THE RESULTS OF THE 1948 —
EASON. THE TOTAL CUMULATIVE
DAYS WERE 8701.

B



FREEZING AND THAWING DATA

THULE A.F.B.



LEGEND

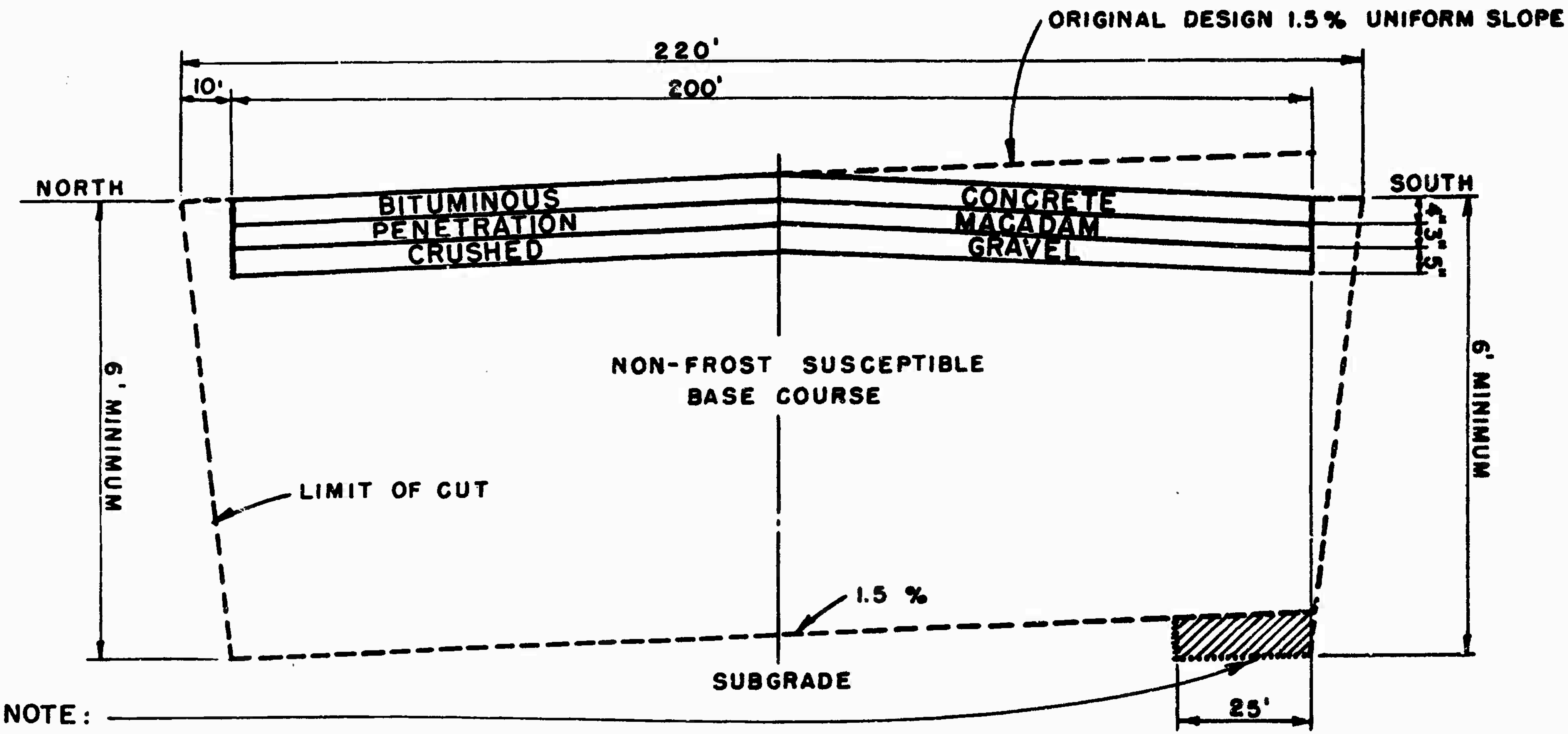
▨ LOCATION OF DENSITY SAMPLE

W = WATER CONTENT IN PER CENT OF DRY WEIGHT OF SOIL

THULE A.F.B.
LOG OF TEST PIT S-716

DATE OF EXPLORATION:
15 JULY 1952

LOCATION: STA. 57+95,
55' LEFT OF RUNWAY ℄

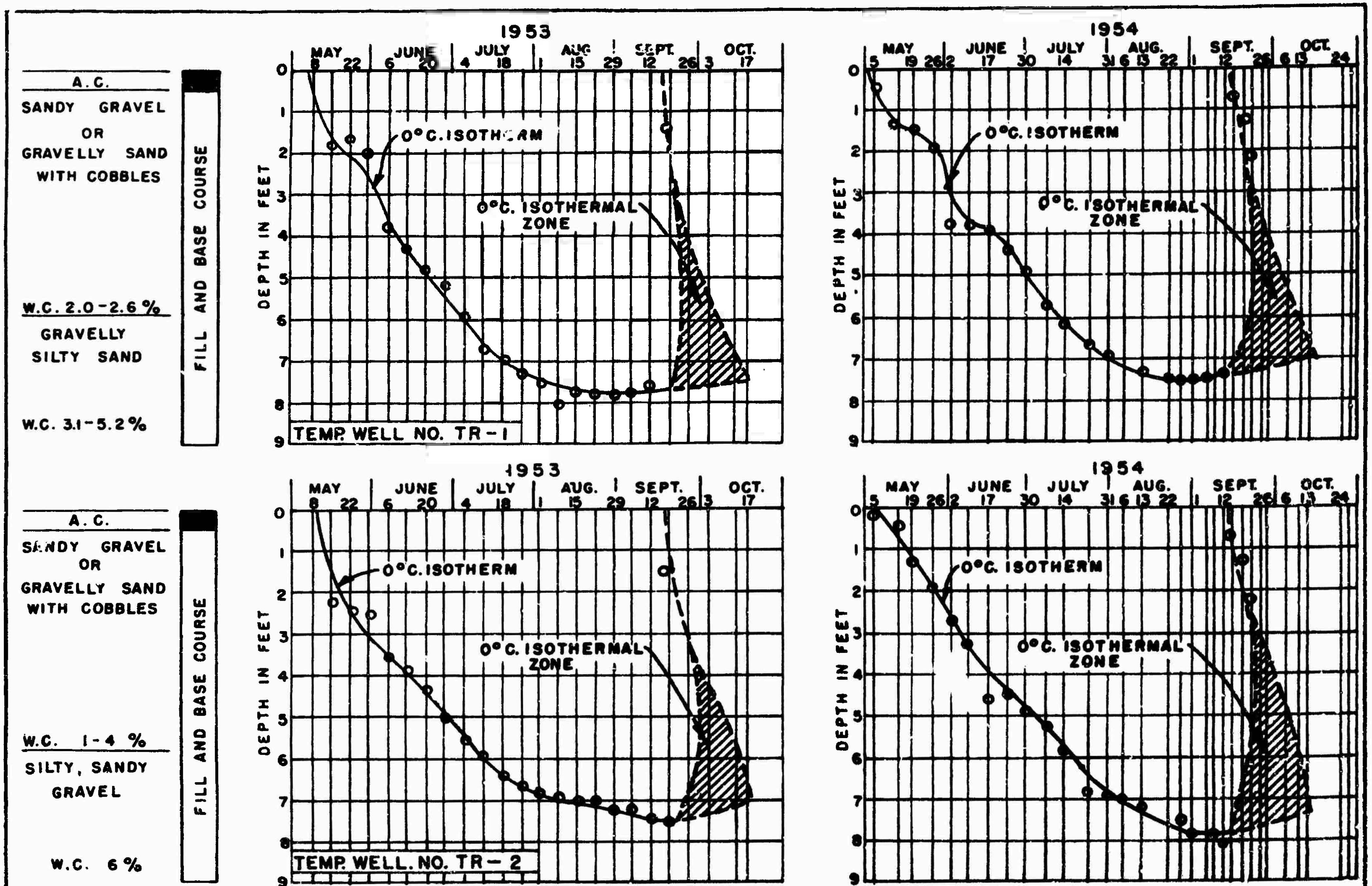


NOTE:
FROM STATION 61+00 TO STATION 75+00 THE BASE THICKNESS INCREASED TO A MINIMUM OF 6' FOR 25' WIDTH ON RIGHT EDGE OF RUNWAY PAVEMENT.

RUNWAY CROSS SECTION
AREA OF SUBGRADE CUT

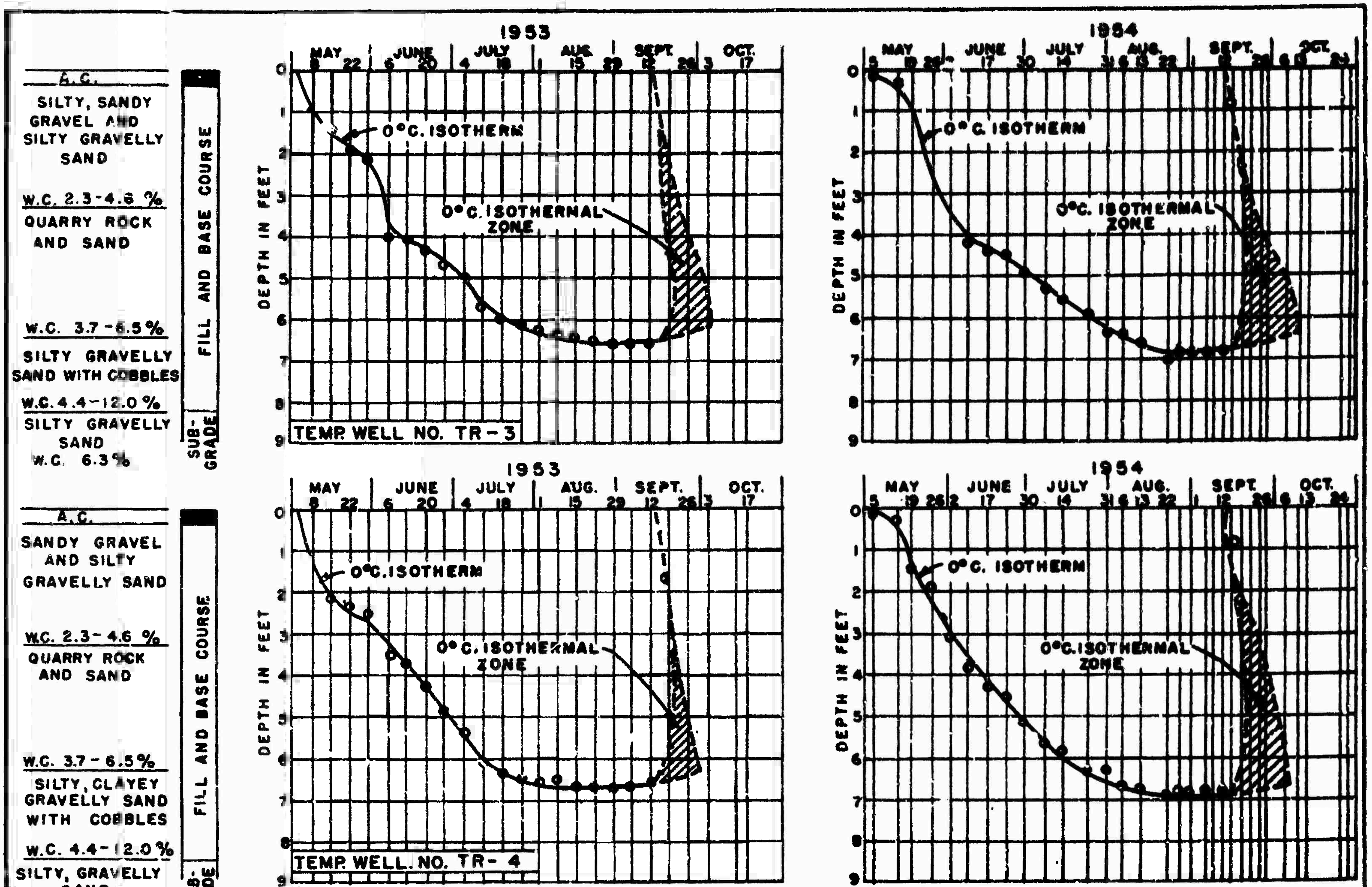
STA. 57+00 TO STA. 74+00
THULE A.F.B.

PLATE 6



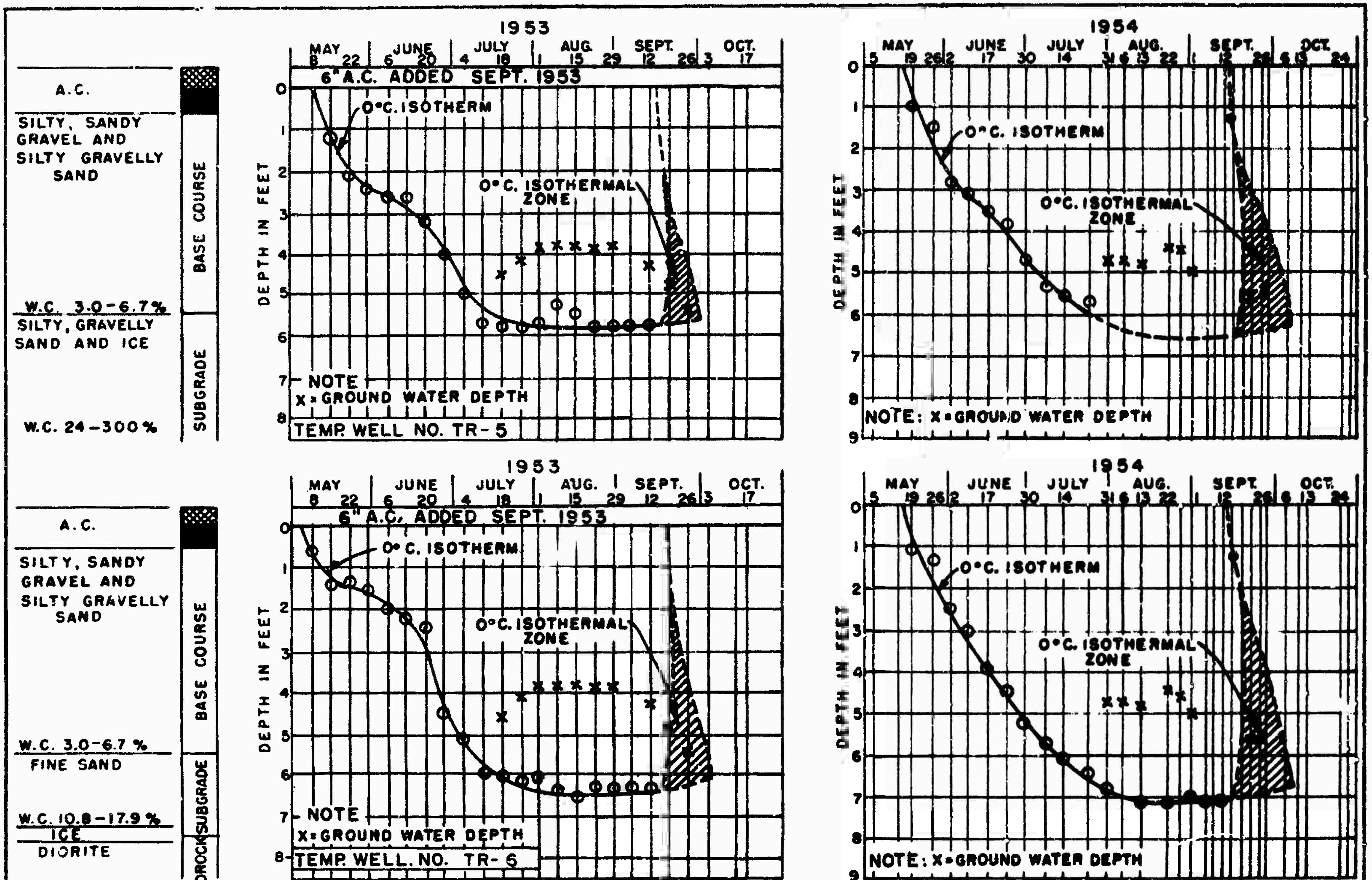
THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE

PLATE 7



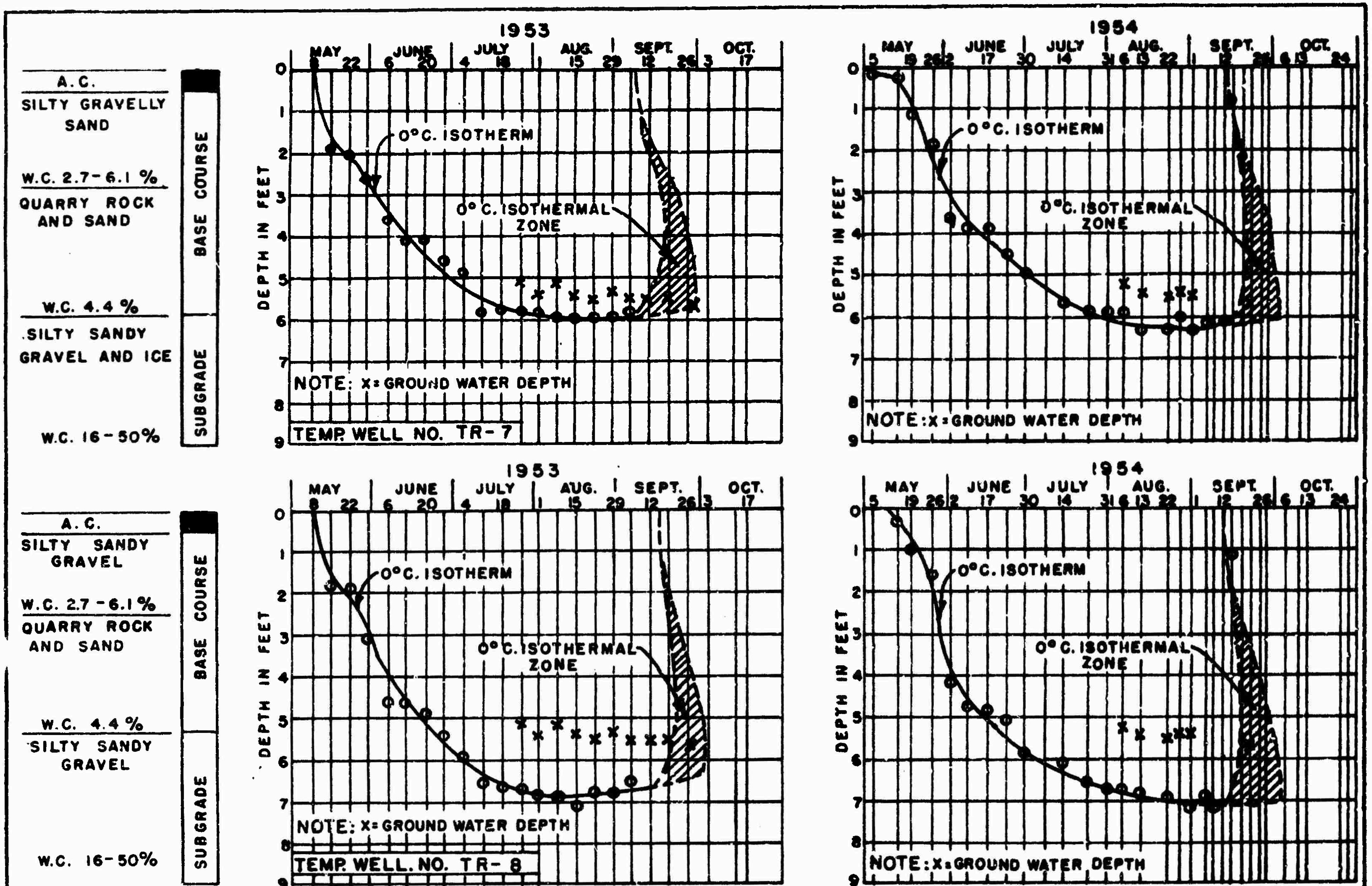
THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE

PLATE 8



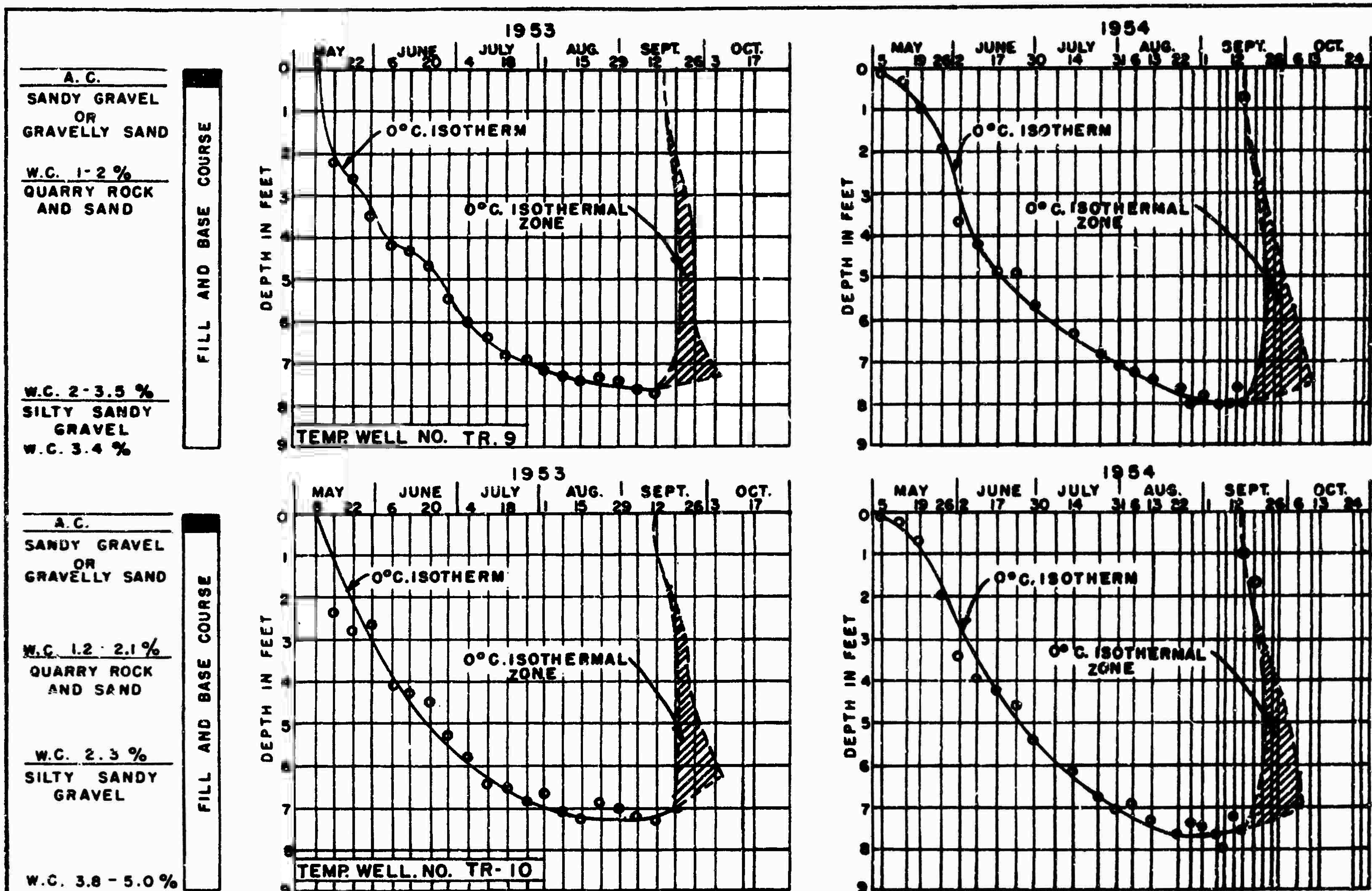
THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE

PLATE 9

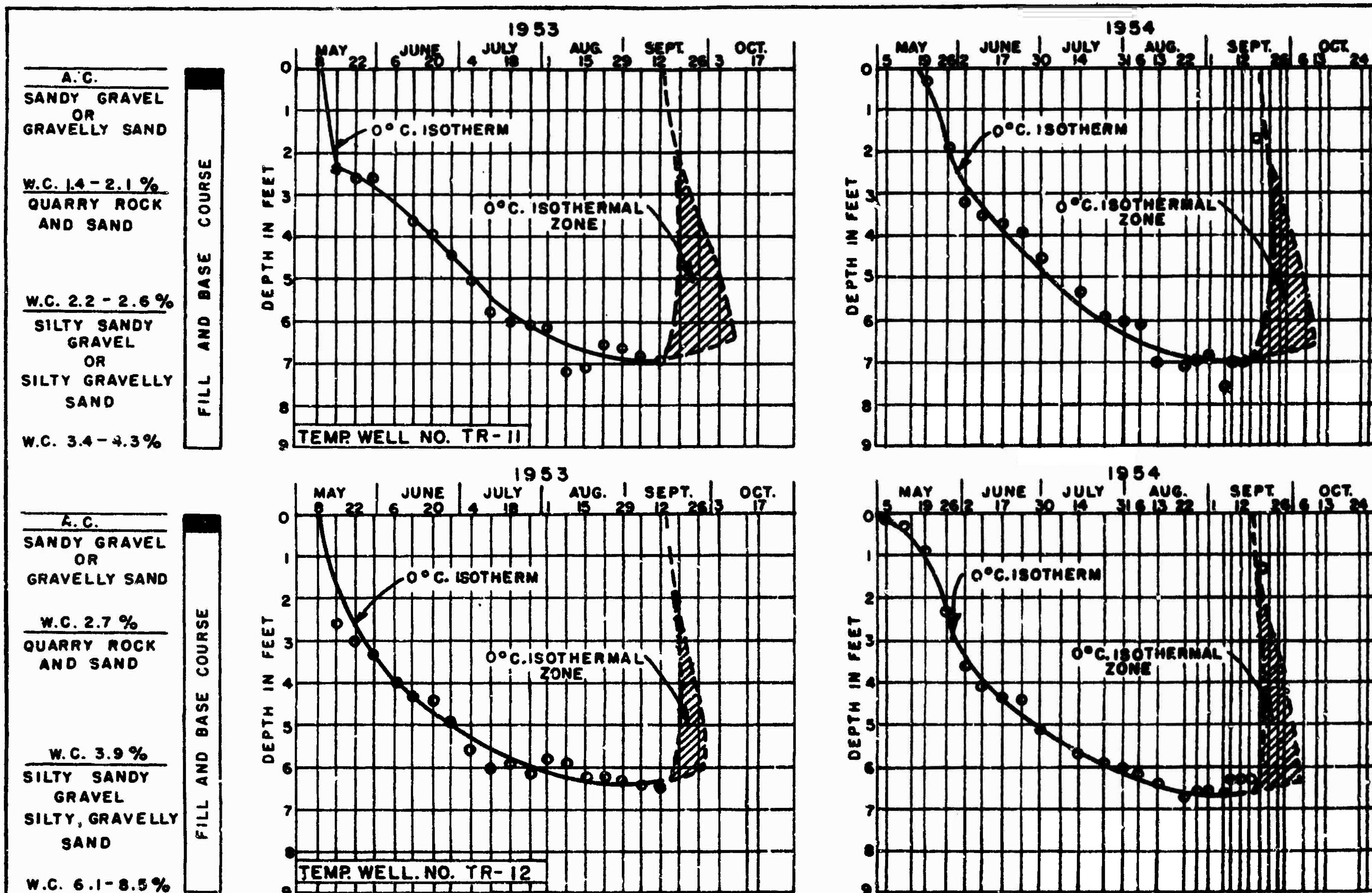


THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE

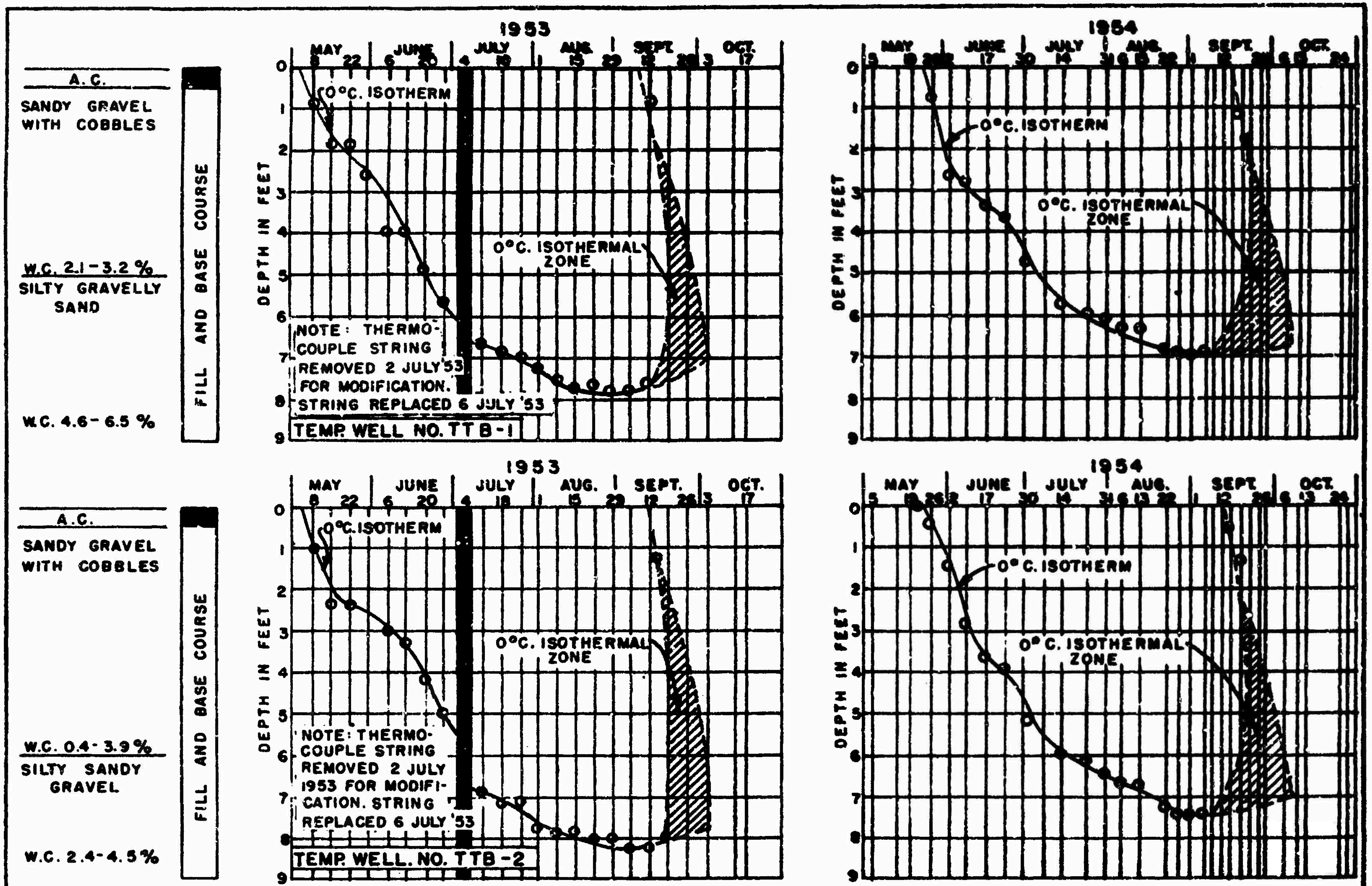
PLATE 10



THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE

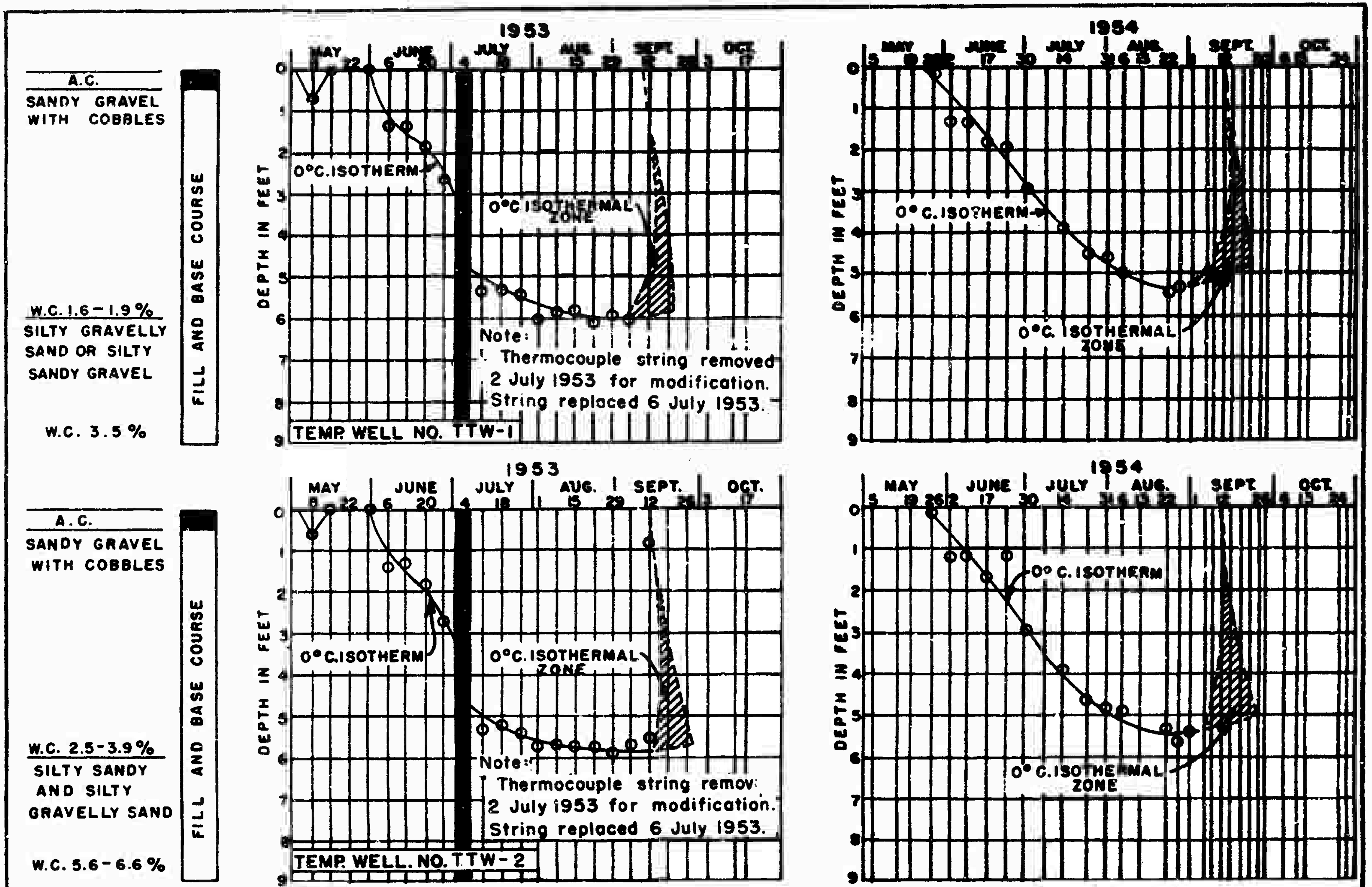


THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE

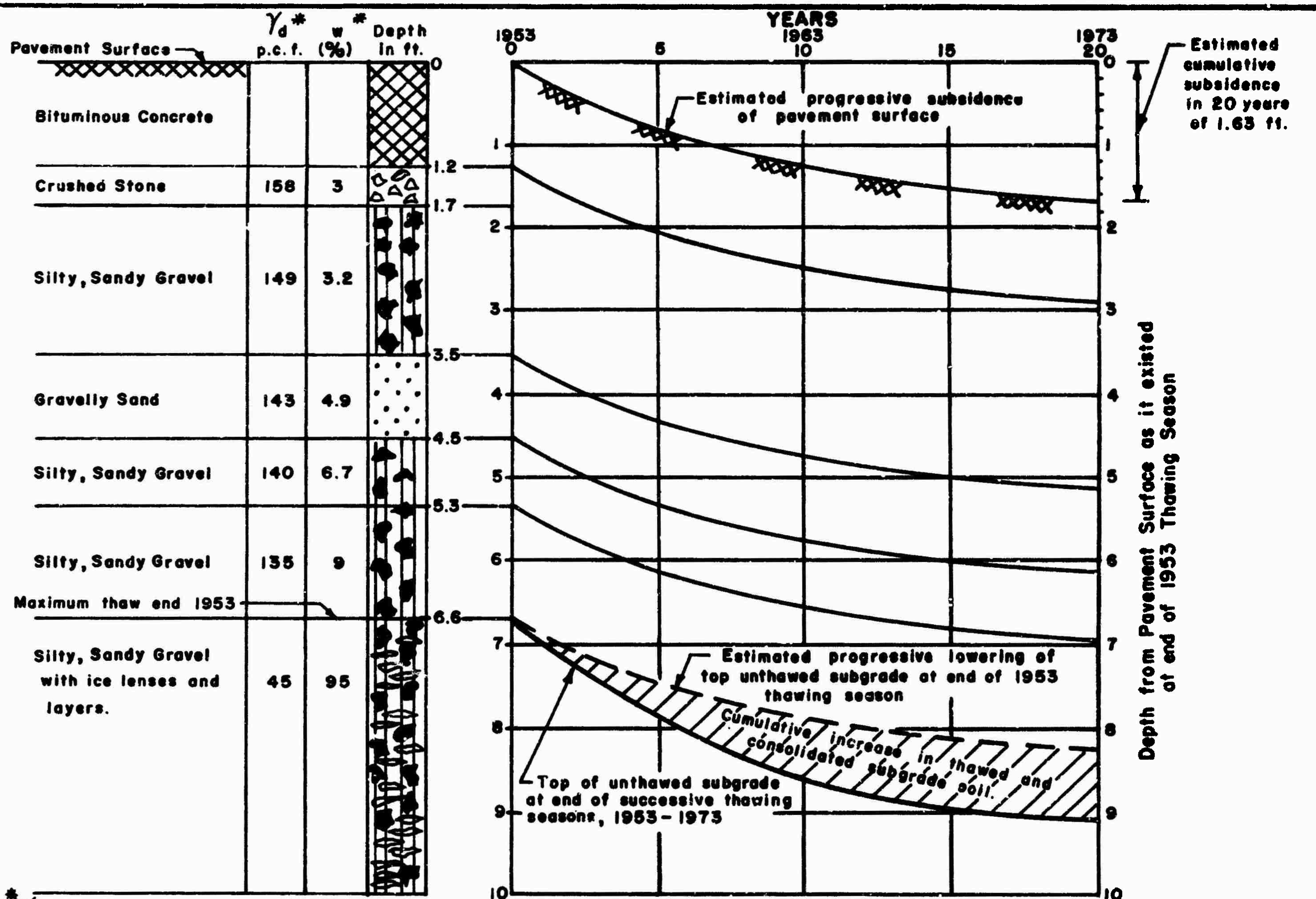


THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE

PLATE 13



THAW PENETRATION BENEATH PAVEMENT, THULE AIR FORCE BASE



* γ_d = Dry density in p.c.f.

