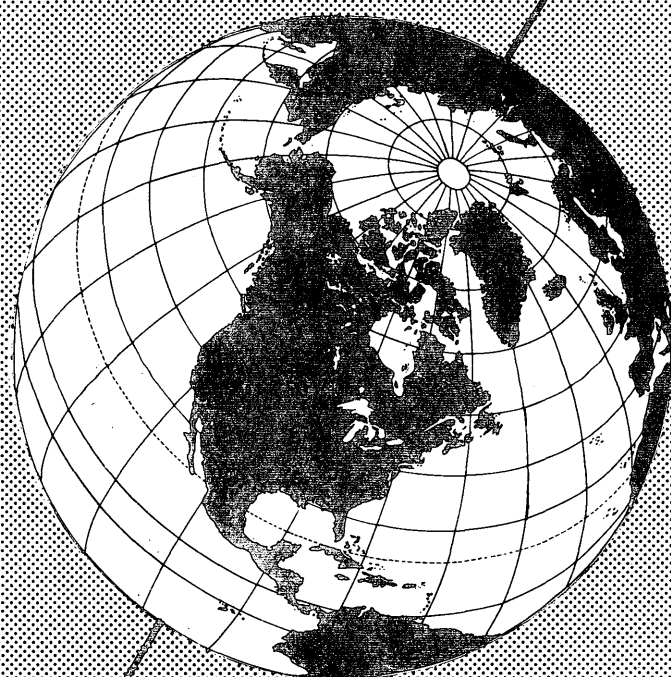


Technical Report 100

JULY, 1962

Ground Temperature Observations Fort Yukon, Alaska



U. S. ARMY
COLD REGIONS RESEARCH AND
ENGINEERING LABORATORY
Corps of Engineers

Technical Report 100

JULY, 1962

Ground Temperature Observations Fort Yukon, Alaska

**U. S. ARMY COLD REGIONS RESEARCH
AND ENGINEERING LABORATORY**

Corps of Engineers

Hanover, New Hampshire

PREFACE

Collection of the data presented herein was authorized in July 1946 by the Chief of Engineers in the "Instructions and Outline on Meteorological Data Study." The program was initiated by the Permafrost Division, St. Paul District and continued by the Arctic Construction and Frost Effects Laboratory (ACFEL), U. S. Army Engineer Division, New England. In February 1961 ACFEL was merged into the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL). The program included the collection of data at 20 stations in Alaska and one in Canada, with this report summarizing the data obtained at Fort Yukon, Alaska. The data obtained at the other stations in this program will be presented in separate reports.

The investigation was a cooperative venture of the Corps of Engineers, the United States Weather Bureau and the Federal Aviation Agency (formerly Civil Aeronautics Administration). Substantial support and assistance in the investigation were provided by personnel of the Alaska Field Station, CRREL (formerly Arctic Construction Investigation Area) at Fairbanks, Alaska. Personnel from the AFS installed and maintained the ground-temperature-measuring equipment and rendered technical assistance to the operating personnel of the U. S. Weather Bureau and Federal Aviation Agency.

CONTENTS

| | Page |
|-------------------------------------|------|
| Preface ----- | ii |
| Summary ----- | iv |
| Introduction ----- | 1 |
| Purpose ----- | 1 |
| Scope ----- | 1 |
| Description of site ----- | 1 |
| Location ----- | 1 |
| Terrain ----- | 1 |
| Climate ----- | 1 |
| Ground-temperature assembly ----- | 5 |
| Location ----- | 5 |
| Drilling the temperature well ----- | 5 |
| Instrumentation ----- | 5 |
| Soil investigations ----- | 7 |
| Exploration ----- | 7 |
| Soil data ----- | 7 |
| Ground temperatures ----- | 7 |
| Observed ground temperatures ----- | 7 |
| Ground-temperature gradients ----- | 7 |
| Depth to permafrost ----- | 7 |

ILLUSTRATIONS

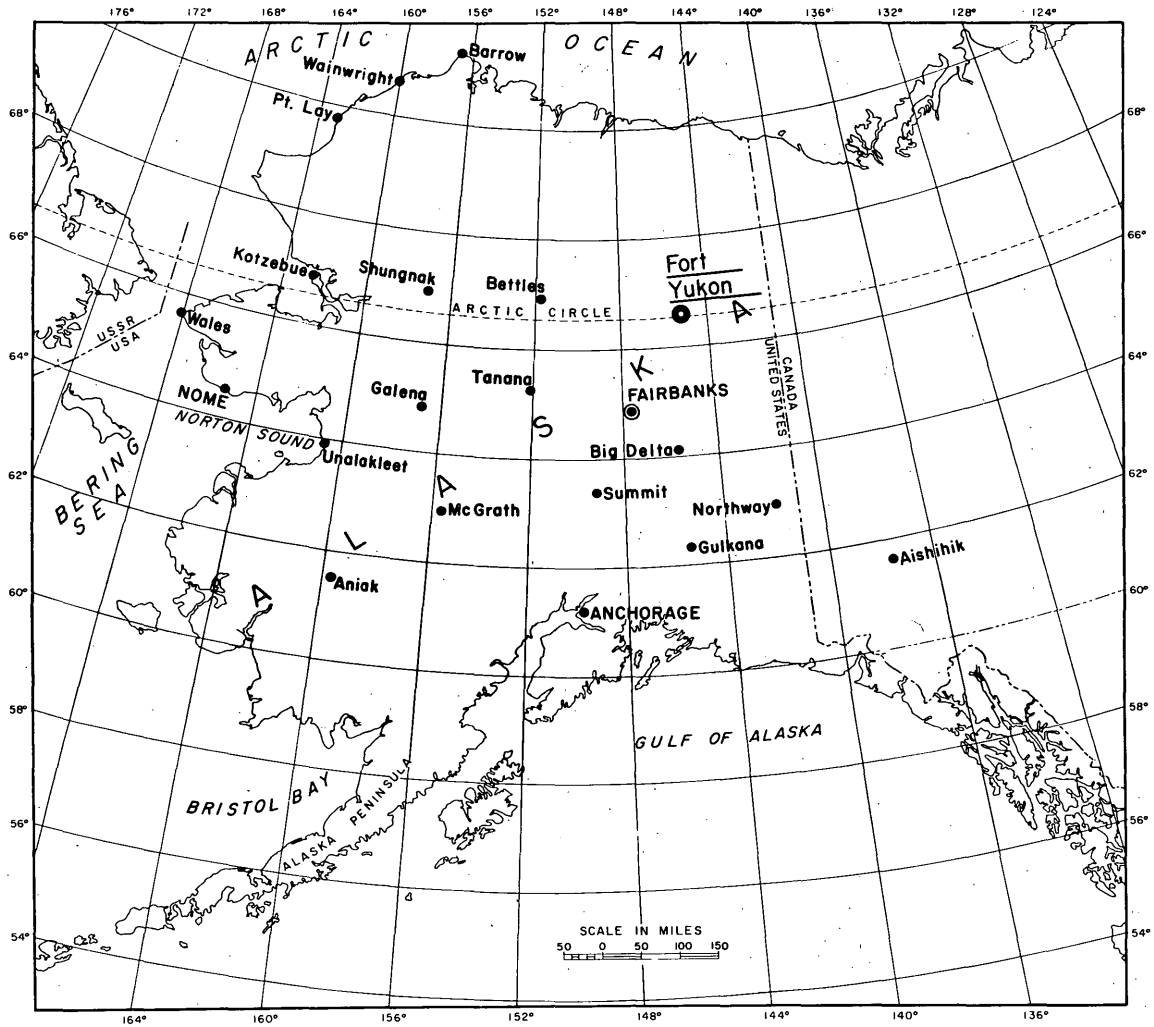
| | |
|--|-------------|
| Figure | |
| Frontispiece: Ground-temperature observation sites ----- | vi |
| 1. Vicinity map ----- | 1 |
| 2. Surface cover in area of ground-temperature assembly- ----- | 2 |
| 3. Climograph ----- | 4 |
| 4. Meteorological data and ground isotherms ----- | facing p. 4 |
| 5. Site location ----- | 5 |
| 6. Resistance thermometer installation ----- | 6 |
| 7. Boring log and soil data, ground-temperature well ----- | 8 |
| 8. Boring log and soil data, exploratory drilling ----- | 9 |
| 9. Ground-temperature gradients ----- | 10 |

TABLES

| | |
|---|----|
| Table | |
| 1. Climatological data for Fort Yukon, Alaska, 1928-1958 | 3 |
| 2. Ground temperatures, °F maximum, minimum, and average observed first day of month, 1947-1958 ----- | 11 |
| 3. Ground temperatures, °F recorded first day of month, 1947-1958 ----- | 12 |

SUMMARY

This report summarizes climatological, ground-temperature, and soil data obtained at Fort Yukon, Alaska. The climatological data were obtained from U. S. Weather Bureau records for the years 1928 to 1958; the ground-temperature data were obtained from daily observations during the years 1947 to 1958; and the soil data were obtained from samples taken while drilling two holes: one in July 1946 and the other in July 1958.



Ground-temperature observation sites

GROUND TEMPERATURE OBSERVATIONS, FORT YUKON, ALASKA

INTRODUCTION

Purpose

The Fort Yukon, Alaska, data summarized in this report were obtained in connection with an investigation to evaluate the relationship between climatic conditions, soil conditions, and soil temperatures in arctic and subarctic areas. These data could be used by agencies requiring general knowledge of this area for such purposes as site selection or as a guide in more detailed research efforts.

Scope

The investigational program involved the collection of climatological, ground-temperature, and soil data from 20 stations in Alaska and one in Canada.

The climatological data for Fort Yukon, Alaska, were obtained from U. S. Weather Bureau records for the years 1928 to 1958. Ground-temperature observations were obtained on a daily basis from 1947 to 1958 by the U. S. Federal Aviation Agency for the Arctic Construction and Frost Effects Laboratory, U. S. Army Engineer Division, New England. Soil data were obtained from samples taken during the drilling of two holes, one in July 1946 and the other in July 1958.

DESCRIPTION OF SITE

Location

Fort Yukon is a small village and trading post in east central Alaska. It is located on the north bank of the Yukon River, approximately one mile upstream from the confluence of the Yukon and Porcupine Rivers, at 66° 34' N latitude and 145° 18' W longitude (Figure 1). The only feasible access to the village is by air from Fairbanks, Alaska, 140 air miles south-southwest, or by river during the months of July through September. An unsurfaced landing strip provides year-round access to the area by air, and there are docking facilities for small boats and barges at the Northern Commercial Company.

Terrain

In the vicinity of the temperature assembly, the terrain slopes slightly, in a southerly direction, to the Yukon River 500 feet away. During the observational period, the vegetation in the general area consisted of a fairly thick, 2- to 3-ft-high growth of grass, weeds, and willow brush (Figure 2).

Climate

Climatological data for Fort Yukon are given in Table 1 and in Figures 3 and 4.

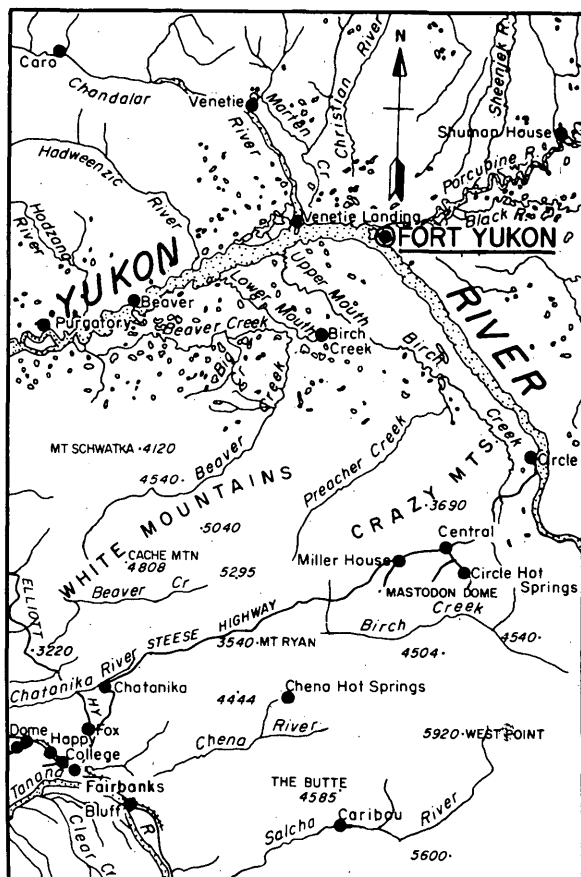


Figure 1. Vicinity map



Figure 2. Surface cover in area of ground-temperature assembly.

Table 1 gives air temperatures, precipitation, amounts of snowfall and snow cover, and the freezing and thawing indexes.

Figure 3, a climograph (also called a hythergraph), gives: mean monthly values of precipitation versus temperature; direction and force of prevailing winds; cloud cover; number of days of precipitation (rain and/or snow); and fog data for the area.

Figure 4 presents meteorological data and ground isotherms for a typical year (1951). The meteorological data includes daily air temperatures, degree days of thaw and freeze (cumulative monthly), daily precipitation (rain and/or snow) and depth of snow on the ground.

GROUND TEMPERATURE OBSERVATIONS

3

Table 1. Climatological data
for
Fort Yukon, Alaska,
1928 - 1958.

| | |
|--|----------|
| Air temperature - F. | |
| Mean annual | 20.7 |
| Recorded high (6/25/55) | 97 |
| Recorded low (12/7/35) | -71 |
| Precipitation - inches | |
| Mean annual | 6.5 |
| Max. annual (1944) | 10.7 |
| Max. monthly (Aug. 1930) | 3.0 |
| Snowfall - inches | |
| Mean annual | 43.3 |
| Max. annual (1948) | 72.6 |
| Max. monthly (Nov. 1939) | 22.8 |
| Freezing index (degree-days, F, below 32) | |
| Average (1947-1958) | -7484 |
| Lowest " " | -6631 |
| Highest " " | -8099 |
| Thawing index (degree-days, F, above 32) | |
| Average (1947-1958) | +3110 |
| Lowest " " | +2780 |
| Highest " " | +3480 |
| Average date start freeze season | 22 Sept. |
| Average date start thaw season | 24 April |
| Average length of freeze season (days) | 215 |
| Average length of thaw season (days) | 150 |

Snow cover - inches
first day of month for 1949-1958

| | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June |
|------------------|-------|------|------|------|------|------|------|------|-----|------|
| Maximum recorded | | 2 | 12 | 21 | 29 | 36 | 41 | 46 | 32 | 0 |
| Minimum recorded | | - | 2 | 5 | 15 | 20 | 15 | 16 | T | 0 |
| 10-Year average | | T | 6 | 13 | 22 | 26 | 35 | 30 | 6 | 0 |