* w = Water content in % of γ_d

ESTIMATED FUTURE PAVEMENT SUBSIDENCE IN THE VICINITY OF RUNWAY STA. 58+00 TO STA. 58+15, 50' L OF ℄

APPENDIX A

BORING LOGS OF RUNWAY AND TAXIWAY EXPLORATIONS

Prepared

by

METCALF & EDDY

and

ALFRED HOPKINS & ASSOCIATES

Architect-Engineers

Metcalf & Eddy

1953 F

Hole No TR*1
Location RUNWAY: STA. 25+00, ℄
Lab. Sample No. 29-S

Sample No & Depth	Graphic Log	Description & Classification	Density lbs/cu ft	M C %	Comp %	Max Size	LA 1 1/2"	3/4"
		Bituminous Concrete Penetration Macadam						
0.8' A	G OR S	Cuttings are light gray, well graded from fine gravel to fine sand - max size = 3/4". No visible ice. Sandy gravel or gravelly sand with cobbles		2.0				
3.0' B		Same as "A" - max. size = 1/2".		2.6				
6.0' C	SM	Cuttings are brownish gray, mostly fine sand and silt with some organic matter. Some of the organic matter consists of wood chips. No visible ice. Gravelly silty sand.		5.2				
8.0' D		Same as "C".		3.1				
11.0' E	S OR SM	Cuttings are brownish gray, mostly med. to fine sand, with some coarse chips and silt - max size = 1/2". No visible ice. Slightly silty gravelly sand with cobbles and a trace of organic matter.		3.0				
14.0'	Continued							

Metcalf & Eddy and Alfred Hopkins & Associates

Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

	M C %	Comp %	Max Size	PERCENT FINER 1½"	3/4"	3/8"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm	LL	PL	PI	Specific Gravity	
	2.0																	S
	2.6																	S
	5.2																	L
	3.1																	L
	3.0																	L N

kins & Associates

Date DH 3-29-53
Submitted by S.B.

tigation

EST DATA									Source of Material	Remarks
FINER					L L	P L	P I	Specific Gravity		
20	No 40	No 60	No 200	.02 mm						
									So. River	Cutting from tri-cone rotary rock bit. Rig bouncing due to coarse gravel and cobbles. Cuttings came up frozen, no visible change when thawed in hand.
									So. River	Same, slight color change when thawed
									Local Borrow	Cuttings from tri-cone rotary rock bit. Rig bouncing very little. Cuttings came up frozen. After thawing, color is darker and is spongy due to organic matter. Chips of light wood appear to be from a plank.
									Local Borrow	Same, less spongy and no wood chips.
									Local Borrow and/or Native Soil	Cuttings from coring bit. No core recovered. Rig bouncing badly at times, then running smoothly due scattered cobbles or boulders. Impossible to determine where fill ends and native soil begins.

Metcalf & Eddy o

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1953 Per

Hole No. TR#1
Location: RUNWAY: STA. 25+00, ℄
Lab. Sample No. 29-S

Sample No @ Depth	Graphic Log		Description & Classification	Density lbs/cu ft	M C %	Comp %	Max Size	1½"	¾"	
E		S or SM	See sample "E" sheet 1.		3.0					
15.0										
F		SM OR GM	Cuttings are greyish brown, mostly fine sand to silt - max. size = 3/8" No visible ice. Gravelly silty sandor sandy silty gravel. Also a trace of organic matter.		6.9					
18.5'										
G		G OR GM	Cuttings are brownish grey, well graded from coarse sand to silt - max. size = 3/8". A few chips of ice. Slightly silty sandy gravel with cobbles and boulders. Also a trace of organic matter.		8.9					
21.3'										
H		SW-SM 11	Brownish grey, well graded, silty gravelly sand. Ice lenses of clear, colorless and hard ice, irregularly oriented, and massive ice with soil particles in suspension. Ice = 40% ± by volume.		29.7		2"	96	85	8(
22.9'	Completed									

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1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs/cu ft	M C %	Comp %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No 10	No 20	No 40	No 100	No 200	.02 mm	LL	PL
		3.0														
ine Sand Gravelly ace of		6.9														
from w chips bbles and		8.9														
sand. , irregularly icles in		29.7		2"	96	85	80	78	62	45	32	16	11	6		

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Date DH 3-23-53
Submitted by S.B.

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ST DATA									Source of Material	Remarks
FINER										
[illegible]	No.40	No.100	No.200	.02 mm	LL	P	[illegible]	Specific Gravity		
									Local Borrow and/or Native Soil	See Sample "E" sheet 1.
									Native Soil	Cuttings from coring bit. No core recovered. Core barrel and bit were coated with wet silty sand. Rig bouncing slightly.
									Native Soil	Cuttings from coring bit. Only recovery was 2-3" stones. Rig bouncing badly to 21.0'. Hit something hard at 21.0', and rig stopped bouncing, probably on a boulder.
	32	16	11	6					Native Soil	Core badly broken and partly thawed-25% recovery. Impossible to run frozen density. Sample may not be representative Hole completed at 22.9 ft.

PLATE A2

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1953 P

Hole No. TR # 2
Location Runway · Sta. 25+13 : ℄
Lab. Sample No. 30 - S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs/cu.ft	M.C %	Comp %	Max Size	1½	¾
0.5'		Bituminous Concrete						
0.7'		Penetration Macadam						
A 1.0'	G	Cuttings are mostly light brownish gray with some black chips of asphalt, mostly fine gravel and coarse sand-max. size=½". No visible ice. Crushed, minus 2½", gravel base course.		14				
B	G OR S	Cuttings are brownish gray, mostly med. to fine sand with some coarse chips-max. size = ½" No visible ice. Sandy gravel or gravelly sand with cobbles.		4.1				
4.0'								
C		Same as "B", color is gray.		1.9				
7.0'								
D	GM OR SM	Cuttings are light brownish gray, mostly med. sand to silt with some coarse chips-max. size=½". No visible ice. Silty sandy gravel or silty gravelly sand with cobbles.		6.1				
10.0'								
E		Same as "D" with a trace of organic matter.		3.2				
12.0'								
F		Same as E		2.6				
14.0'	Continued							

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1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs./cu.ft.	M.C %	Comp %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm	LL	PL	PI
		1.4															
		4.1															
		1.9															
		6.1															
		3.2															
		2.6															

B

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gation

Date: DH 3-29-83

Submitted by: S.B.

ST DATA										
FINER									Source of Material	Remarks
0	No.40	No.100	No.200	.02 mm	LL	PL	PI	Specific Gravity		
									So. River	Cuttings from tri-cone rotary rock bit. Penetration macadam mixed with gravel, can not tell exact depth of penetration.
									So. River	Cuttings from tri-cone rotary rock bit. Rig bouncing due to coarse gravel and Cobbles. Cuttings come up frozen. Sample thawed in hand becomes darker and damp
									So. River and/or No. River	Same - Sample thawed in hand has no visible change. Very hard to tell source of material from cuttings.
									Local Borrow	Same - sample thawed in hand becomes darker and damp.
									Local Borrow	Same - no visible change when thawed, but feels slightly spongy.
									Local Borrow and/or Native Soil	Same as above - Impossible to tell from cuttings where fill ends and native soil begins.

PLATE A3

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1953 Perm

Hole No. T.R. #2
Location Runway: Sta 25+15 · ℄
Lab. Sample No. 30-S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu.ft	M.C. %	Comp. %	Max. Size	1 1/2"	3/4"	3/8"
F (to 15.0')	GM or SM	Cuttings are light brownish gray, mostly med. sand to silt with some coarse chips and a trace of organic matter. Silty gravelly sand or silty sandy gravel with cobbles and organic matter. No visible ice.		2.6					
G (to 17.2')	GP-GM IX	Grayish brown, poorly graded, slightly silty sand with scattered cobbles. A few barely visible ice crystals.		2.8		2"	63	54	43
H (to 18.5')	GM IX-IC	Brownish gray, silty, sandy gravel. Many small ice crystals, minus 1/16", and a coating of clear ice on the underside of all the plus 1/2" material. Ice = 5% ± by volume.	141.3	7.1		2"	88	74	67
J (to 22.5')	GM	Same as "H", but much ice. Impossible to describe ice conditions, because sample is completely thawed.	79.8	37.9		2"	93	73	64
	Completed								

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1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs./cu.ft	M.C. %	Comp. %	Max Size	PERCENT FINER 1½"	3/4"	3/8"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	PL
y med. sand e of organic gravel with e.		2.6														
silty sand. visible ice		2.8		2"	63	54	49	44	37	27	20	13	9	5		
y small clear ice rial. Ice =	141.3	7.1		2"	88	74	67	61	54	48	42	30	23	12	13	11
to describe ely thawed.	79.8	37.9		2"	93	73	64	57	50	43	38	27°	20	9	16	13

B

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Date DH 3-29-53
Submitted by: S. B.

tigation

EST DATA									Source of Material	Remarks
FINER					LL	PL	PI	Specific Gravity		
.20	No.40	No.100	No.200	.02 mm.						
									Local Borrow and/or Native Soil.	See Sample "F" sheet 1.
7	20	13	9	5					Local Borrow and/or Native Soil.	Core badly crumbled - 20% recovery. The sample consisted of loose gravel and 1½" piece of undisturbed core. Tests are unreliable, because sample may not be representative.
8	42	30	23	12	13	11	2	2.81	Local Borrow and/or Native Soil.	Core broken, but good - 100% recovery.
5	38	27°	20	9	16	13	3		Native Soil	Core completely crumbled and thawed - 25% recovery. Sample came out of core barrel in form of mud. Tests on this sample are unreliable. Hole completed at 22.3'.

PLATE A4

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1953 Perm

Hole No. TR#3
Location Runway: Sta. 34+00 - ℄
Lab. Sample No. 31-S

Sample No. @ Depth	Graphic Log	Description & Classification	Density lbs./cu ft	M.C. %	Comp. %	Max. Size	1½"	¾"	⅜"
0.5'		Bituminous Concrete.							
0.7'		Penetration Macadam.							
A (1.0')	GW NP	Brownish grey, minus 2½", crushed gravel base course. No visible ice - poorly bonded.	156.9	2.3	100+	2"	87	64	45
A (1.3')	SW NP	Light brownish grey, very clean, well graded, gravelly sand. Sand grains all rounded. No visible ice - poorly bonded.							
B (2.0')	SP IX-NP	Dark brownish gray, poorly graded, gravelly sand with a trace of organic matter. A few small ice crystals - poorly bonded.	151.0	4.6	100+	2"	95	87	81
C (2.9')	GP IX	Dark brownish gray, poorly graded, sandy gravel with a trace of organic matter. A few barely visible ice crystals - well bonded.	150.6	3.2	100+	2"	90	86	59
D (3.5')	SP-SM IX-NP	Patches of dark brownish gray, sandy gravel and patches of dark brownish gray, poorly graded, silty gravelly sand. A few barely visible ice crystals. Gravel is quite friable, sand is well bonded.	152.3	4.3	100+	2"	95	87	77
E (4.6')	SP-SM ROCK NP	Dark brownish gray, poorly graded, slightly silty, gravelly diorite sand, and diorite quarry rock. Quarry rock = 25% ± by volume. No visible ice - friable.		3.7		2"	91	76	66
F (5.3')	GP ROCK IX-NP	Same as "E" - quarry rock = 50% ± by volume. Ice crystals, up to ⅛", adhering to rock - friable. Poorly graded, sandy gravel.	151.0	6.2	100+	2"	85	61	50
G (6.0')	SP ROCK IX	Same as E - quarry rock = 80% ± by volume. Ice crystals adhering to rock and also in sand. Rock to rock contact with voids up to 3". Poorly graded, gravelly sand.	147.8	6.5	99.2	2"	88	72	64
6.6'		30% ± diorite sand, 30% ± diorite quarry rock, 40% ± local borrow. Local borrow is silty sandy gravel. Many ice crystals and some ice lenses in local borrow. Ice = 10% ±.							
H (7.0')	SM-SC IX-IC	Grayish brown, silty, clayey, gravelly sand with cobbles. Many ice crystals, and 1/16" thick, irregularly oriented ice lenses. Ice = 10% ± by volume. Also a trace of organic matter.	124.6	12.0		1½"	100	84	74
J (7.7')	SP-SM IX	Same as "H", but less silt and no ice lenses.	141.0	6.4		2"	90	78	65
K (8.5')		Same as "J".	149.5	4.4		1½"	100	80	69
L (9.0')	SM IX-IC	Same as "M" - coating of ice around gravel, no ice lenses.	138.3	6.3		1½"	98	88	80
M (10.0')	SM IX-II	Grayish brown, silty gravelly sand with a few cobbles and a small amount of organic matter. Many ice crystals and a few thin ice lenses. The ice is cloudy to dirty and quite soft. Ice = 5% ± by volume.	135.9	7.6		2"	93	85	75
N (10.5')		Same as "M" - ice = 10% ± by volume, no organic matter.	132.2	8.8		2"	96	85	76
P (11.3')		Same as "M" - ice = 20% ± by volume, no organic matter, color is brownish gray.	117.6	15.7		2"	94	85	76
R (13.0')	GM or SM	Cuttings are brownish gray, mostly med. sand to silt with some coarse chips - max. size = ½". Cuttings come up in a thawed state and very wet. About 40% of the cuttings appear to be diorite. Probably badly fractured diorite and till with ice. Impossible to describe ice condition.		15.4					
T (14.0')		Same as "R" - more diorite cuttings		14.7					

Continued

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1953 Permafrost Investigation

LABORATORY TEST DATA

Density lb/cu ft	M.C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	PL	PI	Sp. Gr.
6.9	2.3	100+	2"	87	64	45	35	27	19	12	5	3					2.
1.0	4.6	100+	2"	95	87	81	74	61	43	28	9	4					2.
0.6	3.2	100+	2"	90	86	59	50	43	33	23	8	5					2.
2.3	4.3	100+	2"	95	87	77	71	60	44	30	12	8	4				
	3.7		2"	91	76	66	58	50	38	27	16	5					
1.0	6.2	100+	2"	85	61	50	43	38	29	20	9	5	2				
7.8	6.5	99.2	2"	88	72	64	58	49	36	23	9	4					
4.6	12.0		1½"	100	84	74	66	59	51	44	30	21	13	19	15	4	
1.0	6.4		2"	90	78	65	56	50	41	31	18	11	6				
9.5	4.4		1½"	100	80	69	62	56	45	34	18	11	7				
8.3	6.3		1½"	98	88	80	72	66	57	48	33	20	11	15	13	2	2.
5.9	7.6		2"	93	85	75	67	61	54	48	35	27	14	16	14	2	
2.2	8.8		2"	96	85	76	67	61	56	50	37	30	19	17	14	3	
7.6	15.7		2"	94	85	76	68	61	54	45	29	21	9	14	non plastic		
	15.4																
	14.7																

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Date: DH 3-29-53 : TP 4-7-53 to 4-10-53
Submitted by: S. B.

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EST DATA

FINER /20	No.40	No.100	No.200	.02 mm.	LL	PL	PI	Specific Gravity	Source of Material	Remarks
										Samples A thru P, 0.7'-11.3', are all frozen chunks from test pit.
[illegible]	12	5	3					2.78	So. River	Sample A includes both the base course and So. River sand. Impossible to separate and get a good frozen chunk - too friable.
[illegible]	28	9	4					2.79	No. Mountain	Diorite sand with badly decomposed diorite chunks - max. size = 4".
[illegible]	23	8	5					2.79	No. River and No. Mountain	A mixture of No. River gravel and No. Mountain sand. No. River material = 75%±.
[illegible]	30	12	8	4					No. River and No. Mountain	The two materials are not mixed. No. River gravel = 50%±. Sand is No. Mountain diorite.
[illegible]	27	10	5						No. Mountain and "F" Quarry	Max. size of quarry rock = 10". Too friable to run frozen density.
[illegible]	20	9	5	2					No. Mountain and "F" Quarry	Max. size of quarry rock = 3'
[illegible]	23	9	4						No. Mountain and "F" Quarry	Same.
	44	30	21	13	19	15	4		Local Borrow	No sample taken in this zone. Material from 3 sources all inter-fingered - very hard to get a representative sample. Max. size cobble = 8"
	31	18	11	6					Local Borrow	Max. size = 1.5'
[illegible]	34	18	11	7					Local Borrow	Max. size = 2.0' - No sharp line between local borrow and native soil. The zone from 8.0' to 8.5' is a mixture of borrow and native soil.
[illegible]	48	33	20	11	15	13	2	2.81	Native Soil	Max. size = 8"
	48	35	27	14	16	14	2		Native Soil	Max. size = 8"
	50	37	30	19	17	14	3		Native Soil	Max. size = 2.0'
	45	29	21	9	14	non plastic			Native Soil	Max. size = 2.0'
									Native Soil	Cuttings from tri-cone rotary rock bit. M.C. unreliable - probably low.
[illegible]									Native Soil	Same

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1953 Perm

Hole No. TR #3
Location Runway: Sta 34+00 - ℄
Lab. Sample No. 31-S

Sample No & Depth	Graphic Log		Description & Classification	Density lbs./cu.ft	M.C. %	Comp %	Max. Size	1½"	¾"	⅜
T (15.0')		GM or SM	See sample "T" - sheet 1		14.7					
U (17.0')		ROCK and GM or SM	Cuttings are mostly gray diorite, graded from med. sand to silt with a few coarse chips - max. size = ⅝". Cuttings came up thawed and very wet. Probably badly fractured diorite with much ice and a small amount of till. No way of describing ice condition.		12.7					
	Completed									

A

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1953 Permafrost Investigation

LABORATORY TEST DATA

Density lbs./cu.ft	M.C. %	Comp %	Max. Size	PERCENT FINER										L.L.	P.L.	P
				1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm			
	14.7															
	12.7															

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Date DH 3-29-53; TP 4-7-53 to 4-10-53
Submitted by: S.B.

ation

T DATA									Source of Material	Remarks
NER					LL	PL	P	Specific Gravity		
No.40	No.100	No.200	.02 mm							
									Native Soil	See sample "T" - sheet 1.
									Native Soil and/or Bed Rock	Cuttings from tri-cone rotary rock bit. M.C. unreliable - probably low. This appears to be the upper zone of diorite bed rock. Hole completed at 17.0 ft.