T = Trace

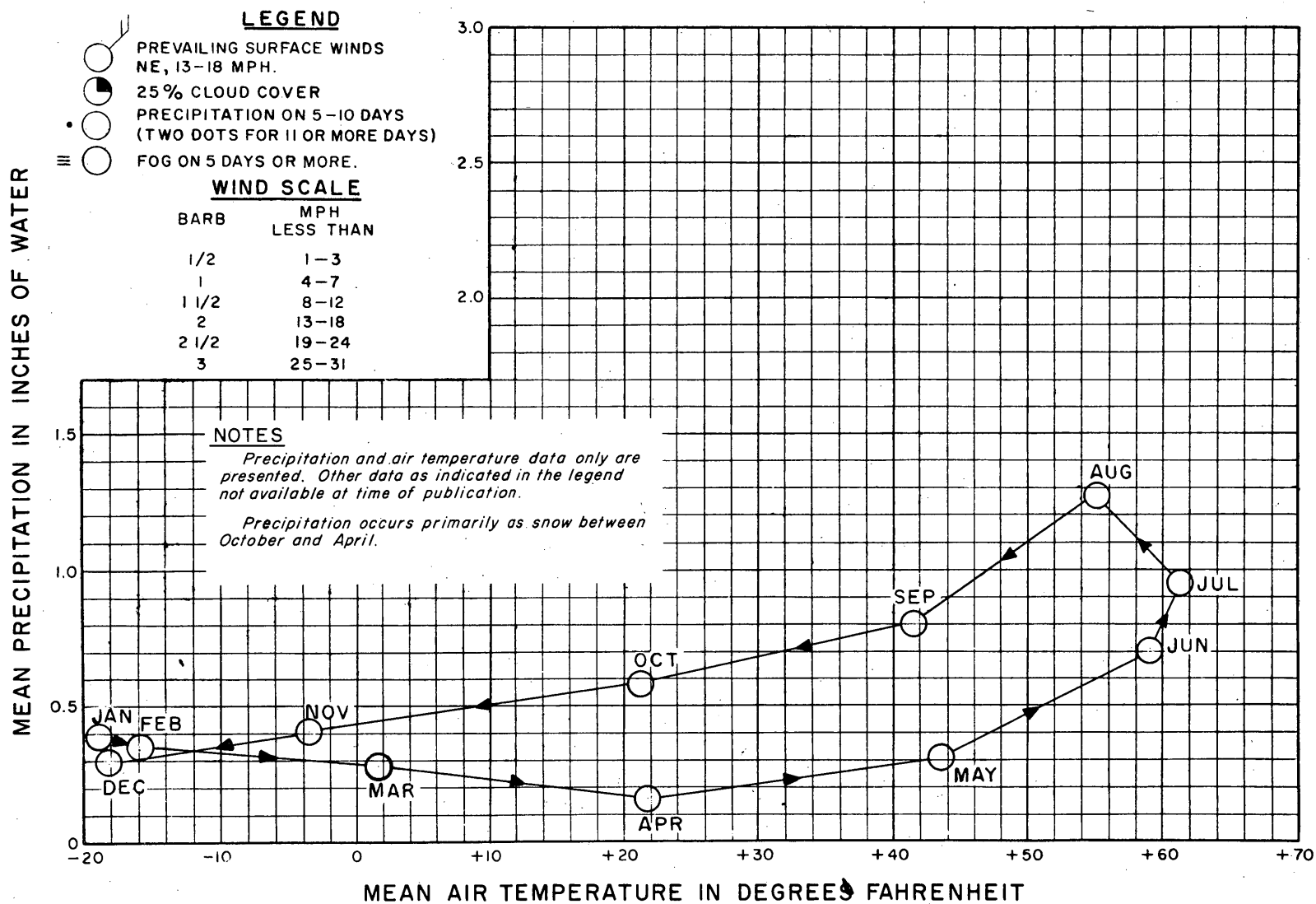


Figure 3. Climograph

GROUND-TEMPERATURE ASSEMBLY

Location

The ground-temperature assembly at Fort Yukon, Alaska is 122 feet northeast of the Federal Aviation Agency (FAA) quarters and control building and 500 feet north of the Yukon River (Fig. 5.) Surface drainage from the immediate area flows directly toward the temperature assembly from the west and south.

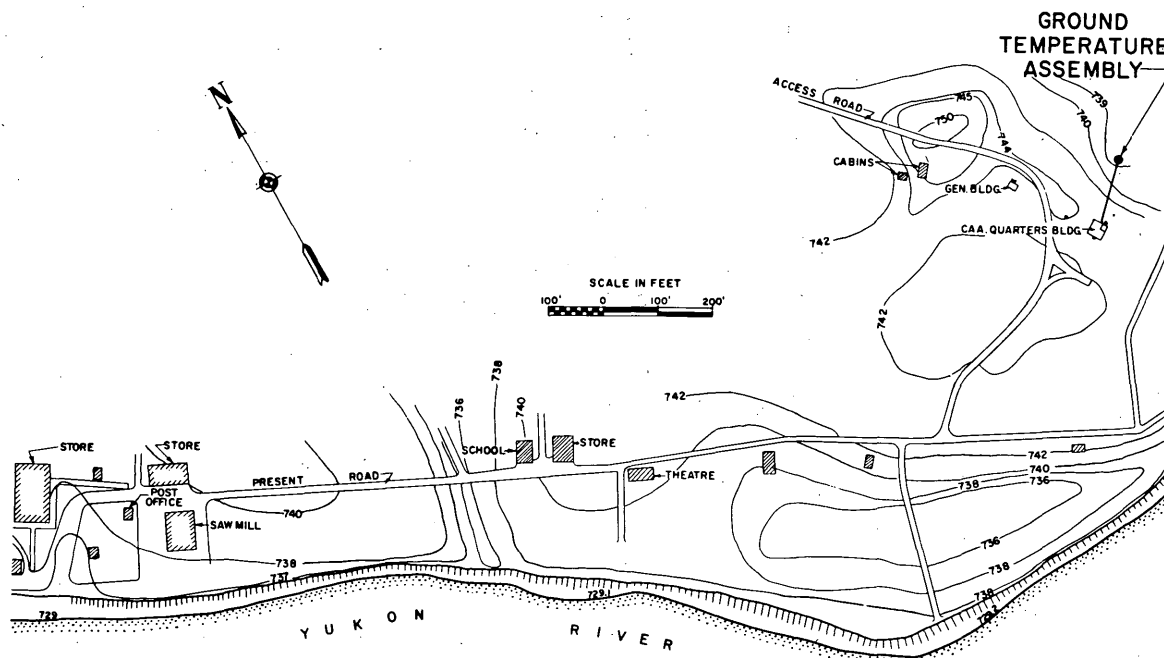


Figure 5. Site location.

The location of the temperature assembly in such close proximity to the Yukon River should be considered when interpreting the ground-temperature data, as it is possible that ground temperatures will vary considerably as the distance from the river increases.

Drilling the temperature well

Drilling operations began on 11 July 1946. The first hole attempted had to be abandoned after drilling to a depth of 6.4 feet, as gravel with cobbles up to 3 inches in diameter was encountered at that depth. A new location was chosen for a second attempt; drilling at that location was successful, although considerable difficulty was experienced in penetrating frozen gravel and sand. By a combination of water jetting and driving, a 22.5-ft-deep temperature well was completed on 14 July.

Instrumentation

The ground-temperature-measuring equipment installed at Fort Yukon consisted of nine copper resistance thermometers (thermohms); the three top thermohms were enclosed in 3/4-in.-diam tubing and the other six were suspended in a 2-in.-diam oil-filled pipe. The thermohms extended from 0.0 to 22.0 ft below the ground surface, spaced as shown in Figure 6. It should be noted that the 0.0-ft thermohm is actually 1/8-inch to 1/4-inch below the ground surface.

Temperature observations were made with a Leeds and Northrup Model 8015-S temperature indicator; it was a double range, Wheatstone-bridge type with one scale range of -50C to -5C and one of -15C to +30C.

GROUND TEMPERATURE OBSERVATIONS

Resistance thermometers were used instead of thermocouples because similar equipment had been used previously by the U. S. Weather Bureau and station personnel were familiar with the observational procedure. Also, the use of thermocouples would have necessitated the daily preparation of an ice bath for reference use, which is not practical when observations are obtained only in a single temperature well.

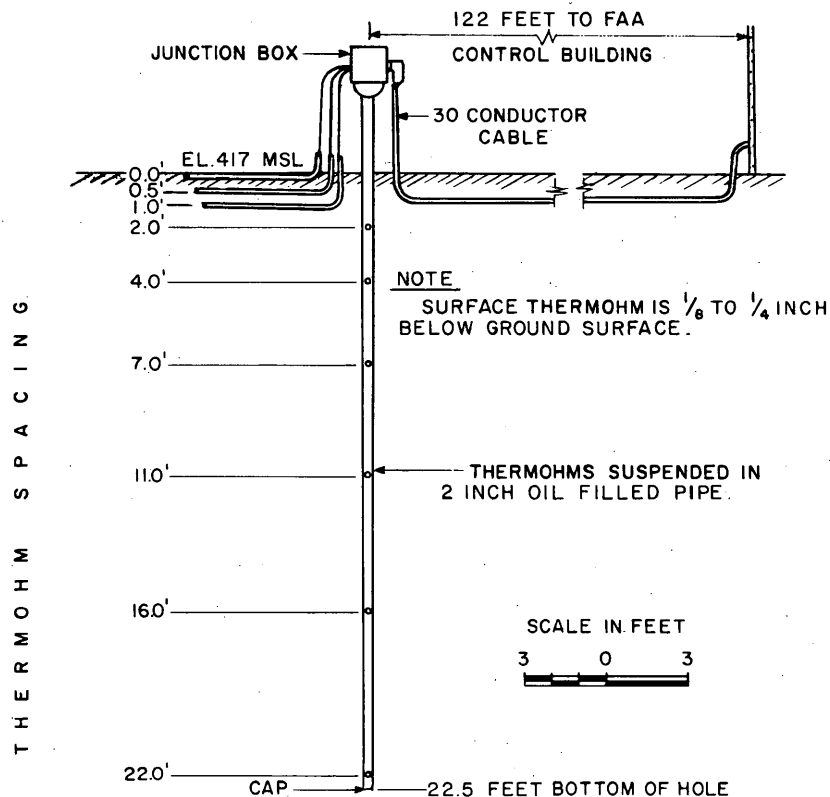


Figure 6. Resistance Thermometer Installation.

SOIL INVESTIGATIONS

Exploration

In conjunction with drilling operations for the temperature well, representative soil samples were obtained with a 4-in. hand auger after each drill run. During a field trip to the site to remove equipment on 23 July 1958, a 7-ft-deep exploratory hole was drilled 6 feet east of the temperature well. The exploratory drilling was performed by drive sampling with a Chicago pneumatic drill rig equipped with a 200-lb drop weight. A 3-in.-diam hardened steel drive tube was used as the sampler. Attempts to drive through the frozen gravelly sands beyond a 7-ft depth resulted in refusal and buckling of the sample tube.

Soil data

Laboratory tests were performed to identify and classify the soil samples obtained, with moisture content and density tests made on suitable representative samples. The boring log and soil data for the temperature well are shown in Figure 7, and the log and soil data for the exploratory hole are shown in Figure 8.

GROUND TEMPERATURES

Observed ground temperatures

Ground temperatures were recorded daily at Fort Yukon for 12 years (1947 to 1958). The maximum, minimum, and the average of the temperatures recorded the first day of each month are shown in Table 2. The actual ground temperatures recorded the first day of each month for the 1947-1958 period of observations are shown in Table 3.

Ground-temperature gradients

Ground-temperature gradients for a typical thaw and freeze season (1951-1952) at Fort Yukon are shown in Figure 9. Gradients were plotted for the end-of-thaw, mid-thaw, mid-freeze and end-of-freeze. The maximum and minimum ground temperatures recorded at each depth during the period of record are also presented.

The end-of-thaw gradient indicates the maximum depth of thaw for the 1951 thawing season; the end-of-freeze gradient shows the minimum subsurface temperatures recorded (at depths greater than 4 feet) for the freezing season. It should be noted that the maximum and minimum temperatures shown for the various depths do not represent the 1951-1952 season as do the gradients; rather, they are the maximum and minimum temperatures recorded at each depth during the years 1947 to 1958.

Depth to permafrost

The seasonal depth of thaw at Fort Yukon varied slightly from year to year; the average seasonal depth of thaw observed during the period of record (1947-1958) was approximately 7.5 feet below the ground surface.

When the ground-temperature well was drilled on 14 July 1946, frozen ground (permafrost) was encountered at a depth of 5.2 feet (Fig. 7). A hand augered hole drilled on 12 August 1949 reached frozen ground 7.5 feet below the surface. On 23 August 1958, an exploration hole was drilled as close as was physically possible (6.0 feet east) to the ground-temperature assembly, and frozen ground was encountered 6.2 feet below the ground surface, (Fig. 8).