Hole No. TR#4
Location Runway: Sta. 34+13 - ℄
Lab. Sample No. 32 - 5

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu ft.	M.C. %	Comp %	Max Size	LAB 1½"	¾"
0.5'		Bituminous Concrete						
0.8'		Penetration Macadam						
A (1.2')	GW NP	Brownish grey, minus 2½", crushed gravel base course. No visible ice - poorly bonded.						
A (1.4')	SW NP	Light brownish grey, very clean, well graded, gravelly sand. Sand grains all rounded. No visible ice - poorly bonded.	156.9	2.8	100+	2"	87	64
B (2.3')	SP IX-NP	Dark brownish grey, poorly graded, gravelly sand with a trace of organic matter. A few small ice crystals - poorly bonded.	151.0	4.6	100+	2"	95	87
C (2.9')	GP IX	Dark brownish grey, poorly graded sandy gravel with a trace of organic matter. A few barely visible ice crystals - well bonded.	150.6	3.2	100+	2"	90	86
D (3.4')	SP-SM IX-NP	Patches of dark brownish grey sandy gravel and patches of dark brownish grey, poorly graded, silty gravelly sand. A few barely visible ice crystals. Gravel is quite friable, sand is well bonded.	152.3	4.3	100+	2"	95	87
E (4.4')	SP-SM ROCK NP	Dark brownish grey, poorly graded, slightly silty, gravelly, diorite sand; mixed with diorite quarry rock. Rock = 25% ± by volume. No visible ice - friable.		3.7		2"	91	76
F (5.3')	GP ROCK IX-NP	Same as "E" - quarry rock = 50% ± by volume. Ice crystals, up to ⅛", adhering to rock - poorly bonded. Poorly graded, sandy gravel.	151.0	6.2	100+	2"	85	61
G (6.0')	SP ROCK IX	Same as "E" - quarry rock = 75% ± by volume. Ice crystals adhering to rock and also in sand. Rock to rock contact with voids up to 3". Gravelly sand.	147.8	6.5	99.2	2"	88	72
(6.4')		30% ± diorite sand, 30% ± quarry rock, 40% ± local borrow. Local borrow is silty sandy gravel. Many ice crystals and some thin ice lenses in local borrow. Ice = 10% ±.						
H (7.0')	SM-SC IX-IC	Grayish brown, silty, clayey gravelly sand with cobbles and a trace of organic matter. Many small ice crystals and a few ⅛", irregularly oriented, ice lenses. Ice = 10% ± by volume.	124.6	12.0		1½"	100	84
J (7.7')	SP-SM IX	Same as "H" - less silt and no ice lenses. Ice = less than 5% by volume.	141.0	6.4		2"	90	78
K (8.6')	SP-SM IX	Same as "J".	149.5	4.4		1½"	100	80
L (9.0')	SM IX-IC	Grayish brown, silty, gravelly sand with cobbles and a trace of organic matter. Many ice crystals and all gravel coated with ice.	138.3	6.3		1½"	98	88
M (10.0')	SM IX-II	Grayish brown, silty, gravelly sand with cobbles and a small amount of organic matter. Many ice crystals and a few thin, irregularly oriented, ice lenses. Ice is cloudy to dirty and quite soft, = 5% ± by volume.	135.9	7.6		2"	93	85
N (10.5')	SM IX-II	Same as "M" - ice = 10% ± by volume, non-organic.	132.2	8.8		2"	96	85
P (11.5')	SM IX-II	Same as "M" - ice = 20% ± by volume, non-organic.	117.6	15.7		2"	94	85
Q (13.0')	GM or SM	Cuttings are light brownish gray, mostly med. sand to silt with some coarse chips - max. size = ⅜". A few chips of ice, but most of the cuttings are thawed and very wet. About 50% of the cuttings appear to be diorite. Probably badly fractured diorite and till with much ice. Impossible to describe ice condition.		17.6				
R (14.0')	GM or SM	Same as "R" - more diorite.		18.0				

Continued

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LABORATORY TEST DATA

ensity /cu ft.	M.C. %	Comp %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	PL	PI	Spe Gra
5.9	2.9	100+	2"	87	64	45	35	27	19	12	5	3					2.7
.0	4.6	100+	2"	95	87	81	74	61	43	28	9	4					2.7.
0.6	3.2	100+	2"	90	86	59	50	43	33	23	8	5					2.75
2.3	4.3	100+	2"	95	87	77	71	60	44	30	12	8	4				
	3.7		2"	91	76	66	58	50	38	27	10	5					
.0	6.2	100+	2"	85	61	50	43	38	29	20	9	5	2				
7.8	6.5	99.2	2"	88	72	64	58	49	36	23	9	4					
.6	12.0		1½"	100	84	74	66	59	51	44	30	21	13	19	15	4	
.0	6.4		2"	90	78	65	56	50	41	31	18	11	6				
.5	4.4		1½"	100	80	69	62	56	45	34	18	11	7				
.3	6.5		1½"	98	88	80	72	66	57	48	33	20	11	15	13	2	2.8
.9	7.6		2"	93	85	75	67	61	54	48	35	27	14	16	14	2	
.2	8.8		2"	96	85	76	67	61	56	50	37	30	19	17	14	3	
.6	15.7		2"	94	85	76	68	61	54	45	29	2	9	14	non-plastic		
	17.6																
	18.0																

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Date OH 3-29-53 : TP 4-7-53 to 4-10-53
Submitted by S.B.

EST DATA

FINER 20	No. 40	No. 100	No 200	.02 mm.	LL	PL	PI	Specific Gravity	Source of Material	Remarks
										Samples A thru P, 0.8'-11.3', are all frozen chunks from test pit.
	12	5	3					2.78	So. River	Sample A includes both the base course and So. River sand. Impossible to separate and get a good frozen chunk-too friable.
	28	9	4					2.79	No. Mountain	Diorite sand with badly decomposed diorite chunks - max. size = 4".
	23	9	5					2.79	No. River and No. Mountain	A mixture of No. River gravel and No. Mountain diorite sand. No River gravel = 75% ±.
	30	12	8	4					Same	Same, but the two materials not intermixed.
	27	10	5						No. Mountain and "F" Quarry	Max. size of quarry rock = 10". Too friable to run frozen density.
	20	9	5	2					Same	Max. size of quarry rock = 3'.
	23	9	4						Same	Same.
										No sample taken in this zone. Material from 3 sources, all interfingered - Very hard to get a represntative sample.
	44	30	21	13	19	15	4		Local Borrow	Max. size cobble = 8"
	31	18	11	6					Local Borrow	Max. size = 1.5'.
	34	18	11	7					Local Borrow	Max. size = 2.0'. No sharp break between local borrow and native soil. The zone from 8.0' to 8.5' is a mixture of borrow and native soil.
	48	33	20	11	15	13	2	2.81	Native Soil	Max. size = 8"
	48	35	27	14	16	14	2		Native Soil	Max. size = 2.0'
	50	37	30	19	17	14	3		Native Soil	Max. size = 2.0'
	45	29	21	9	14	non-plastic			Native Soil	Max. size = 2.0'
									Native Soil	Cuttings from tri-cone rotary rock bit. M.C. unreliable - probably low.
									Native Soil	Same

Metcalf & Eddy [cut off]

P[cut off]

1953 Pe[cut off]

Hole No. TR #4
Location Runway: Sta. 34+13 - ℄
Lab. Sample No. 32 - S

Sample No. & Depth	Graphic Log		Description & Classification	LAB[cut off]						
				Density lbs./cu ft	M. C %	Comp. %	Max. Size	1½"	¾"	
R		GM or SM	See sample "R" sheet 1		18.0					
15.0'										
T		ROCK and GM or SM	Cuttings are mostly gray diorite, graded from med. sand to silt with a few coarse chips - max. size = 3/8". A few chips of ice, but most of the cuttings are thawed and very wet. Badly fractured diorite with a small amount of till and much ice. Impossible to describe ice condition.		15.5					
17	completed									

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1953 Permafrost Investigation

LABORATORY TEST DATA

Density lbs./cu ft	M. C. %	Comp. %	Max. Size	PERCENT FINER										LL	PL	PI
				1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.			
	18.0															
	15.5															

B

kins & Associates

tigation

Date DH 3-29-53 : TP 4-7-53 to 4-10-53
Submitted by S.B.

EST DATA

% FINER					LL	PL	PI	Specific Gravity	Source of Material	Remarks
No.20	No.40	No.100	No.200	.02 mm.						
									Native Soil	See sample "R" sheet 1
									Native Soil and/or Bed Rock	Cuttings from tri-cone rotary rock bit. M.C. unreliable - probably low. This appears to be the upper zone of diorite bed rock. Hole completed at 17.0 ft.

Metcalf & Eddy a

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1953 Per

Hole No. *TR #5*
Location *Runway; sta. 58+0 - 50' Lt. ℄*
Lab. Sample No. *33-S*

Sample No & Depth	Graphic Log	Description & Classification	LABO						
			Density lbs./cu ft.	M. C. %	Comp %	Max Size	1½"	¾"	
0.8'		*Bituminous Concrete*							
1.2'		*Penetration Macadam*							
A 1.7'	GP NP	*Light brownish gray, crushed, minus 2½", poorly graded, sandy gravel. No visible ice - friable*	157.9	3.0	100+	2"	76	47	3
B 2.2'	GP-GM IC	*Grayish brown, poorly graded, slightly silty, sandy gravel. Some of the gravel coated with a thin film of ice.*	144.8	4.2	99.3	2"	86	64	5
C 3.5'		*Same as "B" with many cobbles.*	149.3	3.2	100+	2"	87	69	5
D 4.5'	SP IX-IC	*Grayish brown, poorly graded, gravelly sand with many cobbles and boulders. Scattered small ice crystals, -1/16", and gravel coated with ice.*	143.4	4.9	100+	2"	98	85	70
E 5.3'	GP-GM IX-IC	*Grayish brown, poorly graded, slightly silty, sandy gravel with cobbles. Many small ice crystals, and a few thin ice lenses. All gravel coated with ice.*	139.9	6.7	92.8	2"	92	79	6
F 6.3'	GM or SM	*Cuttings are grayish brown, mostly fine sand to silt, max. size = ½". Many chips of clear ice. Silty sandy gravel or silty gravelly sand. Ice = +20% by volume.*		24.3					
G 7.0'	SM II	*Grayish brown, silty, gravelly, sand. Ice lenses up to 1" thick, irregularly oriented thru entire core. Ice is clear, colorless, and hard = 50% ± by volume.*	47.5	86.9		2"	90	73	6
H 8.0'	ICE / ICE SM	*85% ± ice by volume. Ice is clear, colorless, and hard. Soil particles suspended in ice, and a few small pockets of soil. Grayish brown, silty sand.*		303.5		#4 sieve	100	100	10
J 9.0'	GP-GM II	*Brownish gray, poorly graded, silty sandy gravel. Ice has no definite shape or orientation. Appears to be a mixture of soil and ice. Ice is clear, colorless, and hard, = 60% ± by volume. No gravel between 8.5' and 9.0'.*	50.6	81.6		2"	57	57	5
K 11.8'	ROCK (DIORITE)	*Gray, badly fractured, diorite rock. Surfaces along the fracture planes are weathered and color is grayish brown. Fracture planes were wet, but no visible ice.*		1.6					
L L 16.5'	Completed	*Cuttings are gray diorite, mostly med. to fine sand - max. size = #4 sieve. Diorite bed rock*		1.1					

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LABORATORY TEST DATA

	Density, lbs./cu ft.	M.C. %	Comp %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	P	P
	157.9	3.0	100+	2"	76	47	34	26	19	13	9	5	3				
	144.8	4.2	99.2	2"	86	64	52	44	38	32	24	12	6	3.4			
	149.5	3.2	100+	2"	87	69	57	47	40	33	25	13	7	2.1			
	143.4	4.9	100+	2"	98	85	70	58	47	34	22	9	4				
d d	139.9	6.7	92.8	2"	92	79	62	51	42	31	20	12	6	3.3			
Site, avel		24.3															
up e	47.5	86.9		2"	90	73	62	57	51	44	36	21	14	8			
ll		303.5		#4 sieve	100	100	100	100	94	84	75	60	45	20		non-plastic	
el. to and 3.0'.	50.6	81.6		2"	57	57	51	46	41	36	29	18	12	7	14	non-plasti	
or		1.6															
ne		1.1															

B

Associates

Sheet 1 of 1

Date: DH 3-29-53 : TP 4-12-53 to 4-14-53
Submitted by: S.B.

DATA									Source of Material	Remarks
%	No.100	No.200	.02 mm.	LL	P	P	Specific Gravity			
	5	3						So. River	Frozen chunk from test pit.
	12	6	3.4				2.68	"H" Terrace	Same, max. size = 4"
	13	7	2.1					"H" Terrace	Same - Cobbles, max. size = 12"
	9	4						"H" Terrace	Same - max. size = 2'.
	12	6	3.3				2.73	"H" Terrace	Same - max. size = 6"
								"H" Terrace mixed with Native Soil	Cuttings from tri-cone rotary rock bit. Rig bouncing slightly - drilling fast.
	21	14	8						Core good - 75% recovery
	60	45	20		non-plastic			Native soil	Core broken - 50% recovery
	18	12	7	14	non-plastic			Native soil.	Core broken - 40% recovery. Stony to 8.5', soft to 9.0', hit rock at 9.0'.
								Bed Rock	Core broken and thawed - 75% recovery. Core is 2' long and broke into about 10 pieces when removed from core barrel.
								Bed Rock	Cuttings from tri-cone rotary rock bit. Drilled very hard - rig ran very smoothly. Hole completed at 16.5'

Metcalf & Eddy

1953 R

Hole No. *TR #6*
Location *Runway: Sta. 58+13 - 50' Lt. ℄*
Lab. Sample No. *34-S*

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft	M. C. %	Comp. %	Max Size	1½	¾
		LA						
0.7'		Bituminous Concrete						
1.1'		Penetration Macadam						
A 1.7'	GP NP	Light brownish gray, crushed, minus 2½", poorly graded, sandy gravel. No visible ice - friable.	157.9	3.0	100+	2"	76	47
B 2.2'	GP-GM IC	Grayish brown, poorly graded, slightly silty, sandy gravel. Some of the gravel coated with a thin film of ice.	144.8	4.2	99.3	2"	86	64
C 3.5'	GP-GM IC	Same as "B" with many cobbles.	149.3	3.2	100+	2"	87	69
D 4.5'	SP IX-IC	Grayish brown, poorly graded, gravelly sand with many cobbles and boulders. Scattered small ice crystals. -⅜", and gravel coated with ice.	143.4	4.9	100+	2"	98	85
E 5.6'	GP-GM IX-IC	Grayish brown, poorly graded, slightly silty, sandy gravel with cobbles. Many small ice crystals and a few thin ice lenses. All gravel coated with ice.	139.9	6.7	92.8	2"	92	79
F 6.0'	GM or SM	Cuttings brownish gray, mostly med. sand to silt - max size ±⅛". Many chips of pure ice. Silty sandy gravel or silty gravelly sand. Ice ± +15%.		10.8				
G 7.2'	G II	Cuttings are gray diorite, mostly fine sand - max. size ± #10 sieve. Many chips of clear ice. Ice ± +20% by volume. Badly fractured diorite rock with ice in all the fractures.		17.9				
7.5'	ICE ICE	No sample recovered. Ice with possibly some soil suspended in the ice.						
H 8.2'		Solid diorite rock						
J 10.0'		Cuttings are gray diorite, mostly med. to fine sand - max. size ± #10 sieve. Diorite rock with a few fractures. Ice in the fracture planes.		4.0				
K 12.0'	ROCK (DIORITE)	Same as "J" - Solid bed rock - no ice.		1.2				
L 16.5'	Completed	Same as "K"		0.7				

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1953 Permafrost Investigation

	LABORATORY TEST DATA														
	Density lbs./cu ft	M.C. %	Comp. %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL
… poorly graded,	157.9	3.0	100+	2"	76	47	34	26	19	13	9	5	3		
…ilty, sandy … film of ice.	144.8	4.2	99.3	2"	86	64	52	44	38	32	24	12	6	3.4	
	149.3	3.2	100+	2"	87	69	57	47	40	33	25	13	7	2.1	
… sand with …ll ice crystals,	143.4	4.9	100+	2"	92	85	70	58	47	34	22	9	4		
…y, sandy …stals and a …ith ice.	139.9	6.7	92.8	2"	92	79	62	51	42	31	20	12	6	3.3	
…d to silt- …andy gravel or		10.8													
…nd - max. size …% by volume. … fractures.		17.2													
…ly same soil															
…d. to fine … with a few		4.0													
		1.2													
		0.7													

B

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Sheet 1 of 1

Date: DH 3-29-53 : TP 4-12-53 to 4-14-53

Submitted by: S.B.

...gation

...ST DATA										Source of Material	Remarks
...FINER											
...0	No. 40	No. 100	No. 200	.02 mm.	L.L.	P.L.	P.I.	Specific Gravity			
	9	5	3							So. River	Frozen chunk from test pit.
	24	12	6	3.4				2.60		"H" Terrace	Same, max. size: 4"
	25	13	7	2.1						"H" Terrace	Same - cobbles, max. size = 12".
	22	9	4							"H" Terrace	Same - max. size = 2'.
	20	12	6	3.3				2.73		"H" Terrace	Same - max. size = 6"
										"H" Terrace mixed with Native Soil	Cuttings from tri-cone rotary rock bit. Ice chips partly melted, M.C. unreliable. Rig bouncing due to coarse gravel and/or cobbles.
										Native Soil	Cuttings from coring bit. No core recovered. Rig bouncing badly - drilled hard.
										Native Soil - Bed Rock	Cored from 7.2' to 8.2'. Very soft from 7.2' to 7.5', very hard from 7.5' to 8.2'. Core recovered is solid diorite - 10" long. Bed rock starts at 8.2'. Material overlying bed rock is mostly ice, +75%, which was melted while coring thru diorite.
										Bed Rock	Cuttings from tri-cone rotary rock bit. Drills very hard. Rig bouncing slightly due to fractures in the rock.
										Bed Rock	Same - Rig running very smoothly
										Bed Rock	Same as above. Hole completed at 16.5'.