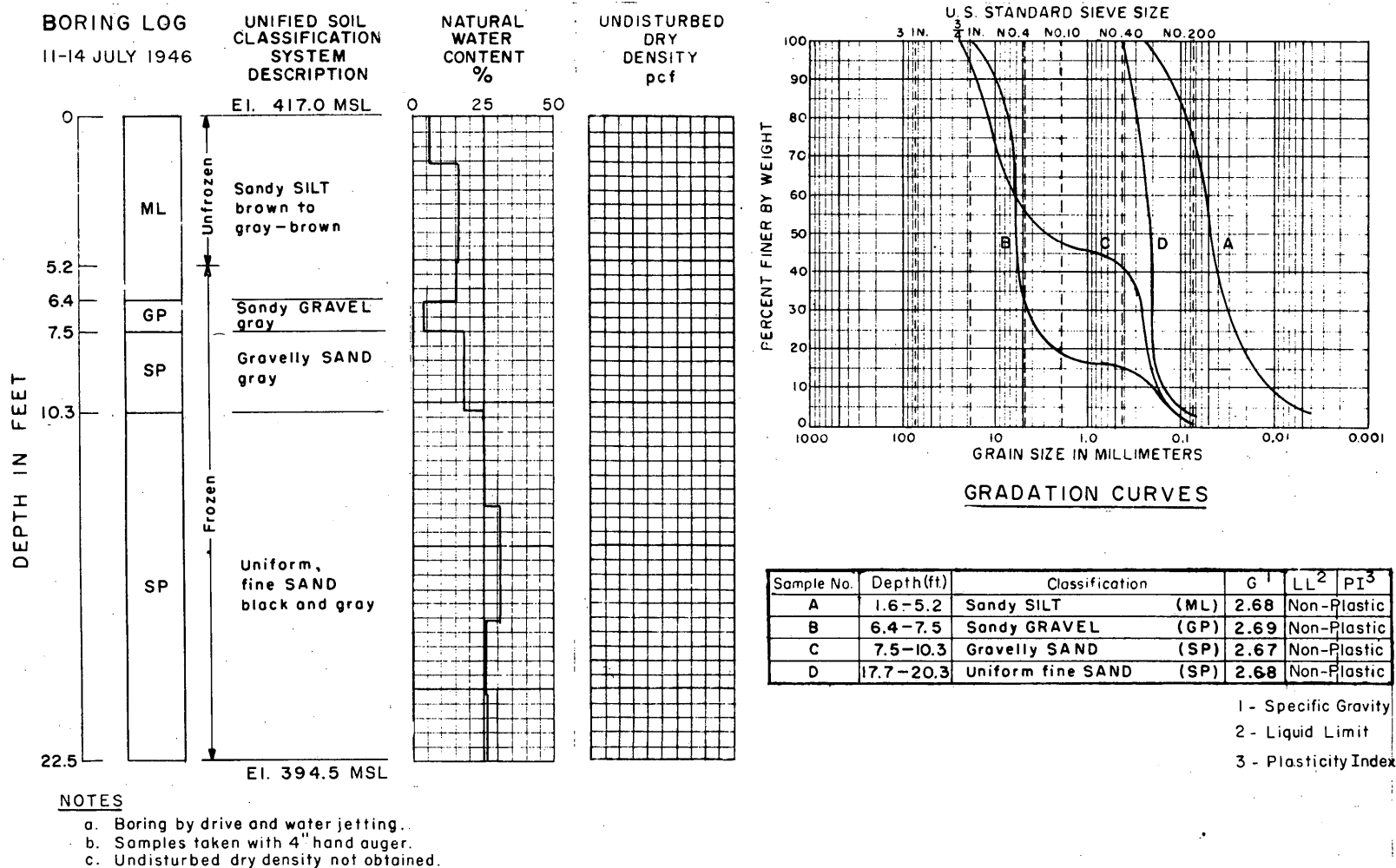


Figure 7. Boring Log and Soil Data, Ground Temperature Well, Fort Yukon, Alaska

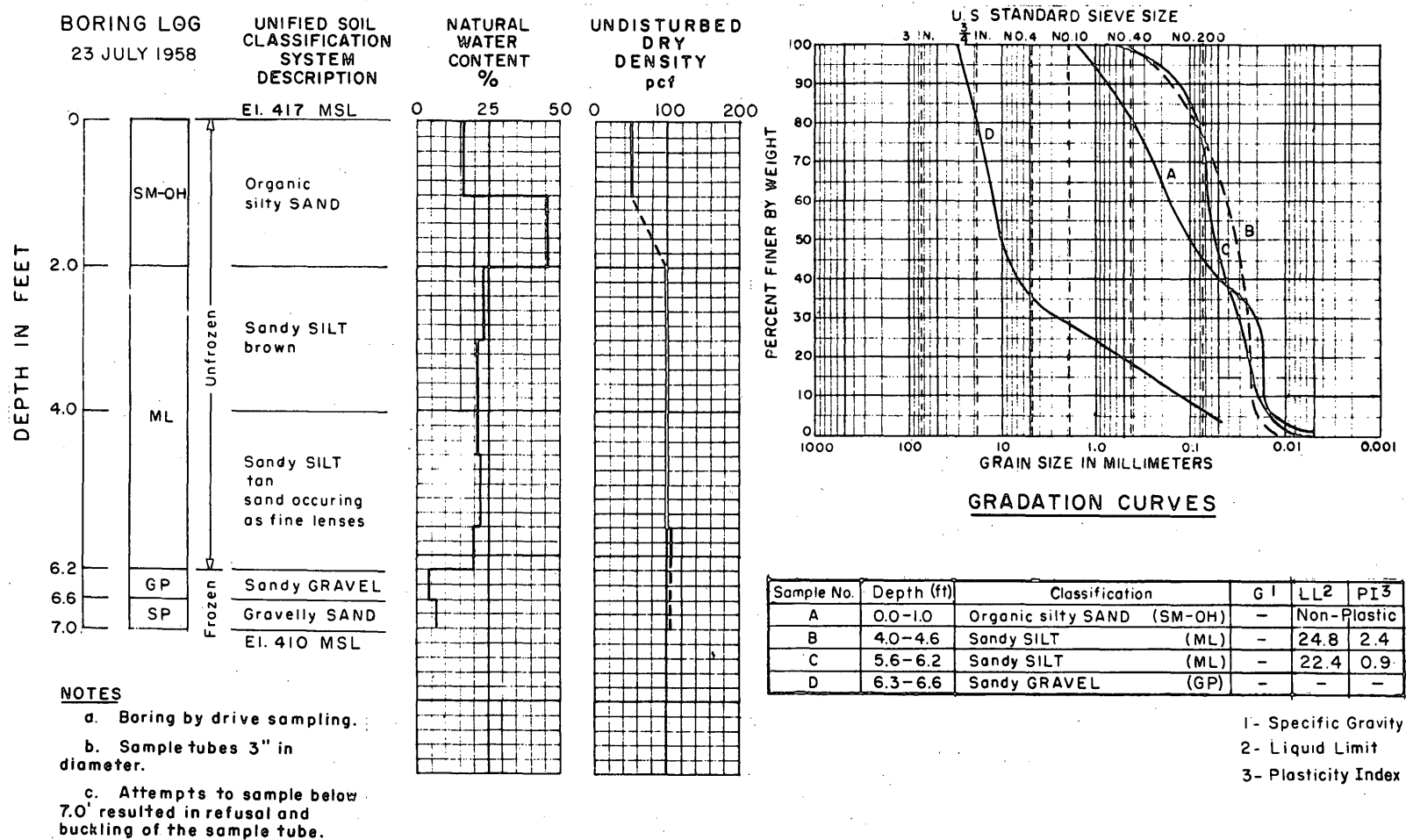


Figure 8. Boring Log and Soil Data, Exploratory Hole, Fort Yukon, Alaska

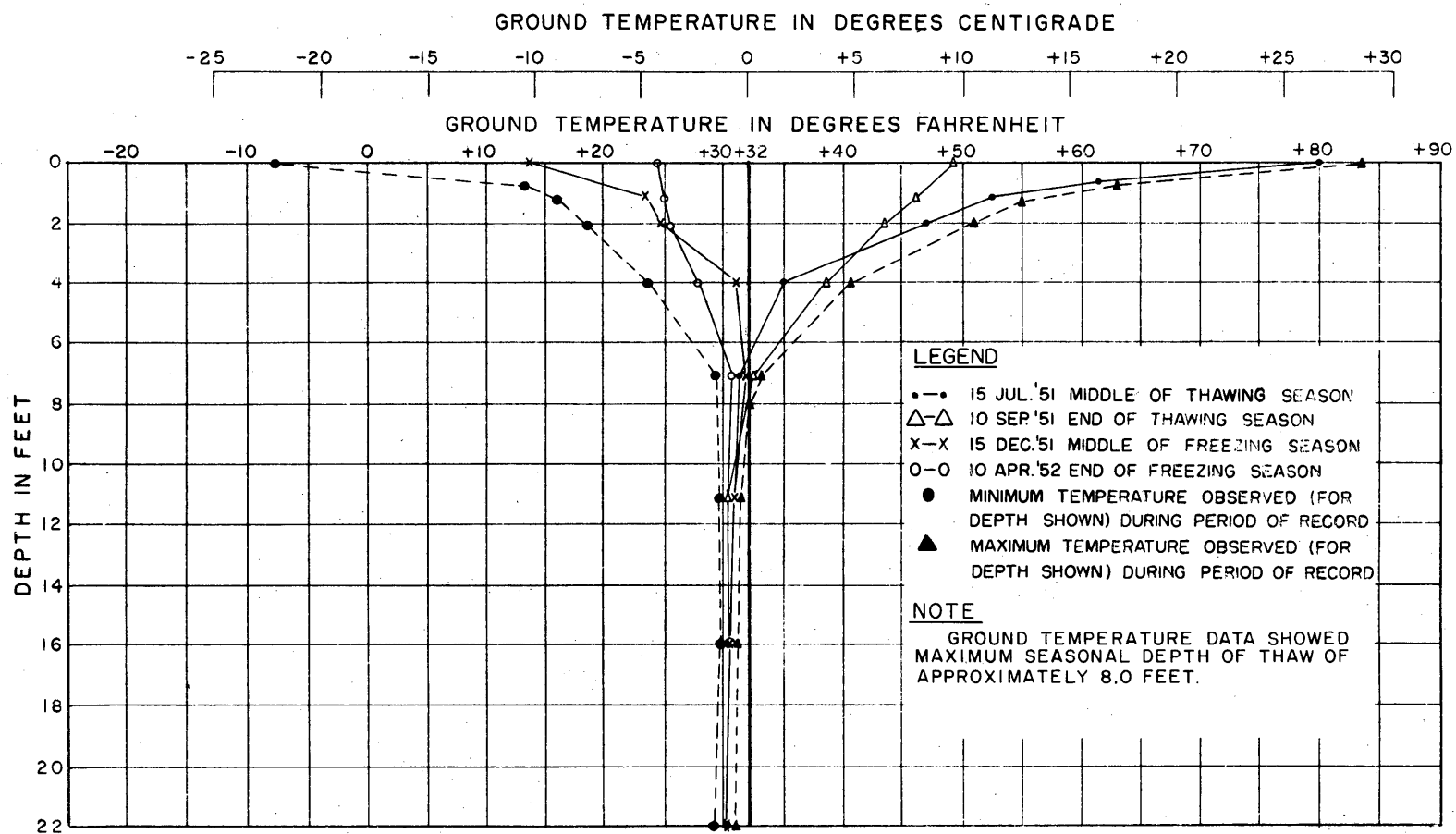


Figure 9. Ground-Temperature Gradients

11

[illegible][illegible]