Metcalf & Eddy

F

1953 P

Hole No. *TR #7*
Location *Runway: Sta. 63+00, 50' Lt. ℄*
Lab. Sample No. *36-S*

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	LAB 1½"	¾"
0.5'		Bituminous Concrete						
0.6'		Penetration Macadam						
A (1.2')	GP NP	Light brownish gray, minus 2½", crushed gravel base course. No visible ice, a trace of frost - poorly bonded.	155.7	2.7	100+	2"	87	68
B (2.2')	SP-SM IC-IX	Grayish brown, slightly silty, poorly graded, gravelly sand with a trace of organic matter. A few barely visible ice crystals and some of the gravel coated with ice.	138.5	6.1	96.3	2"	96	80
C (2.8')	SP IC	Gray, poorly graded, gravelly sand. Some of the gravel coated with a thin film of ice. Also a few cobbles.	142.3	3.8	100+	2"	87	76
D (5.7')	ROCK and GW NP	Diorite quarry rock, choked with brownish gray diorite sand. Quarry rock = 80% ± by volume. Voids up to 6" are common due to bridging of large boulders. No visible ice - friable.		4.4		2"	87	63
E (6.0')	GP-GM II	Grayish brown, poorly graded, silty sandy gravel. Many irregularly oriented ice lenses and masses to ¼". Ice = 20% ± by vol.	117.2	16.0		2"	78	65
F (7.0')	GM II	Grayish brown, silty, sandy gravel with cobbles. Many irregularly oriented ice lenses up to ½" and massive ice around the cobbles. Ice is hard, clear, and colorless, = 30% ± by volume.	74.9	42.8		2"	91	76
G (8.0')	SM II	Grayish brown, silty gravelly sand with scattered cobbles. Many irregularly oriented ice lenses up to ¼" thick and some massive ice, mostly around the gravel. Ice is clear, colorless and hard, = 40% ± by volume.	68.0	50.5		2"	95	81
H (9.0')	SM II	Same as "G", with gray mottling. Ice = 30% ± by volume.	83.4	35.2		2"	97	93
J (10.0')	GM IS-II	Brown silty sandy gravel with scattered cobbles. Many thin ice lenses, up to ⅛". Lenses are parallel and ¼" ± apart, gives soil laminated appearance. Also some massive ice, mostly around stones. Ice = 30% ± by volume	83.6	34.9		2"	77	69
K (11.0')	GM IS-II	Same as "J" - occasional larger lenses to ½".	88.5	31.4		2"	78	70
L (12.0')	SM-SC IS-II	Grayish brown, silty, clayey, gravelly sand with scattered cobbles. Many very thin ice lenses up to 1/16" thick. Lenses are parallel and ⅛" to ¼" apart, gives soil laminated appearance. Also some massive ice, mostly around stones. Ice is clear, colorless, and hard, = 50% ± by volume.	45.7	91.8		1½"	100	86
M (13.8')	SM-SC IS-II	Same as "L".	52.0	76.1		1½"	100	87
N (14.0')	ICE; ICE GP-GM	Ice = 90% ± by volume. Ice is stratified, layers of clear colorless ice with alternating layers of dirty ice containing suspended particles of gravel, sand, and silt.	18.7	272.7		1½"	100	86

Continued

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1953 Permafrost Investigation

	LABORATORY TEST DATA															
	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm	LL	P…
…base …nded.	155.7	2.7	100+	2"	87	68	50	40	30	20	12	5	3			
…elly …y …th ice.	138.5	6.1	96.3	2"	96	80	66	57	51	43	35	17	9	4		
… …bbles.	142.3	3.8	100+	2"	87	76	64	54	44	34	22	7	3			
…ray …ds up …rs.		4.4		2"	87	63	46	36	29	21	13	5	3			
…any …t by vol.	117.2	16.0		2"	78	69	57	44	38	29	22	13	11	8		
… Many …ive …ess, =	74.9	42.8		2"	91	76	68	58	52	44	38	29	24	14	16	13
…ered …¼" …l. Ice	68.0	50.5		2"	95	81	72	62	55	47	41	30	24	15	17	13
…lume.	83.4	35.2		2"	97	93	81	73	65	58	49	34	26	15	17	14
… Many …¼" I …lume	83.6	34.9		2"	77	69	59	51	44	37	29	19	15	10		
	88.5	31.4		2"	78	70	61	56	50	44	37	21	15	9		
…ttered …enses …ed …stones. ….	45.7	31.8		1½"	100	86	77	68	61	51	45	33	26	14	17	12
	52.0	76.1		1½"	100	87	77	68	61	52	46	33	26	15	17	12
…rs …dirty …nd silt.	18.7	272.7		1½"	100	66	56	48	42	35	29	18	11	9		

B

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Date: DM 3-31-53 : TP 4-15-53 to 4-18-53
Submitted by: S. B.

ST DATA								Source of Material	Remarks
INER				LL	PL	PI	Specific Gravity		
No.40	No.100	No.200	.02mm						
									Samples A thru H, 0.5'-3.0, and K, L, 10'-12', are all frozen chunks from test pit.
12	5	3						So. River	
35	17	9	4				2.86		Source of material possibly "H" Terrace or area around "F" Quarry.
22	7	3						No. River	Max. size cobble = 6".
13	5	3						"F" Quarry and No. Mountain	Max. size of quarry rock = 3.0'. Sample consists of diorite sand and gravel size quarry rock. Material too friable to run frozen density.
22	13	11	8					Native Soil	Native soil at 5.7'. Change from fill to native soil is sharp.
38	29	24	14	16	13	3		Native Soil	
41	30	24	15	17	13	4		Native Soil	
49	34	26	15	17	14	3	2.68	Native Soil	
29	19	15	10					Native Soil	Core broken, but good - 75% recovery.
37	21	15	9					Native Soil	
45	33	26	14	17	12	5	2.75	Native Soil	Test pit completed at 12.0'.
46	33	26	15	17	12	5		Native Soil	Core good - 100% recovery
29	18	11	9					Native Soil	Core good - 75% recovery

PLATE A11

Metcalf & Eddy ...

Hole No. TR # 7
Location Runway: Sta 69+00, 50' Lt. ℄
Lab. Sample No. 36-S

P...

1953 Pe...

Depth	Graphic Log		Description & Classification	Density lbs./cu.ft.	M.C %	Comp. %	Max. Size	$1\frac{1}{2}$"	$\frac{3}{4}$"	...
N	ICE	ICE GP-GM	Ice = 90% ± by volume. Ice is stratified, layers of clear, colorless ice with alternating layers of dirty ice containing suspended particles of gravel, sand, and silt.	18.7	272.7		1½"	100	66	...
15.5 P			Same as "N" - ice = 95% ± by volume	10.8	495.2					
16.5 Q 16.8		GW II	Gray, badly fractured, diorite rock. Ice in the form of wedges between all the broken faces. Broken faces are matching, and separated by ice.	115.9	18.6		1½"	100	95	...

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1953 Permafrost Investigation

	LABORATORY TEST DATA														
	Density lbs./cu ft.	M. C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL
...ed, layers of ...yers of dirty ...el, sand, and silt.	18.7	272.7		1½"	100	66	56	48	42	35	29	18	11	9	
	10.8	495.2													
in the form of ...ken faces are	115.9	18.6		1½"	100	95	59	32	13	11	8	4	3		

B

...kins & Associates

...tigation

Date: DH 3-31-53 TP 4-15-53 to 4-18-53
Submitted by. S.B.

...TEST DATA									Source of Material	Remarks
FINER					LL	PL	PI	Specific Gravity		
...o.20	No.40	No.100	No.200	.02 mm.						
...5	29	18	11	9					Native Soil	Core good - 75% recovery
									Native Soil	Core good - 100% recovery. Insufficient material to run laboratory tests.
11	8	4	3						Native Soil and/or Bed Rock	Core good - 100% recovery. Probably the upper zone of diorite bed rock.
										Hole completed at 16.8 ft.

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Hole No. *TR #8*
Location *Runway: Sta. 69+13, 50' Lt. ℄*
Lab. Sample No. *35 - 5*

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs/cu ft	M. C. %	Comp %	Max Size	1½"	¾"	⅜"
0.3'		*Bituminous Concrete*							
0.6'		*Penetration Macadam*							
A (1.0')	GP NP	*Light brownish gray, minus 2½", crushed gravel base course. No visible ice, a trace of frost - poorly bonded.*	155.7	2.7	100+	2"	87	68	50
B (1.9')	SP-SM IC-IX	*Grayish brown, poorly graded, slightly silty, gravelly sand with a trace of organic matter. A few barely visible ice crystals, and some of the gravel coated with ice.*	138.5	6.1	96.3	2"	96	80	66
C (2.5')	SP IC	*Gray, poorly graded, gravelly sand with cobbles. Some of the gravel coated with a very thin film of ice.*	142.3	3.8	100+	2"	87	76	64
D (5.7')	ROCK and GW NP	*Diorite quarry rock, choked with brownish gray diorite sand. Quarry rock = 80% ± by volume. Voids up to 6" are common due to bridging of large cobbles. No visible ice - friable.*		4.4		2"	87	63	46
E (6.0')	GP-GM II	*Grayish brown, poorly graded, silty, sandy gravel. Many irregularly oriented ice lenses and masses to ½". Ice = 20% ± by volume.*	117.2	16.0		2"	78	69	57
F (7.0')	GM II	*Grayish brown, silty, sandy gravel with cobbles. Many irregularly oriented ice lenses up to ½", and massive ice around the cobbles. Ice is hard, clear and colorless = 30% ± by volume.*	74.9	42.8			91	76	68
G (8.0')	SM II	*Grayish brown, silty, gravelly sand with scattered cobbles. Many irregularly oriented ice lenses up to ¼" and some massive ice, mostly around the gravel. Ice is clear, colorless and hard = 40% ± by volume.*	68.0	50.5		2"	95	81	72
H (9.0')		*Same as "G", with gray mottling. Ice = 30% ± by volume.*	83.4	35.2		2"	97	93	81
J (9.8')	SM-SC IS-II	*Brownish gray, silty, clayey, gravelly sand with cobbles. Many small ice lenses up to ⅛". Lenses run in all directions and form an intricately laced pattern. Ice = 40% ± by volume.*	58.3	62.9		¾"	100	100	90
K (10.8')		*Same as "J", but color is grayish brown.*	61.8	58.8		1½"	100	89	80
L (12.0')	GM-GC IS-II	*Grayish brown, silty, clayey, sandy gravel with cobbles. Many thin ice lenses up to 1/16" thick. Lenses are parallel and ⅛" to ¼" apart, gives soil laminated appearance. Also massive ice around the gravel. Much of the ice was melted, and outside of core crumbled.*		34.8		1½"	100	89	77
M (13.0')	SM-SC IS-II	*Light pinkish brown, silty, clayey, gravelly sand with scattered cobbles. Many small ice lenses up to 1/16" thick. Lenses run in all directions and form intricately laced pattern. Ice = 50% ± by volume.*	55.1	69.7		1½"	100	86	79
N (15.0')		*Gravel, sand, silt and possibly clay with much ice. Badly fractured diorite rock at bottom of hole. Sample completely thawed and unreliable.*							

LABO[...]

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1953 Permafrost Investigation

	LABORATORY TEST DATA														
	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL
...ect gravel base ...-poorly bonded.	155.7	2.7	100+	2"	87	68	50	40	30	20	12	5	3		
...tly silty, gravelly ...few barely visible ...ced with ice.	138.5	6.1	96.3	2"	96	80	66	57	51	43	33	17	9	4	
...th cobbles, some ...film of ice.	142.3	3.8	100+	2"	87	76	64	54	44	34	22	7	3		
...wnish grey ...lume. Voids up ...of large cobbles.		4.4		2"	87	63	46	36	29	21	18	5	3		
..., sandy gravel. ...and masses	117.2	16.0		2"	78	69	57	44	38	29	22	13	11	8	
...cobbles. Many ...and massive ice ...and colorless =	74.9	42.8			91	76	68	58	52	44	38	29	24	14	16
...with scattered ...lenses up to ¼". ...the gravel. Ice ...by volume.	68.0	50.5		2"	95	81	72	62	55	47	41	30	24	15	17
...30%± by volume.	83.4	35.2		2"	97	93	81	73	65	58	49	34	26	15	17
...sand with cobbles ...es run in all ...ced pattern.	58.3	62.9		¾"	100	100	90	81	70	62	53	39	31	17	18
...brown.	61.8	58.8		1½"	100	89	80	69	60	52	44	31	24	14	17
...ravel with ..." thick. Lenses ...soil laminated ...the gravel. ...of core crumbled.		34.8		1½"	100	89	77	63	56	49	40	36	32	29	22
...velly sand with ...nses up to 1/16" ...form intricately	55.1	69.7		1½"	100	86	79	69	61	53	46	34	26	15	16
...with much ice. ...of hole. Sample															

B

...kins & Associates

Sheet 1 of 1

...tigation

Date - DH 3-30-53 : TP 4-15 to 18-53

Submitted by: S.B.

TEST DATA									Source of Material	Remarks
FINER					LL	PL	PI	Specific Gravity		
No. 20	No. 40	No. 100	No. 200	.02 mm						
										Samples "A" thru "H", 0.6'-3.0' are all frozen chunks from test pit.
0	12	5	3						So. River	
3	33	17	9	4				2.86		Source of material possibly "N" Terrace or area around "F" Quarry
4	22	7	3						No. River	Max. size cobble = 6".
1	18	5	3						"F" Quarry and No. Mountain	Max. size quarry rock = 3'±. Sample consists of diorite sand and gravel size quarry rock. Material too friable to run frozen density.
9	22	13	11	8					Native Soil	Native soil at 5.7'. Change from fill to native soil is sharp.
4	38	29	24	14	16	13	3		Native Soil	
7	41	30	24	15	17	13	4		Native Soil	NOT REPRODUCIBLE
8	49	34	26	15	17	14	3	2.68	Native Soil	
2	53	39	31	17	18	14	4		Native Soil	Core partially thawed, as witnessed by pebbles on outside with large voids around them. M.C. and density results unreliable. 100% recovery.
2	44	31	24	14	17	13	4		Native Soil	Same
9	40	36	32	29	22	16	6		Native Soil	Core badly thawed. M.C. unreliable. Impossible to run frozen density, because all but center of core crumbled.
3	46	34	26	15	16	11	5		Native Soil	Core good - surfaces slightly thawed - 100% recovery
									Native Soil	Only recovery in this zone was 3" of crumbled core of which about 75% was badly fractured diorite. Probably hit diorite at 15.8'± and material above was mostly ice that thawed. See samples N, P, Q Log TR #7.

PLATE A13

Metcalf & Eddy

F

1953 P

Hole No. TR# 9

Location Runway: Sta. 91+00, ℄

Lab. Sample No. 23-S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	1½"	¾"
0.3'		Bituminous Concrete						
A (0.8')	G	Cuttings are gray and brown with asphalt. Top 3" is asphalt pavement overlying 6" of minus 1½", crushed gravel base course		1.7				
B (2.0')	G or S	Cuttings are grayish brown, clean, well graded, sand - max. size ≈ ½". No visible ice. Sandy gravel or gravelly sand with cobbles.		2.1				
C (3.0')	G or S	Cuttings are grayish brown, mostly med. to fine sand - max. size ≈ ½". About 30% of the cuttings appear to be diorite. No visible ice. Sandy gravel or gravelly sand. Also some diorite quarry rock between 2.5' and 3.0'.		1.2				
D (4.0')	ROCK and S or G	Cuttings are mostly gray diorite, graded from med. to fine sand with a few coarse chips - max. size ≈ ½". Gray diorite quarry rock choked with sand and/or gravel.		2.0				
E (5.0')	ROCK and S or G	Same as "D"		2.7				
F (6.0')	ROCK and S or G	Same as "D"						
G (7.0')	ROCK and S or G	Same as "D"		2.8				
H (8.0')	ROCK and S or G	Same as D		3.5				
J (9.0')	G or GM	Cuttings are brownish gray, well graded from coarse sand to silt - max. size ≈ 3/8". A few chips of diorite. Slightly silty sandy gravel or gravelly sand with cobbles.		3.4				
K (10.0')	S or SM	Cuttings are light brown, graded from coarse sand to silt - max. size ≈ #4 sieve. Slightly silty gravelly sand or sandy gravel with a small amount of organic matter.		4.3				
L (11.0')	S or SM	Same as "K" - color grayish brown.		3.9				
M (12.0')	SM NW	Light brownish gray, silty, gravelly sand with a trace of organic matter. No visible ice - well bonded.	135.9	5.4		1"	100	89.
N (13.0')	G or GM	Cuttings are gray, mostly uniform coarse sand with some fine sand and silt. Slightly silty sandy gravel with cobbles. No visible ice, cuttings are quite wet.		6.6				
P (14.0')	GP II	Brownish gray, poorly graded, sandy gravel 50% ± of the gravel is diorite. Surface of core completely thawed, showing loose stones and large voids. Center of core is 50% ± ice. Many pockets of massive ice up to ¾" and many irregularly oriented ice lenses.		19.1		2"	71	36

Continued

A

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Project Blue Jay

1953 Permafrost Investigation

tion y	LABORATORY TEST DATA													
	Density lbs/cu. ft.	M. C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.
with asphalt. Top g 6" of minus 3/4",		1.7												
clean, well graded. ice. Sandy gravel		2.1												
ostly med. to fine , the cuttings appear dy gravel or gravelly k between 2.5' and 3.5'.		1.2												
e, graded from med. ps-max. size = ½". h sand and/or gravel.		2.0												
		2.7												
		2.8												
		3.5												
well graded from 3/8". A few chips ravel or gravelly		3.4												
ded from coarse e. Slightly silty with a small amount		4.3												
wn.		3.9												
velly sand with a visible ice - well	135.9	5.4		1"	100	89	77	70	64	54	45	31	25	14
form coarse sand lightly silty sandy tings are quite wet.		6.6												
sandy gravel 50% ± core completely thawed, ds. Center of core ive ice up to ¼" and s.		19.1		2"	71	36	26	21	17	13	10	6	4	

B

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igation

Date: DH 3-27-53 : DH 4-6-53
Submitted by: S.B.

EST DATA									Source of Material	Remarks
FINER					LL	PL	PI	Specific Gravity		
20	No.40	No.100	No.200	.02 mm.						
									No. River	Sample "A" includes both the asphalt pavement and base course. Cuttings from tri-cone rotary rock bit.
									"H" Terrace	Cuttings from tri-cone rotary rock. Rig bouncing due to coarse gravel and/or cobbles.
									"H" Terrace and "F" Quarry	Same
									"F" Quarry	Same - drilling very hard
									"F" Quarry	Same - drilling very hard
									"F" Quarry	Same - drilling very hard
									"F" Quarry	Same - drilling very hard
									"F" Quarry	Same - drilling very hard
									Local Borrow	Same
									Local Borrow and/or Native Soil	Cuttings from coring bit. Cored thru this zone, but no core recovered. Hard to tell where fill ends and native soil starts. Estimated depth to native soil is 9.5'.
									Native Soil	Cuttings from coring bit - no core recovered.
	45	31	25	14	14	Non plastic		2.69	Native Soil	Core badly broken - 75% recovery. About 3" of solid core, rest crumbled and mostly gravel. Tests run on 3" solid core. Sample may not be representative.
									Native Soil	Cuttings from core bit - no core recovered.
	10	6	4						Native Soil and Bed Rock	Core badly crumbled and thawed - 75% recovery M.C. unreliable. Hit the upper surface of diorite bed rock at 18.3'±.

PLATE A14

Metcalf & Eddy

1953 P

Hole No. TR# 9
Location Runway: Sta. 11+00, ℄
Lab. Sample No. 23-S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs/cu ft	M. C. %	Comp. %	Max Size	1½"	¾"
Q (–14.7')	GM II-IX	Gray silty sandy gravel. The material is all broken up diorite. Many ice crystals and irregularly oriented ice lenses up to ½" thick. Ice is clear, colorless and hard; 50% ± by volume	75.3	45.4		1"	100	83
R (–15.0')		Badly fractured diorite rock, with ice in the fractures. Ice is clear, colorless, and hard.	143.8	11.1				
T (–16.0')		Cuttings are gray, mostly med. to fine sand. A few chips of ice. Badly fractured diorite with ice in the fracture planes		8.4				
U (–17.0')		Same as "T" - no ice, not as badly fractured.		4.3				
V (–18.0')		Cuttings are gray, mostly medium to fine sand - max. size ≈ 3/16". No visible ice, very dry. Rock now solid diorite.		1.5				
W (–19.0')	Completed	Same as V		3.7				

LAB

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Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

Density lbs./cu ft	M.C. %	Comp. %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm	L.L.	P.L.	P.I.	S G
75.3	45.4		1"	100	85	63	54	46	36	30	23	19	10				
143.8	11.1																
	8.4																
	4.3																
	1.5																
	3.7																

B

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Sheet 2 of 2

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Date. DH 3-27-53: DH 4-6-53
Submitted by: S.B.

ST DATA										Source of Material	Remarks
FINER											
20	No.40	No 100	No.200	.02 mm	LL	PL	PI	Specific Gravity			
[illegible]	30	25	19	10'						Bed Rock	Core good - 100% recovery
										Bed Rock	Core good - 100% recovery. Not broken up enough to get an M.A.
										Bed Rock	Cuttings from tri-cone rotary rock bit. Rig bouncing badly
										Bed Rock	Same - rig bouncing slightly
										Bed Rock	Same - rig running smoothly, drilling very hard.
										Bed rock	Same Hole completed at 19.0'

PLATE A15

Metcalf & Eddy [illegible]

Hole No. TR #10
Location Runway: Sta. 91+13, ℄
Lab. Sample No. 22-S

P[illegible]

1953 Pe[illegible]

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	1½"	¾"	
(0.5')		Bituminous Concrete							
A (0.5'–0.8')	G	Cuttings grey and brown, graded from ¾" to fine sand-max. size = ½" Minus 2½" crushed gravel base course.		2.1					
B (0.8'–2.0')	G or S	Cuttings are gray, graded from pea gravel to fine sand-max. size = ¾". No visible ice. Sandy gravel or gravelly sand.		1.8					
C (2.0'–3.0')	G or S	Same as "B" - max. size = ½		2.2					
D (3.0'–4.0')	G or S / ROCK and G or S	Cuttings are gray, mostly med and fine sand-max size = ¼". About 30% diorite. No visible ice. Sandy gravel or gravelly sand with diorite quarry rock.		1.8					
E (4.0'–5.0')	ROCK and G or S	Cuttings are gray, mostly med. and fine sand with a few coarse chips - max. size = ⅜". About 30% appears to be diorite. No visible ice. Diorite quarry rock choked with sand or gravel.		2.3					
F (5.0'–6.0')	ROCK and G or S	Same as "E" - about 75% diorite		2.3					
G (6.0'–7.0')	G or S	Cuttings are brown, well graded from coarse to fine sand - max. size = ¼". No visible ice. Sandy gravel or gravelly sand with cobbles.		4.4					
H (7.0'–8.0')	G or S	Same as "G" - color grayish brown		5.0					
J (8.0'–9.0')	G or S	Same as "G".		3.8					
K (9.0'–10.0')	GM or SM	Cuttings are grayish brown, graded from med. sand to silt with a few coarse chips and a small amount of organic matter. No visible ice. Silty sandy gravel or silty gravelly sand with a small amount of organic matter.		4.5					
L (10.0'–12.0')	GM or SM	Same as "K" - less organic.		3.5					
M (12.0'–13.0')	GP 15-11	Brownish gray, poorly graded, sandy gravel. Many ice lenses up to 1½" thick and a few pockets of ice up to 1". Ice is clear colorless and hard = 25% ± by volume. About 50% of the gravel is angular diorite fragments.	117.6	16.4		1½"	100	55	4[illegible]
N (13.0'–14.0')	GW 11	Brownish gray, well graded, sandy gravel. The sand is decomposed and weathered diorite, while the gravel is badly fractured diorite. The upper zone of diorite bed rock. Ice is slightly cloudy and wedged between the fractured diorite = 40% ± by volume.	92.8	31.3		2"	87	65	5[illegible]

continued

A

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Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs./cu. ft.	M.C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	PL	P
he urse.		2.1															
ive al		1.8															
		2.2															
[illegible]		1.8															
d e ngth		2.3															
		2.3															
ine		4.4															
		5.0															
		3.8															
/ ount		4.3															
		3.5															
ny ume. s.	117.6	16.4		1½"	100	55	42	28	23	20	15	7	4				
ne f d	92.8	31.3		2"	87	65	51	42	31	21	16	8	4	2			

B

...ins & Associates

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Sheet 1 of 2

Date: DH 3-27-53 : DH 4-6-53

Submitted by: S.B.

...ST DATA										
FINER									Source of Material	Remarks
...0	No.40	No.100	No.200	.02 mm.	LL	PL	PI	Specific Gravity		
									No. River	Samples "A" thru "L", 0.3'-12.0', consist of cuttings from tri-cone rotary rock bit. Rig bouncing badly.
									"H" Terrace	Same
									"H" Terrace	Same
									"H" Terrace and "F" Quarry	Same - hit quarry rock between 3' and 4'.
									"F" Quarry	Rig bouncing badly - drilling very hard
									"F" Quarry	Same
										Rig bouncing - Sourse of material unknown, possibly local borrow.
										Same
										Same
									Native Soil	Same - hard to tell where fill ends and native soil begins Estimated depth to native soil = 9.0'
									Native Soil	Rig bouncing slightly
	15	7	4						Native Soil and Bed Rock	Same - Estimated depth to start of diorite bed rock = 12.7'. Core good - 100% recovery
	16	8	4	2					Bed Rock	Rig bouncing badly. Core good - 100% recovery.

PLATE A16

Metcalf & Eddy

1953 P

Hole No. TR # 10
Location Runway: Sta. 91+13, ℄
Lab. Sample No. 22-S

Sample No. & Depth	Graphic Log		Description & Classification	Density lbs./cu.ft.	M.C. %	Comp %	Max Size	1½	¾
N (14.5')		GW II	See sample "N", sheet 1	92.0	31.3		2"	87	65
P (15.0')		GP II	Badly fractured diorite rock. Ice along the fracture planes. Ice = 10% ± by volume.		7.8		2"	83	42
Q (16.0')		G	Cuttings are gray diorite, mostly med. sand in size. A few small chips of ice. Badly fractured diorite with ice in the fracture planes.		10.4				
R (17.0')		ROCK	Same as "Q" - rock less fractured.		3.8				
T (19.0')			Same as "Q" - no ice, solid rock		1.7				
	Completed								

LAB

Metcalf & Eddy and Alfred Hopkins & Associates

Project Blue Jay

1953 Permafrost Investigation

	LABORATORY TEST DATA														
	Density lbs/cu ft	M.C. %	Comp %	Max Size	PERCENT FINER										LL
					1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 m/m	
	92.8	31.3		2"	87	65	51	42	31	21	16	8	4	2	
long the fracture		7.8		2"	83	42	32	26	20	14	11	6	3		
and in size. A few with ice in the		10.4													
		3.8													
		1.7													

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Sheet 2 of 2

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Date DH 3-27-53 : DH 4-6-53
Submitted by: S.B.

ST DATA									Source of Material	Remarks
FINER										
0	No.40	No.100	No.200	.02 mm	LL	PL	PI	Specific Gravity		
	16	8	4	2					Bed Rock	Core good - 100% recovery
	11	6	3						Bed Rock	Core crumbled - 75% recovery.
									Bed Rock	Cuttings from core bit. No core recovered. Rig bouncing badly, drilling hard.
									Bed Rock	Same - rig bouncing slightly.
									Bed Rock	Cuttings from tri-cone rotary rock bit. Rig running smoothly - drilling very hard.
										Hole completed at 19.0'

PLATE A17

Metcalf & Eddy

1953 P

Hole No. TR#11
Location Runway: Sta. 93+50, ℄
Lab. Sample No. 17-5

Sample No & Depth	Graphic Log	Description & Classification	Density lbs./cu ft	M.C. %	Comp %	Max Size	1½"	¾"
0.5'		Bituminous Concrete						
A (0.5'–0.8')	G	Cuttings are brownish gray, graded from pea gravel to fine sand. No visible ice. Minus 2½", crushed gravel base course.		1.4				
B (0.8'–2.0')	G or S	Cuttings are light brownish gray, mostly med. to fine sand-max. size = 3/8". No visible ice. Sandy gravel or gravelly sand with scattered cobbles.		1.7				
C (2.0'–3.0')	G or S	Same as "B".		2.1				
D (3.0'–4.0')	ROCK and G or S	Cuttings are gray, graded from coarse to fine sand-max. size = ½". About 75% of cuttings are diorite. No visible ice. Diorite quarry rock choked with sand or gravel.		2.2				
E (4.0'–5.0')	ROCK and G or S	Same as "D" - about 60% diorite		2.6				
F (5.0'–6.0')	ROCK and G or S	Same as "D" - about 50% diorite		2.2				
G (6.0'–7.0')	G or GM	Cuttings are light brownish gray, mostly med. sand to silt - max. size = 3/8". No visible ice. Silty sandy gravel or silty gravelly sand with scattered cobbles.		3.4				
H (7.0'–8.0')	G or GM	Same as "G", max. size = ½"		4.3				
J (8.0'–9.0')	GM or SM	Same as "G", but more silt		3.8				
K (9.0'–10.0')	GM or SM	Same as "J"		3.3				
L (10.0'–12.0')	SM IX-IC	Grayish brown, silty, gravelly sand with cobbles and organic matter. Many small ice crystals, and all the gravel is coated with a film of ice, = 10% ± by volume.	138.2	7.3		1"	100	95
M (12.0'–14.0')	GM IX-IC	Same as "L" - silty sandy gravel	136.0	7.2		2"	96	81

Continued

A

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Project Blue Jay

1953 Permafrost Investigation

	LABORATORY TEST DATA															
	Density lbs./cu ft.	M.C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	
...ace. gravel to ...vel base course.		1.4														
...y med. to fine ...y gravel or		1.7														
		2.1														
... to fine sand- ...diorite. No ...ith sand or		2.2														
		2.6														
		2.2														
...ely med. sand ...silty sandy ...red cobbles.		3.4														
		4.3														
		3.8														
		3.3														
...ith cobbles ...crystals, ... film of ice,	138.2	7.3		1"	100	95	85	75	67	59	51	36	27	12		n
	136.0	7.2		2"	96	81	66	55	50	44	38	27	21	9	21	/

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Sheet 1 of 2

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Date: DH 3-20-53 : DH 4-5-53

Submitted by: S.B.

EST DATA									Source of Material	Remarks
FINER					LL	PL	PI	Specific Gravity		
20	No.40	No.100	No.200	.02 mm.						
										· Samples "A" thru "K", 0.5'-10', consist of cuttings from tri-cone rotary rock bit.
									No. River	Rig bouncing
									"H" Terrace	Same
									"H" Terrace	Same
									"F" Quarry	Same
									"F" Quarry	Same
									"F" Quarry	Same
									Local Borrow	Same
									Local Borrow	Same
									Local Borrow	Same
									Local Borrow	Same
	51	36	27	12		non	plastic		Native Soil	Core badly broken - 40 % recovery. Native soil starts between 10' and 11'.
	38	27	21	9	21	19	2	2.57	Native Soil	Core badly broken - 50 % recovery

PLATE A18

Metcalf & Eddy

Hole No. TR# 11
Location Runway: Sta. 93+00, ℄
Lab. Sample No. 17-S

1953 F

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu ft.	M.C. %	Comp %	Max Size	1½"	¾"
N (–15.0')	GM or SM	Cuttings are brownish gray, mostly fine sand with some silt and a trace of organic matter. No visible ice. Silty gravelly sand or silty sandy gravel.		3.9				
P (15.0'–16.0')	G or S	Cuttings are brownish gray, clean well graded sand with some coarse chips - max size = ½". No visible ice. Sandy gravel or gravelly sand.		2.1				
Q (16.0'–17.0')	GM or SM	Cuttings are brownish gray fine sand with some silt and a trace of organic matter. No visible ice. Silty sandy gravel or silty gravelly sand.		7.2				
R (17.0'–18.0')	GM or SM	Same as Q		6.6				
T (18.0'–19.0')	SM or ML	Cuttings are brownish gray, mostly fine sand and silt. Cuttings very wet, and many small chips of ice. Silty gravelly sand or gravelly sandy silt with much ice.		31.2				
U (19.0'–20.0')	SM or ML	Same as "T" - no visible ice, a few chips of diorite.		13.4				
V (20.0'–22.0')	G or GM	Cuttings are brownish gray, mostly med to fine sand with some silt. About 90% diorite. No visible ice. Badly fractured diorite rock with some silt and sand in the fractures.		4.2				
W (22.0'–25.0')	ROCK	Cuttings are gray, uniform med. to fine sand. Solid diorite rock.		0.9				
X (25.0'–26.5')	ROCK	Same as "W"		1.0				
26.5'	Completed							

Metcalf & Eddy and Alfred Hopkins & Associates

Project Blue Jay

1953 Permafrost Investigation

...on	LABORATORY TEST DATA														
	Density lbs./cu. ft.	M.C. %	Comp %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	L...
...stly fine sand with ...tter. No visible ice. ...red.		3.9													
...n well graded ...ize = ½". No visible		2.4													
...sand with some ...r. No visible ice. ...red.		7.2													
		6.6													
...tly fine sand and ...all chips of ice. ...dy silt with much		31.2													
...w chips of diorite.		13.4													
...ostly med to fine ...orite. No visible ...ith some silt and		4.2													
... to fine sand.		0.9													
		1.0													

B

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Sheet 2 of 2

Date. DH 3-20-53 : DH 4-5-53

Submitted by: S.B.

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EST DATA										Source of Material	Remarks
FINER											
20	No.40	No.100	No.200	.02 mm.	LL	PL	PI	Specific Gravity			
										Native Soil	Cuttings from core bit. No core recovered.
										Native Soil	Same - This material appears too clean to be from this zone, possibly cave in from above.
										Native Soil	Cuttings from core bit. No core recovered.
										Native Soil	Same
										Native soil	Same
										Native Soil	Same - hit upper surface of diorite bed rock between 19' and 20'
										Bed Rock	Cuttings from tri-cone rotary rock bit. Drilling very hard, rig bouncing badly.
										Bed Rock	Same - rig running smoothly.
										Bed Rock	Same as above Hole completed at 26.5'

PLATE A19

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1953 Perm…

Hole No. TR #12

Location Runway Sta. 93+63, ℄

Lab. Sample No. 16-S

LABO…

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu.ft.	M.C. %	Comp. %	Max. Size	1½"	¾"	3/8
0'–0.3'		Bituminous Concrete							
A (0.3'–0.8')	G	Cuttings are brownish gray, graded from -¾" to fine sand. Minus 2½" crushed gravel base course.		2.8					
B (0.8'–2.8')	G or S	Cuttings are brown, graded from coarse sand to fine sand - max. size = ¼". No visible ice. Sandy gravel or gravelly sand with cobbles.		2.7					
C (2.8'–6.0')	ROCK and S or G	Cuttings are gray, mostly med. to fine sand - max. size = ¼". No visible ice. Diorite quarry rock choked with sand or gravel.		3.9					
D (6.0'–7.5')	SM or GM	Cuttings are brownish gray, mostly fine sand to silt. No visible ice. Silty gravelly sand or silty sandy gravel with cobbles.		8.5					
E (7.5'–9.0')	SM IC	Gray, silty, gravelly sand with scattered cobbles. No visible ice crystals or lenses, but a few of the stones are partly coated with a very thin film of ice, well bonded.	144.1	6.1		2"	91	87	80
F (9.0'–11.0')	GM SM	Cuttings are brownish gray, graded from coarse sand to silt - max. size = 3/8". No visible ice. Silty sandy gravel or silty gravelly sand with cobbles.		4.1					
G (11.0'–12.0')		Same as "F".		3.6					
H (12.0'–13.0')	GM NW	Brownish gray, silty, sandy gravel with cobbles. No visible ice - well bonded.	144.5	4.9		1½"	100	86	71
J (13.0'–14.0')	GM-Pt NW	Brownish gray, silty, sandy gravel with very dark brown peat. Peat = 30% ± by volume. No visible ice, but peat very hard in frozen state - well bonded.	93.7	23.1					
	continued								

A

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1953 Permafrost Investigation

	LABORATORY TEST DATA															
	Density lbs/cu ft.	M. C. %	Comp. %	Max. Size	PERCENT FINER										LL	PL
					1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.		
...om ⅜" to ...course.		2.9														
...sand by ...ndy gravel		2.7														
...d - max. size = ...ed with sand		3.9														
...and to silt. ... sandy		8.5														
...ed cobbles. ...ew of the ...ilm of ice,	144.1	6.1		2"	91	87	80	72	65	56	46	30	22	13	18	15
...om coarse ...ice. Silty ...obbles.		4.1														
		3.6														
...obbles. No	144.5	4.9		1½"	100	86	71	58	51	45	37	25	19	11	19	16
...very dark ...sible ice, ...ed.	93.7	23.1														

B

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Sheet 1 of 2

Date: DH 3-19-53: DH 4-4-53

Submitted by: S.B

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EST DATA									Source of Material	Remarks
FINER					LL	P.L.	P.I.	Specific Gravity		
.20	No.40	No.100	No.200	.02 mm.						
									No. River	Cuttings from tri-cone rotary rock bit. Rig bouncing.
									"H" Terrace	Same
									"F" Quarry	Same - drilling hard.
									Local Borrow	Same
6	46	30	22	13	18	15	3		Local Borrow	Core good - 100% recovery
									Local Borrow	Cuttings from core bit. No core recovered - rig bouncing
									Local Borrow	Same
-	37	25	19	11	19	16	3		Local Borrow	Core good - 50% recovery
									Native Soil	Core good - 100% recovery. Impossible to run M.A, hydrometer, and Atteberg Limits due to large amount of organic matter.