TABLE 3
GROUND TEMPERATURES IN DEGREES FAHRENHEIT
RECORDED FIRST DAY OF MONTH, 1947-1958

| DEPTH IN FEET | 1947 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | * | 13.3 | 21.9 | 22.3 | 29.5 | 43.9 | 69.8 | 56.5 | 56.5 | 30.9 | 27.7 | 26.9 |
| 0.5 | * | 18.3 | 23.4 | 24.8 | 28.8 | 38.1 | 47.8 | 52.2 | 43.7 | 31.6 | 30.9 | 29.8 |
| 1.0 | * | 20.5 | 21.6 | 25.1 | 28.0 | 34.2 | 43.5 | 50.0 | 43.7 | 30.9 | 31.6 | 30.5 |
| 2.0 | * | 21.6 | 24.8 | 25.1 | 28.0 | 30.2 | 39.6 | 46.0 | 41.0 | 30.9 | 31.3 | 30.5 |
| 4.0 | * | 29.1 | 28.4 | 28.4 | 28.4 | 29.3 | 30.2 | 35.2 | 35.8 | 30.9 | 31.6 | 31.5 |
| 7.0 | * | 31.6 | 31.3 | 30.9 | 30.2 | 29.8 | 29.8 | 29.8 | 30.5 | 30.2 | 30.9 | 30.5 |
| 11.0 | * | 30.5 | 30.5 | 30.5 | 30.5 | 30.0 | 29.8 | 29.8 | 29.8 | 30.2 | 30.5 | 30.5 |
| 16.0 | * | 30.2 | 30.2 | 30.5 | 30.5 | 30.2 | 30.2 | 30.2 | 29.8 | 30.2 | 30.2 | 30.2 |
| 22.0 | * | 30.4 | 30.5 | 30.2 | 30.2 | 30.2 | 30.2 | 30.2 | 29.8 | 29.8 | 29.8 | 29.8 |

| DEPTH IN FEET | 1948 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 24.4 | 24.1 | 14.7 | 22.8 | 31.6 | 66.9 | 70.2 | 62.6 | 44.6 | 29.5 | 25.9 | 10.4 |
| 0.5 | 28.0 | 27.0 | 22.3 | 25.1 | 31.6 | 46.4 | 50.4 | 50.0 | 39.6 | 32.4 | 31.3 | 21.9 |
| 1.0 | 29.5 | 28.4 | 24.8 | 25.3 | 31.1 | 41.4 | 49.3 | 50.4 | 42.8 | 33.1 | 31.3 | 26.6 |
| 2.0 | 29.5 | 27.7 | 25.5 | 26.4 | 29.1 | 33.1 | 44.6 | 47.1 | 41.7 | 33.6 | 31.1 | 26.6 |
| 4.0 | 31.3 | 30.7 | 30.5 | 29.7 | 29.8 | 30.2 | 33.8 | 39.9 | 38.8 | 34.3 | 31.6 | 31.3 |
| 7.0 | 31.3 | 30.9 | 30.5 | 30.9 | 30.9 | 29.8 | 30.2 | 32.7 | 32.7 | 31.6 | 31.1 | 31.6 |
| 11.0 | 30.5 | 30.2 | 30.5 | 30.5 | 30.4 | 30.4 | 30.4 | 30.2 | 30.5 | 30.5 | 30.7 | 30.9 |
| 16.0 | 30.5 | 29.7 | 30.2 | 30.5 | 30.4 | 30.2 | 30.2 | 30.4 | 30.2 | 30.5 | 30.5 | 30.5 |
| 22.0 | 29.8 | 29.8 | 30.2 | 30.2 | 30.2 | 30.2 | 30.2 | 30.2 | 30.2 | 30.5 | 30.2 | 30.4 |

| DEPTH IN FEET | 1949 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 9.7 | 18.3 | 15.8 | 21.6 | 23.0 | * | * | * | 60.4 | 36.3 | 23.0 | 16.9 |
| 0.5 | 17.9 | 21.6 | 19.0 | 23.7 | 24.4 | * | * | * | 53.6 | 39.9 | 28.0 | 23.7 |
| 1.0 | 21.9 | 23.4 | 20.1 | 24.4 | 25.1 | * | * | * | 47.8 | 36.7 | 31.3 | 28.0 |
| 2.0 | 22.6 | 24.4 | 22.3 | 24.4 | 24.8 | * | * | * | 45.7 | 39.2 | 30.9 | 28.6 |
| 4.0 | 30.2 | 29.1 | 28.0 | 28.0 | 28.0 | * | * | * | 38.8 | 37.7 | 31.6 | 31.6 |
| 7.0 | 31.5 | 31.3 | 30.9 | 30.9 | 29.5 | * | * | * | 31.6 | 33.8 | 31.6 | 31.6 |
| 11.0 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | * | * | * | 30.5 | 31.6 | 30.9 | 30.5 |
| 16.0 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | * | * | * | 30.5 | 31.3 | 30.5 | 30.7 |
| 22.0 | 30.5 | 30.4 | 30.9 | 30.9 | 30.4 | * | * | * | 30.5 | 31.6 | 30.5 | 30.7 |

*Defective equipment

| DEPTH IN FEET | 1950 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 10.6 | 22.5 | 15.1 | 24.1 | 29.8 | 52.5 | 75.9 | 64.4 | 55.7 | 38.1 | 20.5 | 26.2 |
| 0.5 | 20.1 | 25.1 | 19.8 | 25.5 | 27.7 | 25.5 | 55.7 | 49.6 | 44.3 | 35.4 | 26.6 | 26.6 |
| 1.0 | 24.8 | 26.8 | 22.3 | 26.2 | 28.4 | 36.7 | 48.6 | 47.5 | 45.3 | 37.4 | 30.9 | 28.8 |
| 2.0 | 23.9 | 26.6 | 23.7 | 25.5 | 28.8 | 32.0 | 44.6 | 46.8 | 43.9 | 36.7 | 29.8 | 29.1 |
| 4.0 | 30.9 | 30.5 | 29.5 | 29.5 | 29.5 | 30.2 | 31.6 | 30.9 | 39.2 | 35.6 | 32.0 | 31.3 |
| 7.0 | 31.6 | 31.6 | 31.6 | 31.6 | 31.6 | 30.9 | 30.9 | 30.9 | 31.6 | 31.3 | 31.6 | 31.6 |
| 11.0 | 31.1 | 31.1 | 31.3 | 30.9 | 30.9 | 30.9 | 30.9 | 30.5 | 30.9 | 31.3 | 30.9 | 30.9 |
| 16.0 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | 30.5 | 30.6 | 31.3 | 30.9 | 30.9 |
| 22.0 | 30.5 | 30.5 | 30.7 | 30.5 | 30.5 | 30.5 | 30.2 | 30.2 | 30.5 | 30.5 | 30.5 | 30.5 |

TABLE 3 (CONT'D)
GROUND TEMPERATURES IN DEGREES FAHRENHEIT
RECORDED FIRST DAY OF MONTH, 1947-1958

| DEPTH IN FEET | 1951 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 25.5 | 20.8 | 23.0 | 26.6 | 30.5 | 60.1 | 74.1 | 70.2 | 45.0 | 29.5 | 23.4 | 21.4 |
| 0.5 | 26.6 | 23.0 | 23.7 | 26.2 | 28.8 | 42.8 | 52.2 | 50.7 | 42.8 | 30.2 | 24.8 | 23.2 |
| 1.0 | 28.0 | 25.5 | 25.5 | 27.0 | 28.4 | 44.2 | 50.0 | 51.4 | 46.4 | 30.2 | 28.8 | 27.0 |
| 2.0 | 28.0 | 24.4 | 25.5 | 27.3 | 29.1 | 33.4 | 43.2 | 47.5 | 43.9 | 29.8 | 29.8 | 27.0 |
| 4.0 | 30.9 | 30.5 | 29.8 | 29.5 | 29.5 | 30.2 | 31.3 | 38.8 | 39.2 | 28.8 | 31.6 | 30.9 |
| 7.0 | 31.6 | 31.6 | 31.6 | 31.3 | 31.3 | 30.9 | 30.9 | 31.6 | 31.3 | 31.6 | 31.6 | 31.5 |
| 11.0 | 30.9 | 30.9 | 31.3 | 31.1 | 30.9 | 30.9 | 30.9 | 30.5 | 30.9 | 30.5 | 31.3 | 30.9 |
| 16.0 | 30.9 | 30.5 | 31.3 | 30.9 | 30.9 | 30.9 | 30.5 | 30.5 | 30.5 | 30.9 | 30.5 | 30.0 |
| 22.0 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.2 | 29.8 | 30.2 | 30.9 | 30.7 |