PLATE A20

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Hole No. TR # 12
Location Runway Sta. 93+65, ℄
Lab. Sample No. 16-S

Sample No. & Depth	Graphic Log	Description & Classification	LABO						
			Density lbs./cu.ft.	M.C. %	Comp. %	Max. Size	1½"	¾"	⅜
K	GM NP	Grayish brown, silty, sandy gravel with a small amount of organic matter and scattered cobbles. No visible ice - poorly bonded.		7.4		2"	93	72	64
15.5' L	SM NP	Grayish brown, silty, gravelly sand with a trace of organic matter and scattered cobbles, also some reddish brown mottling. No visible ice - poorly bonded.		5.8		2"	95	81	75
16.0' M	SM IC	Same as "L" - coating of ice on some of the gravel.	128.4	10.1		2"	96	76	66
17.5' N	GW-GM	Dark brown slightly silty sandy gravel mixed with grayish brown silty sand. Scattered cobbles and a trace of organic matter. Core is thawed, but not very wet.		7.9		2"	69	51	39
18.5' P	GW-GM II	Brownish gray, well graded, slightly silty, sandy gravel. The gravel is badly fractured diorite, while the sand and silt is badly weathered and decomposed diorite. Many irregularly oriented ice lenses. Ice is clear, colorless, and hard = 30% ± by volume.		14.8		2"	91	72	53
21.1' Q	GP II	Badly fractured diorite rock. Ice is clear, hard, and colorless, and is wedged in the fissures = 20% ± by volume.	118.4	17.1		2"	94	54	33
22.2' R	GP-GM II	Same as "Q" - more fines	107.1	21.6		2"	95	62	47
23.4' T	ROCK	Cuttings are diorite, uniform med. to fine sand in size. Fractured diorite rock.		1.0					
25.0'	completed								

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1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	L L	P ...
... a small ... cobbles.		7.4		2"	93	72	64	56	51	45	39	27	20	9		non...
... a trace of ... some ... rly bonded.		5.8		2"	95	81	75	69	64	56	47	31	19	12	18	17
...ne gravel.	128.4	10.1		2"	96	76	66	59	53	47	40	25	16	7	23	non
...mixed with ...s and a ..., but not		7.9		2"	69	51	39	33	29	24	18	10	7	3		
..., sandy ...te, while ... decomposed ...es. Ice is ...		14.8		2"	91	72	59	46	32	21	15	8	5			
... clear, hard, ...es = 20% ±	113.4	17.1		2"	94	54	33	24	18	14	11	6	3			
	107.1	21.6		2"	95	62	47	34	24	18	14	9	7			
... sand in		1.0														

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Sheet 2 of 2

Date DH 3-19-53 : DH 4-4-53

Submitted by S.B.

TEST DATA

FINER					LL	PL	PI	Specific Gravity	Source of Material	Remarks
20	No. 40	No. 100	No. 200	.02 mm.						
5	39	27	20	9		non	plastic		Native Soil	Core crumbled - 100% recovery
6	47	31	19	12	18	17	1		Native Soil	Same
7	40	25	16	7	23	non	plastic		Native Soil	Core good - 50% recovery
[illegible]	18	10	7	3				2.69	Native Soil	Core broken and thawed - 75% recovery
[illegible]	15	8	5						Bed Rock	Core badly broken and partly thawed - 75% recovery. M.C. unreliable.
[illegible]	11	6	3						Bed Rock	Core broken - 50% recovery.
8	14	9	7						Bed Rock	Same
									Bed Rock	Cuttings from core bit - no core recovered. Rig bouncing slightly - drilling very hard.
										Hole completed at 2[illegible]0'.

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1953 Perm[...]

Hole No. TTW1
Location South Loop Taxiway, Sta 34+75, 18.75' Lt. ℄
Lab. Sample No. 26-S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu ft	M.C. %	Comp. %	Max Size	1½"	¾"	⅜"
0.3'		Asphalt Pavement							
A	GW	Cuttings are gray, mostly well graded sand with a few coarse chips. Minus 2½", crushed gravel base course.		3.6					
1.0'									
B		Cuttings are light brownish gray, mostly med. to fine sand - max. size = ⅜". No visible ice. Clean, sandy gravel with cobbles.		1.9					
3.0'	G								
C		Same as "B", max. size = ¾".		1.6					
6.0'									
D	SM or GM	Cuttings are light brownish gray, mostly fine sand and silt - max. size = ¾". No visible ice. Silty gravelly sand or silty sandy gravel with cobbles.		3.5					
9.5'	Completed								

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LABORATORY TEST DATA

	Density lbs./cu ft	M.C. %	Comp. %	Max Size	PERCENT FINER										LL	P..	P..
					1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.			
...ch a few ...oarse.		3.6															
...ed. to ...ain.		1.9															
		1.6															
...ne. ...Silty ...bles.		3.5															

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Sheet 1 of 1

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Date: DH 3-27-53

Submitted by. S B.

ST DATA									Source of Material	Remarks
FINER					LL	PL	PI	Specific Gravity		
20	No.40	No.100	No.200	.02 mm.						
									No. River	Cuttings from tri-cone rotary rock bit.
									"H" Terrace	Same - rig bouncing due to cobbles.
									"H" Terrace	Same - rig bouncing badly from 4.5' to 6.0'. Material is mostly cobbles and boulders.
									Local Borrow	Same - rig bouncing slightly
										Hole completed at 9.5'.
										Material placed same time as TTW2, Should be same.

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1953 Perm…

Hole No. TTW #2
Location South Loop Taxiway - Sta 94+75, 18.75' Rt. ℄
Lab. Sample No. 27-S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu ft.	M C %	Comp %	Max. Size	1½"	¾"	3/8"
		Asphalt pavement							
0.4' A 1.0'	GW NP	Grayish brown, well graded, minus 2½" crushed gravel base course. No visible ice, but hoar-frost on underside of stones. Poorly bonded.	153.5	3.0	100+	2"	94	71	50
B 2.0'	GW NP	Brown, well graded, sandy gravel. No visible ice, but hoar-frost on underside of some of the gravel. Poorly bonded	147.7	3.9	100+	2"	95	71	47
C 3.0'		Same as "B"	150.2	2.9	100+	2"	76	51	38
D 4.0'	GW IX-IC	Grayish brown, well graded, sandy gravel. A few small ice crystals, minus 1/16", and a thin film of ice around some of the gravel. Also cobbles.	155.9	2.5	100+	2"	94	67	47
E 5.0'	GW IC-NP	Grayish brown, well graded, sandy gravel with many cobbles. Quite bony with some rock to rock contact. No visible ice crystals or lenses, some gravel partly coated with a thin film of ice - poorly bonded.	153.9	2.7	100+	2"	94	65	44
F 6.0'	GP NP	Mostly Cobbles and boulders with poorly graded sandy gravel. Much rock to rock contact. No visible ice - poorly bonded.	155.2	2.9	100+	1½"	100	63	49
G 6.0'	GP-GM IX	Grayish brown, with much reddish brown mottling, silty, poorly graded, sandy gravel. Also a small amount of organic matter. Many barely visible ice crystals - very firmly bonded.	158.5	6.6		1½"	100	91	68
H 8.0'	SP-SM IX	Same as "G", but silty gravelly sand.	138.1	5.6		2½"	92	89	70
J 9.3'	GM or SM	Cuttings are light gray, mostly med. sand to silt with a few coarse chips - max. size = ½". Silty sandy gravel or silty gravelly sand with cobbles. No visible ice.		2.6					
	Completed								

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Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs./cu ft	M C %	Comp %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 60	No. 200	.02 mm	[illegible]
ravel e of	153.5	3.0	100+	2"	94	71	50	39	30	21	14	8	5	2	
ice, /.	147.7	3.9	100+	2"	95	71	47	36	29	17	14	6	3		
	150.2	2.9	100+	2"	76	51	38	28	22	16	11	4	2		
ew ice	155.9	2.5	100+	2"	94	67	47	34 F	24	17	11	4	2		
many ace: itly	153.9	2.7	100+	2"	94	65	44	32	23	16	11	5	3		
sandy ce-	155.2	2.8	100+	1½"	100	63	49	42	33	24	13	5	2		
, silty, of very	138.5	6.6		1½"	100	91	68	55	46	36	28	18	12	6	
	138.1	5.6		2½"	92	80	70	62	55	45	34	17	12	6	
silt andy isible		2.6													

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Sheet 1 of 1

Date. DH 3-27-53: TP 4-4-53 to 4-5-53
Submitted by: S.B.

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ST DATA										
FINER									Source of Material	Remarks
20	No.40	No.60	No.200	.02 mm.	LL	PL	PI	Specific Gravity		
	14	8	5	2					No. River	Frozen chunk from test pit.
	14	6	3						"H" Terrace	Same - max size = 10"
	11	4	2						"H" Terrace	Same - max. size = 8"
	11	4	2							- max size = 8"
	11	5	3						"H" Terrace	Same - max. size = 1.5'
	13	5	2						"H" Terrace	Same - max. size = 1.5'
	28	18	12	6					Local Borrow	Same - Scattered cobbles and boulders to 1.5'.
	34	17	12	6					Local Borrow	Same - Test pit completed at 8.0'.
									Local Borrow	Cuttings from tri-cone rotary rock bit. Rig bouncing badly due to cobbles.
										Hole completed at 9.0'.

Hole No. TTB1
Location South Loop Taxiway, Sta. 96+00, 18.75' Lt. ℄
Lab. Sample No. 24-5

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	1½"	¾"	
		Asphalt Pavement							
0.4'–1.0' A.	GW NP	Gray, well graded, minus 2½", crushed gravel base course. No visible ice, but some hoar-frost on the underside of some of the gravel - poorly bonded.	154.8	2.4	100+	2"	94	67	4
1.0'–2.0' B	GP NP	Grayish brown, poorly graded, sandy gravel with cobbles. No visible ice, but hoar-frost on the underside of some of the gravel - poorly bonded.	157.2	1.8	100+	2"	88	65	5
2.0'–3.0' C	GW NP	Grayish brown, well graded, sandy gravel with cobbles. No visible ice, but hoar-frost on the underside of some of the gravel - poorly bonded.	150.7	3.2	100+	2"	81	61	4
3.0'–4.0' D	GW IX-IC	Same as "C", a few barely visible ice crystals and a thin film of ice around some of the gravel.	150.9	3.2	100+	2"	84	64	4
4.0'–5.0' E	GP IX	Grayish brown, poorly graded, sandy gravel with many cobbles. Very bony with some rock to rock contact. A few small ice crystals and hoar-frost on some of the gravel.	162.2	2.1	100+	2"	91	83	4
5.0'–5.9' F	SM NP	Cobbles and boulders choked with silty gravelly sand. About 75% is +2". Much rock to rock contact. No visible ice - poorly bonded.	136.5	6.5		2"	93	89	7
5.9'–6.8' G	SM-SC IX	Grayish brown, silty, gravelly sand with scattered cobbles and boulders. Some barely visible ice crystals and hoar-frost around the gravel - well bonded.	143.6	4.6		2	94	86	75
6.8'–8.0' H	SM-SC IX	Same as "G", color is darker and slightly reddish.	142.9	4.6		2	92	84	7
8.0'–9.0' J	SM or GM	Cuttings are light brownish gray, mostly med sand to silt with some coarse chips - max. size = ½". No visible ice. Silty gravelly sand or silty sandy gravel with scattered cobbles.		2.8					
	Completed								

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1953 Permafrost Investigation

LABORATORY TEST DATA

Density lbs./cu. ft	M.C. %	Comp %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	P	P	S
154.8	2.4	100+	2"	94	67	49	39	28	19	12	5	2					2
157.2	1.8	100+	2"	88	65	50	40	30	20	13	5	3					
150.7	3.2	100+	2"	81	61	44	34	26	20	13	5	3					2
150.9	3.2	100+	2"	84	64	46	36	28	21	13	5	3					
162.2	2.1	100+	2"	91	83	44	36	30	23	14	4	2					
136 5	6 5		2"	93	84	73	64	55	47	38	24	16	9	15	non plastic		
143.6	4.6		2	94	86	75	68	59	51	43	30	21	11	18	13	5	
142.9	4.6		2	92	84	74	66	61	53	47	34	23	12	16	10	6	2.
	2.8																

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Sheet 1 of 1

Date DH 3-27-53 : TP 4-5-53 to 4-7-53
Submitted by S.B.

TEST DATA									Source of Material	Remarks
FINER					LL	PL	PI	Specific Gravity		
No.20	No.40	No.100	No.200	.02 mm						
19	12	5	2					2.70	No. River	Frozen chunk from test pit.
20	13	5	3						"H" Terrace	Same - max size cobble = 12"
20	13	5	3					2.71	"H" Terrace	Same - max. size = 8"
21	13	5	3						"H" Terrace	Same - max. size = 8"
23	14	4	2						"H" Terrace	Same - max. size = [illegible]"
47	38	29	16	9	15	non plastic			"H" Terrace	Same - max. size = 1.7'. Sample is not representative. Material is very friable and difficult to obtain frozen chunk
51	43	30	21	11	18	13	5		Local Borrow	Same - max. size = 1.5'
53	47	34	23	12	16	10	6	2.69	Local Borrow	Same - max size = 1.5'. Test pit completed at 8.0'
									Local Borrow	Cuttings from tri-cone rotary rock bit. Rig bouncing due to cobbles.
										Hole completed at 9.0'.

PLATE A24

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1953 Perm

Hole No. TTB 2

Location South Loop Taxiway, Sta 96+00, 18.75' Rt. ℄

Lab. Sample No. 25-3

				LABORA						
Sample No. & Depth	Graphic Log		Description & Classification	Density lbs./cu. ft.	M. C. %	Comp. %	Max Size	1½"	¾"	⅜"
0.3'			Asphalt Pavement							
A (0.3'–1.0')		GW	Cuttings are gray, well graded sand - max size = ½". Minus 2½", crushed, well graded, gravel base course.		3.9					
B (1.0'–3.0')		G	Cuttings are light brownish gray, mostly med. and fine sand - max size = ⅜". No visible ice. Clean sandy gravel with cobbles.		3.7					
C (3.0'–5.0')		G	Same as "B".		0.4					
D (5.0'–6.0')		G	Same as "B", but more coarse cuttings. Mostly cobbles.		2.3					
E (6.0'–7.0')		GM NW	Gray silty sandy gravel with cobbles. No visible ice - well bonded.	139.9	4.5		2"	80	65	54
F (7.0'–9.2')		GM or SM	Cuttings are light gray, mostly fine sand and silt - max size = ⅜". No visible ice. Silty sandy gravel or silty gravelly sand with scattered cobbles.		2.4					
9.2'	Completed									

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1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs./cu.ft.	M.C. %	Comp. %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	[illegible]	[illegible]
ce.		3.9															
ained sandy		3.7															
		0.4															
		2.3															
	139.9	4.5		2"	80	65	54	46	38	32	24	13	9	5			
t- or		2.4															

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Sheet 1 of 1

Date: DH 3-27-55
Submitted by: S. B.

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T DATA								Source of Material	Remarks
NER									
No 40	No 100	No 200	.02 mm	LL	PL	PI	Specific Gravity		
								Ne. River	Cuttings from tri-cone rotary rock bit.
								"H" Terrace	Same - rig bouncing due to cobbles.
								"H" Terrace	Same - rig bouncing.
								"H" Terrace	Same - rig bouncing badly.
24	13	9	5					Local Borrow	Core badly broken - 50% recovery.
								Local Borrow	Cuttings from core bit. Rig bouncing badly. Material placed same time as TTB1, Should be same.

PLATE A25

Metcalf & Eddy

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Hole No. T.R. 3-4 {Hand Dug}
Location RUNWAY STATION 34+06 ℄
Lab. Sample No. 41-S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs/cu ft	M.C. %	Comp. %	Max Size	1½"	¾"
0.10'		Bituminous Concrete						
0.75'		Penetration Macadam						
AA 1.0'	GW-NP	Light brown gray, well graded, crushed, 2½" minus, sandy gravel. No visible ice.						
AA 1.3'	GW-NP	Light brown gray, well graded, gravelly sand. No visible ice.	156.9	2.3	100+	2"	87	64
AB 1.80	SP-IX	Dark brown gray, poorly graded, silty gravelly sand. Slightly organic. Few small ice crystals.	161.0	4.6	100+	2"	95	87
AC 2.9	GP IX	Dark brown gray, poorly graded, sandy gravel with slight organic content. Many very small ice crystals.	150.6	3.2	100+	2"	90	86
AD 3.9	SP-SM NW	Mixture of dark gray brown, sandy gravel and a poorly graded sand of the same color. Combination gives silty, gravelly sand, poorly graded. Very little visible ice.	152.9	4.3	100+	2"	95	87
AE 4.5	SP-SM NP R	Diorite quarry rock {25% by volume} surrounded by poorly graded silty, gravelly diorite sand. No visible ice.		3.7		2"	91	76
AF 5.3	GP IX R	Same as AE except the rock is approximately 50% by volume, there is more gravel in the surrounding material and ice crystals appear.	151.0	6.2	100+	2"	85	61
AG 6.0	SP IX-IC R	Same as AE, except visible ice forms approximately 15% by volume of sand in the form of crystals and coating of stones. Rock 60% by volume approx.	147.8	6.5	99.2	2"	88	72
6.4		Mixture of AG and AH.						
AH 7.0	SM-SC IX-IS	Medium gray brown, silty and clayey gravelly sand. Some small ice crystals and lenses. Ice about 10% by volume. Slight organic content.	124.6	12.0		1½"	100	84
AJ 7.7	SP-SM IX	Same as AH but with no ice lenses	141.0	6.4		2"	90	78
AK 8.5	SP-SM IX	Medium brown gray, poorly graded, silty gravelly sand. Few small ice crystals.	149.5	4.4		1½"	100	80
AL 9.0	SM IX-IC	Gray brown silty gravelly sand. Ice coats the gravel particles and there are many small ice crystals. Some organic content.	138.3	6.3		2"	98	88
AM 10.0	SM IX-II	Same as AL except for few thin ice lenses.	135.9	7.6		2"	93	85
AN 10.5	SM IX-II	Same as AM but with larger ice lenses. About 10% ice by volume.	133.2	8.8		2"	96	85
AP 11.5	SM IX-II	Medium brown gray, silty gravelly sand. Many ice lenses up to ¼" thick. Approximately 20% ice by volume.	117.6	15.7		2"	94	85
12.0	ICE	Clear ice.						
		Bottom of pit.						