| DEPTH IN FEET | 1952 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 20.7 | 19.9 | 21.6 | 23.0 | 31.3 | 63.7 | 69.1 | 56.5 | 50.4 | 18.7 | 27.3 | 23.0 |
| 0.5 | 21.2 | 20.7 | 21.2 | 23.0 | 29.8 | 39.2 | 50.4 | 44.3 | 43.2 | 26.6 | 28.0 | 23.4 |
| 1.0 | 27.5 | 23.2 | 23.0 | 24.4 | 29.5 | 37.0 | 49.3 | 49.3 | 45.3 | 32.0 | 29.8 | 27.3 |
| 2.0 | 23.4 | 22.6 | 23.4 | 23.7 | 28.8 | 32.0 | 43.2 | 46.0 | 42.3 | 30.2 | 30.2 | 28.4 |
| 4.0 | 30.5 | 28.9 | 28.0 | 27.7 | 28.4 | 29.5 | 30.2 | 37.7 | 37.7 | 30.2 | 30.9 | 30.5 |
| 7.0 | 31.3 | 31.5 | 31.6 | 30.9 | 30.5 | 30.5 | 29.8 | 30.5 | 32.0 | 31.3 | 31.3 | 30.5 |
| 11.0 | 30.4 | 30.7 | 30.9 | 30.5 | 30.2 | 30.5 | 30.5 | 30.2 | 29.8 | 29.8 | 30.2 | 30.2 |
| 16.0 | 30.4 | 30.9 | 30.9 | 30.5 | 30.5 | 30.2 | 30.2 | 30.2 | 30.5 | 30.2 | 30.5 | 30.5 |
| 22.0 | 30.5 | 30.5 | 30.5 | 30.2 | 30.5 | 30.5 | 30.2 | 30.5 | 30.2 | 29.8 | 30.2 | 30.2 |

| DEPTH IN FEET | 1953 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 22.3 | 12.9 | 20.5 | 21.9 | 29.8 | 66.6 | 54.7 | 77.0 | 51.1 | 30.2 | 15.8 | 13.6 |
| 0.5 | 24.4 | 16.9 | 21.6 | 21.9 | 29.8 | 45.7 | 46.0 | 54.7 | 44.6 | 28.8 | 18.9 | 18.1 |
| 1.0 | 27.7 | 21.0 | 23.7 | 30.5 | 30.5 | 42.4 | 47.5 | 54.0 | 40.6 | 34.2 | 27.3 | 23.7 |
| 2.0 | 27.7 | 19.0 | 23.7 | 30.2 | 30.2 | 35.6 | 43.9 | 50.4 | 43.5 | 32.7 | 26.2 | 24.8 |
| 4.0 | 30.9 | 29.5 | 28.8 | 27.7 | 29.1 | 29.5 | 31.3 | 38.8 | 39.2 | 34.5 | 28.4 | 30.7 |
| 7.0 | 31.6 | 31.6 | 31.6 | 31.3 | 30.5 | 30.5 | 30.5 | 30.9 | 32.7 | 32.4 | 30.9 | 31.5 |
| 11.0 | 31.3 | 30.9 | 30.9 | 30.9 | 30.5 | 30.5 | 30.5 | 30.9 | 30.5 | 30.5 | 30.9 | 30.9 |
| 16.0 | 30.9 | 30.9 | 30.9 | 30.9 | 30.5 | 30.5 | 30.5 | 30.9 | 30.5 | 30.5 | 30.5 | 30.5 |
| 22.0 | 30.9 | 30.9 | 30.9 | 30.9 | 30.5 | 30.5 | 30.5 | 30.9 | 30.5 | 30.5 | 30.5 | 30.2 |

| DEPTH IN FEET | 1954 | | | | | | | | | | | |
|---------------------|------|------|------|------|-----|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 19.8 | 16.2 | 14.2 | * | * | 62.2 | 72.0 | 61.2 | 51.8 | 31.6 | 28.0 | 22.6 |
| 0.5 | 20.3 | 17.6 | 15.1 | * | * | 42.5 | 62.2 | 47.1 | 41.7 | 25.9 | 29.8 | 23.4 |
| 1.0 | 21.6 | 20.5 | 19.4 | * | * | 40.3 | 55.0 | 48.6 | 46.4 | 33.4 | 29.8 | 28.0 |
| 2.0 | 21.9 | 20.3 | 26.4 | * | * | 35.2 | 47.1 | 45.7 | 44.2 | 34.5 | 30.2 | 28.4 |
| 4.0 | 27.9 | 26.9 | 31.3 | * | * | 29.5 | 33.8 | 37.7 | 39.2 | 34.2 | 31.6 | 30.9 |
| 7.0 | 31.5 | 31.3 | 31.1 | * | * | 30.2 | 30.5 | 31.6 | 31.6 | 31.6 | 32.0 | 31.6 |
| 11.0 | 28.4 | 25.5 | 31.1 | * | * | 30.9 | 30.9 | 30.9 | 30.9 | 30.5 | 30.5 | 30.9 |
| 16.0 | 30.2 | 30.2 | 30.9 | * | * | 30.9 | 30.9 | 30.9 | 30.9 | 30.5 | 30.5 | 30.9 |
| 22.0 | 29.7 | 30.2 | 30.2 | * | * | 30.9 | 30.9 | 30.9 | 30.9 | 30.5 | 30.9 | 30.9 |

GROUND TEMPERATURE OBSERVATIONS

TABLE 3 (CONT'D)
GROUND TEMPERATURES IN DEGREES FAHRENHEIT
RECORDED FIRST DAY OF MONTH, 1947-1958

| DEPTH IN FEET | 1955 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 18.0 | 20.8 | 20.1 | 23.4 | 37.7 | * | * | * | 44.6 | 31.6 | 17.6 | 21.2 |
| 0.5 | 20.5 | 20.8 | 22.6 | 23.0 | 24.8 | * | * | * | 39.9 | 30.9 | 21.2 | 23.4 |
| 1.0 | 24.8 | 24.4 | 22.3 | 24.4 | 26.2 | * | * | * | 43.5 | 34.2 | 29.3 | 27.7 |
| 2.0 | 23.0 | 24.8 | 22.6 | 23.7 | 27.3 | * | * | * | 42.4 | 34.9 | 28.4 | 27.3 |
| 4.0 | 30.5 | 29.8 | 28.4 | 28.4 | 28.4 | * | * | * | 39.2 | 35.2 | 32.0 | 31.3 |
| 7.0 | 31.6 | 31.6 | 31.3 | 31.3 | 31.3 | * | * | * | 32.7 | 32.4 | 32.0 | 32.0 |
| 11.0 | 30.9 | 30.5 | 30.9 | 30.9 | 31.6 | * | * | * | 30.9 | 31.3 | 31.1 | 30.9 |
| 16.0 | 30.9 | 30.5 | 30.9 | 30.9 | 31.3 | * | * | * | 30.9 | 31.3 | 31.1 | 30.9 |
| 22.0 | 30.9 | 30.5 | 30.5 | 30.5 | 31.3 | * | * | * | 30.9 | 30.9 | 31.1 | 30.9 |

| DEPTH IN FEET | 1956 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 20.3 | 21.2 | 20.5 | 23.0 | 32.0 | 47.1 | 69.1 | 55.0 | 40.6 | 29.8 | 25.1 | 24.1 |
| 0.5 | 21.7 | 21.6 | 21.2 | 23.0 | 29.1 | 37.7 | 49.6 | 48.6 | 38.9 | 28.8 | 27.0 | 26.1 |
| 1.0 | 24.8 | 24.1 | 23.4 | 24.4 | 29.8 | 38.8 | 50.0 | 47.1 | 43.9 | 33.8 | 29.8 | 28.8 |
| 2.0 | 25.3 | 23.0 | 22.6 | 24.4 | 29.1 | 33.1 | 45.0 | 47.5 | 42.1 | 34.5 | 29.8 | 27.9 |
| 4.0 | 30.5 | 30.2 | 28.8 | 28.0 | 28.4 | 30.2 | 33.1 | 39.6 | 38.8 | 33.8 | 31.6 | 29.8 |
| 7.0 | 31.8 | 32.0 | 31.6 | 31.3 | 30.5 | 30.5 | 31.1 | 32.4 | 32.7 | 32.4 | 32.0 | 31.6 |
| 11.0 | 31.3 | 31.3 | 31.3 | 31.3 | 30.9 | 30.9 | 31.3 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 |
| 16.0 | 30.9 | 31.3 | 31.3 | 31.3 | 30.9 | 30.9 | 30.2 | 30.9 | 31.3 | 30.5 | 30.5 | 30.2 |
| 22.0 | 30.9 | 31.3 | 30.9 | 30.9 | 30.9 | 30.9 | 31.3 | 30.9 | 30.9 | 30.9 | 30.9 | 29.3 |

| DEPTH IN FEET | 1957 | | | | | | | | | | | |
|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | * | * | * | 23.4 | 28.0 | 48.2 | 56.5 | 59.7 | 52.5 | 25.1 | 22.8 | 21.2 |
| 0.5 | * | * | * | 23.7 | 28.8 | 35.6 | 43.9 | 45.0 | 38.5 | 27.3 | 26.9 | 23.4 |
| 1.0 | * | * | * | 25.1 | 29.5 | 35.2 | 45.0 | 46.4 | 47.1 | 32.7 | 31.3 | 29.8 |
| 2.0 | * | * | * | 25.5 | 28.0 | 32.0 | 40.6 | 47.1 | 45.0 | 33.4 | 31.1 | 29.1 |
| 4.0 | * | * | * | 29.8 | 29.5 | 29.5 | 33.8 | 38.8 | 39.2 | 34.2 | 31.6 | 30.5 |
| 7.0 | * | * | * | 31.6 | 31.6 | 30.5 | 30.5 | 30.9 | 32.7 | 30.2 | 32.0 | 31.6 |
| 11.0 | * | * | * | 30.9 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.9 | 28.8 | 30.2 |
| 16.0 | * | * | * | 30.5 | 30.9 | 30.9 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 |
| 22.0 | * | * | * | 30.9 | 30.5 | 30.9 | 30.5 | 30.2 | 30.5 | 30.2 | 30.2 | 30.5 |

| DEPTH IN FEET | 1958 | | | | | | | | | | | |
|---------------------|------|------|------|------|-----|------|------|------|------|------|------|------|
| | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
| 0.0 | 23.0 | 21.9 | 20.5 | 23.7 | | | | | | | | |
| 0.5 | 23.7 | 24.8 | 21.9 | 24.1 | | | | | | | | |
| 1.0 | 29.1 | 24.1 | 25.5 | 25.5 | | | | | | | | |
| 2.0 | 28.0 | 26.6 | 25.5 | 26.2 | | | | | | | | |
| 4.0 | 29.8 | 31.3 | 29.8 | 29.8 | | | | | | | | |
| 7.0 | 31.6 | 32.0 | 31.6 | 31.6 | | | | | | | | |
| 11.0 | 30.5 | 30.2 | 30.2 | 30.2 | | | | | | | | |
| 16.0 | 30.2 | 31.3 | 30.5 | 30.5 | | | | | | | | |
| 22.0 | 30.5 | 31.3 | 30.5 | 30.2 | | | | | | | | |

GROUND TEMPERATURE OBSERVATIONS

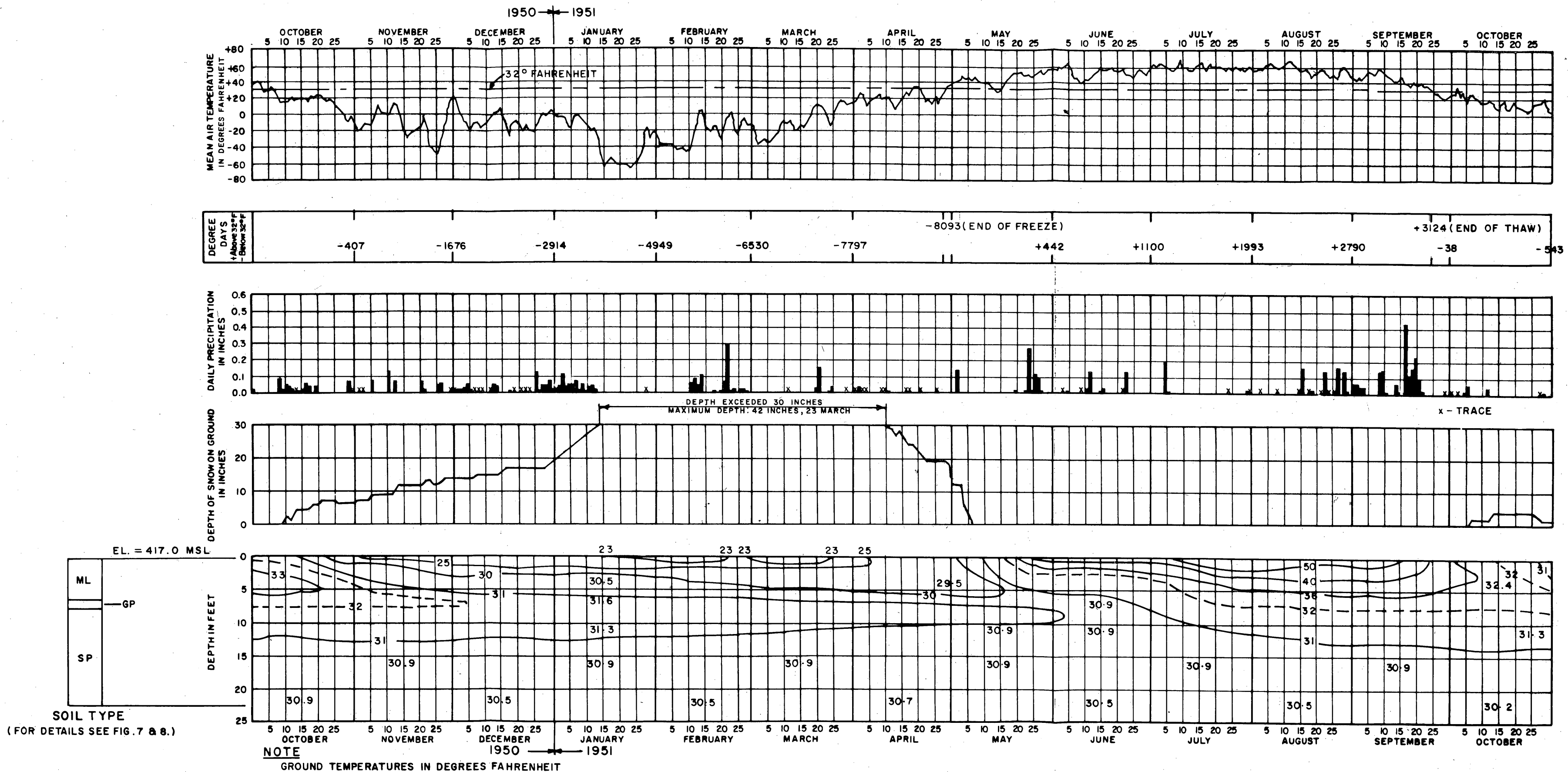


Figure 4. Meteorological Data and Ground Isotherms