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Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

...sity ...cu. ft.	M.C. %	Comp. %	Max Size	PERCENT FINER 1½"	3/4"	3/8"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	L.L.	P.L.	P.I.	Spec... Grav...
6.9	2.3	100+	2"	87	64	45	35	27	19	12	5	3					2.7
1.0	4.6	100+	2"	95	87	81	74	61	43	28	9	4					2.7
10.6	3.2	100+	2"	90	86	59	50	43	33	23	8	5					2.7
2.9	4.3	100+	2"	95	87	77	71	60	44	30	12	8	3.9				
	3.7		2"	91	76	66	58	50	38	27	10	5					
51.0	6.2	100+	2"	85	61	50	43	38	29	20	9	3	2.1				2.6
47.8	6.5	99.2	2"	88	72	64	58	49	36	23	9	4					
4.6	12.0		1½"	100	84	74	66	59	51	44	30	21	13	19	15	4	
1.0	6.4		2"	90	78	65	56	50	41	31	18	11	6.1				
9.5	4.4		1½"	100	80	67	62	56	45	34	18	11	7.0				
8.3	6.3		2"	98	88	80	72	66	57	48	33	26	11.0	15	13	2	2.8
5.9	7.6		2"	93	85	75	67	61	54	48	35	27	14	16	14	2	
3.2	8.8		2"	96	85	76	67	61	56	50	37	30	19	17	14	3	
7.6	15.7		2"	94	85	76	68	61	54	45	29	21	9	14	14	0	

Hopkins & Associates
Jay
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Sheet 1 of 1
Date: April 7, 1953
Submitted by: M.M.C.

TEST DATA										Source of Material	Remarks
T FINER						LL	PL	PI	Specific Gravity		
10	No. 20	No. 40	No. 60	No. 200	.02 mm.						
7	19	12	5	3					2.78	So. Fk. Delta.	Impossible to separate these two lifts. Frozen chunk sample.
1	43	28	9	4					2.79	No. Mt.	Frozen chunk sample.
3	33	23	8	5					2.79	No. River	Frozen chunk sample. Cobbles, maximum size 1', few.
0	44	30	12	8	3.9					No. Mt.	Frozen chunk sample. Few cobbles, maximum size 8".
0	38	27	10	5						No. Mt.	Frozen chunk could not be obtained due to friability of the material
8	29	20	9	5	2.1				2.68	No. Mt.	Frozen chunk sample.
9	36	23	9	4						No. Mt.	Frozen chunk sample.
9	51	44	30	21	13	19	15	4		Local Borrow	Transition zone, fill and local borrow mixed. Frozen chunk sample. Scattered cobbles, maximum size 8".
0	41	31	18	11	6.1					Local Borrow	Many cobbles, maximum size 1.5'. Frozen chunk sample.
6	43	34	18	11	7.0					Local Borrow	Frozen chunk sample. Scattered cobbles, maximum size 2'.
6	57	48	33	26	11.0	15	13	2	2.81	Native Soil	Frozen chunk sample. Scattered cobbles, maximum size 8".
1	54	48	35	27	14	16	14	2		Native Soil	Same.
1	56	50	37	30	19	17	14	3		Native Soil	Frozen chunk sample; many cobbles, maximum size 2'.
1	54	45	29	21	9	14	14	0		Native Soil	Frozen chunk sample. Jack hammer blade driven to 13.8' and was still in ice.

PLATE A26

Metcalf & Edd

1953

Hole No. T.R. 5-6 [Hand Dug]
Location RUNWAY, STATION 58+06.5 50' Lt. ℄
Lab. Sample No. 39-5

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft.	M.C. %	Comp. %	Max. Size	$1\frac{1}{2}$"	$\frac{3}{4}$"
		Bituminous Concrete						
0.7'		Penetration Macadam						
1.1' AA	GP NP	Light brown gray, poorly graded, crushed, 2½ minus, sandy gravel. No visible ice.	157.9	3.0	100+	2"	76	47
1.7' AB	GP-GM NP	Medium gray brown, poorly graded, silty sandy gravel. No visible ice.	144.8	4.2	99.5	2"	86	64
2.2' AC	GP-GM IC-IX	Medium brown, poorly graded, silty sandy gravel with cobbles to 1' diameter. A few small ice crystals and a thin ice film on the gravel particles.	149.3	3.2	100+	2"	87	69
3.5' AD	SP IC-IX	Medium gray brown, poorly graded gravelly sand with many cobbles to 2' diameter. Ice condition same as AC.	143.4	4.9	100+	2"	98	85
4.3' AE	GP-GM IS-IC	Medium gray brown, poorly graded, silty sandy gravel. Many small ice lenses and crystals, with an ice film around the particles.	139.9	6.7	96.5	2"	92	79
5.3'	ICE	Lens of clear ice.						
5.5' AF	SM ICE	Silty gravelly sand suspended in ice. Ice 95% by volume.	44.8	95.0		2"	91	85
5.7'	SM ICE	Same as AF.						
6.7'	ICE	Lens of clear ice.						
7.0'	ROCK ICE	Broken and weathered bedrock with ice filling the fissures.						
7.8'		Bottom of pit.						

SEP 24 1953

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Metcalf & Eddy and Alfred Hopkins & Associates

Project Blue Jay

1953 Permafrost Investigation

	LABORATORY TEST DATA																
	Density lbs/cu ft	M.C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No 20	No. 40	No. 60	No. 200	.02 mm	L.L.	P.–	P
	157.9	3.0	100+	2"	76	47	34	26	19	13	9	5	3				
...lty	144.8	4.2	99.5	2"	86	64	52	44	38	32	24	12	6	3.4			
...ly ...e	149.9	3.2	100+	2"	87	69	57	47	40	33	25	13	7	2.1			
...lly ...e	143.4	4.9	100+	2"	98	85	70	58	47	34	22	9	4				
...ly ...es.	139.9	6.7	96.5	2"	92	79	62	51	42	31	20	12	6	3.3			
	44.8	95.0		2"	91	85	75	66	59	51	42	26	19	10.6	16	15	1

...s & Associates

Sheet 1 of 1

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Date: APRIL 13, 1959

Submitted by: M.M.C.

...T DATA								Source of Material	Remarks
...NER									
No.40	No.CC	No.200	.02 mm	LL	P_	P	Specific Gravity		
9	5	3						So. Riv. Delta	Frozen Chunk sample.
24	12	6	3.4				2.68	Unknown	Same
25	13	7	2.1					Area 45	Same
22	9	4						No. River	Same
20	12	6	3.3				2.73	Area 45 or H-Terrace	Same
42	26	19	10.6	16	15	1		Native Soil	Same
									No sample taken.
									No sample taken.
									No sample taken.

Metcalf & Eddy

1953 P

Hole No. TR 7-8 (Hand Dug)
Location Runway, Station 69+06.5, 50' Lt. ℄
Lab. Sample No. 37-3

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft.	M. C. %	Comp. %	Max. Size	1½	¾
0.4		Bituminous Concrete Pavement						
AA 1.2	GP NP	Light brown gray, 2½" minus crushed gravel base. No visible ice.	153.7	2.7	100+	2½"	87	68
AB 2.2	SP-SM IC-IX	Medium gray brown silty gravelly sand, poorly graded: Thin film of ice coats particles of gravel. Some frost crystals present.	138.5	6.1	96.4	2"	96	80
AC 2.7	SP IC	Medium gray brown, poorly graded ~~silty~~ gravelly sand. Thin film of ice coats stone.	142.3	3.8	100+	2"	87	76
AD 5.7	R GW NP	Diorite quarry rock makes 75 to 90% of this sample by volume. Between boulders is a dark gray sandy gravel of diorite. No visible ice. Voids of sizes up to 6" in height noted between pieces of rock.		4.4		3"	87	63
AE 6.0	GP-GM II-IC	Medium gray brown, poorly graded, silty sandy gravel. Ice 20% by volume, in irregular lenses and masses, and coating stone.	117.2	16.0		2"	78	69
AF 7.0	GM II-IC	Medium gray brown silty sandy gravel. Ice 20% by volume in clear irregular lenses and masses.	74.9	42.8		2"	91	76
AG 8.0	SM IS-IC	Medium gray brown silty gravelly sand. Ice is 30% by volume, clear, and in form of many small parallel lenses up to ⅛" thick and a few masses around stones.	68.0	30.5		2"	95	81
AH 9.0	SM IS-IC	Medium brown silty gravelly sand. Same ice condition as AG.	83.4	35.2		2"	97	93
AJ 10.0	GM IS-II	Same as AK.						
AK 11.0	GM IS-IC	Medium brown silty sandy gravel. Same ice condition as AG.	88.5	31.4		2"	78	70
AL 12.0	SM-SC IS-IC	Gray brown silty and clayey gravelly sand. Ice is 30% of total volume and is in parallel lenses close together. Maximum thickness 1/16".	45.7	91.8		1½"	100	86
		Bottom of pit						

SEP 24 1953

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Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

	Density lbs./cu.ft.	M.C. %	Comp. %	Max. Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	L.L.	P.L.	P
/	153.7	2.7	100+	2½"	87	68	50	40	30	20.	12	5	3				
perly	138.5	6.1	96.4	2"	96	80	66	57	51	43	33	17	9	4			
ravelly	142.3	3.8	100+	2"	87	76	64	54	44	34	22	7	3				
% lders No		4.4		3"	87	63	46	36	29	21	13	5	3				
andy s	117.2	16.0		2"	78	69	57	44	38	29	22	13	11	8			
e 20% ses.	74.9	42.8		2"	91	76	68	58	52	44	38	29	24	14	16	13	3
ice ony	68.0	30.5		2"	95	81	72	62	55	47	41	30	24	15	17	13	4
ice	83.4	35.2		2"	97	93	81	73	65	58	49	34	26	15	17	14	3
ice	88.5	31.4		2"	78	70	61	56	50	44	37	21	13	8			
l. el	45.7	91.8		1½"	100	86	77	68	61	52	45	33	26	14	17	12	5

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Sheet 1 of 1

Date: APRIL 15, 1953

Submitted by: M.M.C

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EST DATA

FINER									Source of Material	Remarks
.20	No.40	No.100	No.200	.02 mm.	L.L.	P L	P I	Specific Gravity		
0.	12	6	3						So.Riv.Delta	Frozen chunk sample.
33	33	17	9	4						Same
34	22	7	3						No.River	Same
11,	13	5	3						"F" Quarry or "B" Quarry	Sample is of the gravel between the rock. It is dry frozen and loose and a density could not be obtained
9	22	13	11	8					Native Soil	Frozen chunk sample.
4	38	29	24	14	16	13	3		Native Soil	Frozen chunk sample
7	41	30	24	15	17	13	4		Native Soil	Frozen chunk sample
8	49	34	26	15	17	14	3	2.68	Native Soil	Frozen chunk sample
										No tests.
4	37	21	15	8					Native Soil	Frozen chunk sample
[illegible]	45	33	26	14	17	12	5	2.75	Native Soil	Frozen chunk sample

PLATE A28

Metcalf & Eddy

P

1953 Pe

Hole No. TTW 2a [Hand Dug]

Location SOUTH LOOP TAXIWAY, STATION 94+80, 19' Rt. ℄

Lab. Sample No. 45-S

Sample No. & Depth	Graphic Log	Description & Classification	Density lbs/cu ft	M.C. %	Comp. %	Max Size	1½"	¾"
0 – 0.4		Bituminous Concrete.						
A (0.4 – 1.0)	GW-GM NP	Medium gray, well graded, 2½" minus, crushed gravel base. No visible ice.	153.3	3.0	100+	2"	94	71
B (1.0 – 2.0)	GW NP	Medium gray brown, well graded, sandy gravel. No visible ice.	147.7	3.9	100+	2"	95	71
C (2.0 – 3.0)	GW NP	Same as Sample B.	150.2	2.9	100+	2"	76	51
D (3.0 – 4.0)	GW IC-IX	Same as Sample B except for few small ice crystals and ice around some of the gravel particles.	155.9	2.5	100+	2"	94	67
E (4.0 – 5.0)	GW IC	Same as Sample D except there are no ice crystals	153.9	2.7	100+	2"	94	65
F (5.0 – 6.0)	GP NP	Medium grey brown, poorly graded, sandy gravel with many cobbles. No visible ice	155.2	2.8	100+	1½"	100	63
G (6.0 – 6.8)	GP-GM IX	Medium gray brown, silty sandy gravel. A little organic material. A few small ice crystals. Material poorly graded	138.5	6.6		1½"	100	91
H (6.8 – 8.0)	SP-SM IX	Same as Sample G, but more sandy.	138.1	5.6		2"	92	80
8.0		Bottom of pit.						

SEP 24 1953

Metcalf & Eddy and Alfred Hopkins & Associates

Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

Density lbs./cu ft.	M. C. %	Comp. %	Max Size	PERCENT FINER 1½"	¾"	⅜"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	L.L.	P.L.	P.I.
-153.3	3.0	100+	2"	94	71	50	39	30	21	14	8	5	2.4			
147.7	3.9	100+	2"	95	71	47	36	29	17	14	6	3				
150.2	2.9	100+	2"	76	51	38	28	22	16	11	4	2				
155.9	2.5	100+	2"	94	67	47	34	24	17	11	4	2				
153.9	2.7	100+	2"	94	65	44	32	23	16	11	5	3				
155.2	2.8	100+	1½"	100	63	49	42	33	24	13	5	2				
138.5	6.6		1½"	100	91	68	55	46	36	28	18	12	6			
138.1	5.6		2"	92	80	70	62	55	45	34	17	12	6			

B

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Sheet 1 of 1

Date: April 4, 1953

Submitted by: M.M.C.

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EST DATA										
FINER									Source of Material	Remarks
20	No.40	No.100	No.200	.02 mm.	LL	PL	PI	Specific Gravity		
1	14	8	5	2.4					No. River	Frozen chunk sample.
7	14	6	3						H-Terrace	Same
6	11	4	2						H-Terrace	Same
7	11	4	2						H-Terrace	Same. Cobbles to 8" maximum diameter
6	11	5	3						H-Terrace	Frozen chunk sample. Many cobbles Maximum diameter 1.3'
4	13	5	2						H-Terrace	Same
6	28	18	12	6					Local Borrow	Frozen chunk sample.
5	34	17	12	6					Local Borrow	Frozen chunk sample

Metcalf & Edd

Hole No. TTB 1a [Hand Dug]
Location South Loop Taxiway Station 93+91, 19' Lt. ℄
Lab. Sample No. 46-5

1953

Sample No & Depth	Graphic Log	Description & Classification	Density lbs./cu. ft.	M C %	Comp. %	Max. Size	1½"	¾"
0.4'		Bituminous Concrete						
A (0.4'–1.0')	GW NP	Medium gray, well graded, 2½" minus, crushed gravel base. No visible ice.	154.9	2.4	100+	2"	94	67
B (1.0'–2.0')	GP NP	Medium gray brown, poorly graded, sandy gravel. No visible ice.	157.2	1.8	100+	2"	88	65
C (2.0'–3.0')	GW NP	Same as sample B, except well graded.	150.7	3.2	100+	2"	81	61
D (3.0'–4.0')	GW IX-IC	Same as sample C with a few small ice crystals.	150.9	3.2	100+	2"	84	64
E (4.0'–5.0)	GP IX	Medium gray brown, poorly graded, sandy gravel with cobbles. A few small ice crystals.	162.2	2.1	100+	2"	91	83
F (5.0–5.9)	SM NP	Medium gray brown, silty gravelly sand with many cobbles. No visible ice.	136.5	6.5	94.0	2"	93	84
G (5.9–6.8)	SM-SC IX	Medium gray brown, silty and clayey gravelly sand. Few small ice crystals. Scattered cobbles	143.6	4.6		2"	94	86
H (6.8–8.0)	SM-SC IX	Same as Sample G except color is slightly reddish.	142.9	4.6		2"	92	84
8.0		Bottom of pit.						

SEP 24 1953

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Metcalf & Eddy and Alfred Hopkins & Associates

Project Blue Jay

1953 Permafrost Investigation

LABORATORY TEST DATA

Density lbs./cu.ft	M C %	Comp. %	Max. Size	PERCENT FINER 1 1/2"	3/4"	3/8"	No. 4	No. 10	No. 20	No. 40	No. 100	No. 200	.02 mm.	LL	PL	PI
154.8	2.4	100+	2"	94	67	49	39	28	19	12	5	2				
157.2	1.8	100+	2"	88	65	50	40	30	20	13	5	3				
150.7	3.2	100+	2"	81	61	44	34	26	20	13	5	3				
150.9	3.2	100+	2"	84	64	46	36	28	21	13	5	3				
162.2	2.1	100+	2"	91	83	44	36	30	23	14	4	2				
136.5	6.5	94.0	2"	93	84	73	64	55	47	38	24	16	9	15	non-plastic	
143.6	4.6		2"	94	86	75	68	59	51	43	30	23	11	18	13	5
142.9	4.6		2"	92	84	74	66	61	53	47	34	27	12	16	10	6

B

kins & Associates

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Sheet 1 of 1

Date APRIL 5, 1953

Submitted by: M.M.C.

EST DATA									Source of Material	Remarks
FINER					L.L.	P.L.	P.I.	Specific Gravity		
.20	No.40	No.100	No.200	.02 mm.						
9	12	5	2					2.70	No. River	Frozen chunk sample.
20	13	5	3						H-Terrace	Frozen chunk sample. Cobbles to 1½" in diameter.
20	13	5	3					2.71	H-Terrace	Frozen chunk sample. Cobbles to 8" in diameter.
21	13	5	3						H-Terrace	Frozen chunk sample.
23	14	4	2						H-Terrace	Frozen chunk sample.
47	38	24	16	9	15	non-plastic			H-Terrace	Frozen chunk sample with many cobbles, about 75% of material is + 1". Maximum diameter is 1.7'.
51	43	30	23	11	18	13	5		Local Borrow	Frozen chunk sample. Scattered cobbles, maximum diameter 1.5'.
53	47	34	27	12	16	10	6	2.69	Local Borrow	Same.