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Ground Temperature Observations Big Delta, Alaska

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PREFACE

Collection of the data presented herein was authorized in July 1946 by the Chief of Engineers, in "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. It was carried out for the Civil Engineering Branch, Engineering Division, Military Construction, Office, Chief of Engineers. In February 1961 ACFEL was merged with the U. S. Army Snow Ice and Permafrost Research Establishment to form the U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL).

The program included the collection of data at 20 stations in Alaska and one in Canada. The present report summarizes the data obtained at one of these stations. 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, under the direction of Mr. F. F. Kitze, Chief. 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.

This report was prepared by the Construction Engineering Branch (Mr. E. F. Lobacz, Chief) as a project of the Experimental Engineering Division (Mr. K. A. Linell, Chief).

Construction Engineering Branch personnel actively engaged in this project have been Messrs. George W. Aitken, C. W. Fulwider, and Spc. R. Huck. Mr. J. F. Haley, formerly Assistant Chief, ACFEL, Mr. Harry Carlson, formerly Chief, Permafrost Division, and many others of these organizations contributed substantially in this investigation. Mr. Aitken and Mr. Fulwider analyzed the project data and prepared the basic format for the report series.

Commanding Officer of USA CRREL during the preparation and publication of this report was Colonel William L. Nungesser. Technical Director was Mr. W. K. Boyd.

This report has been reviewed and approved for publication by the Office of the Chief of Engineers, U. S. Army.

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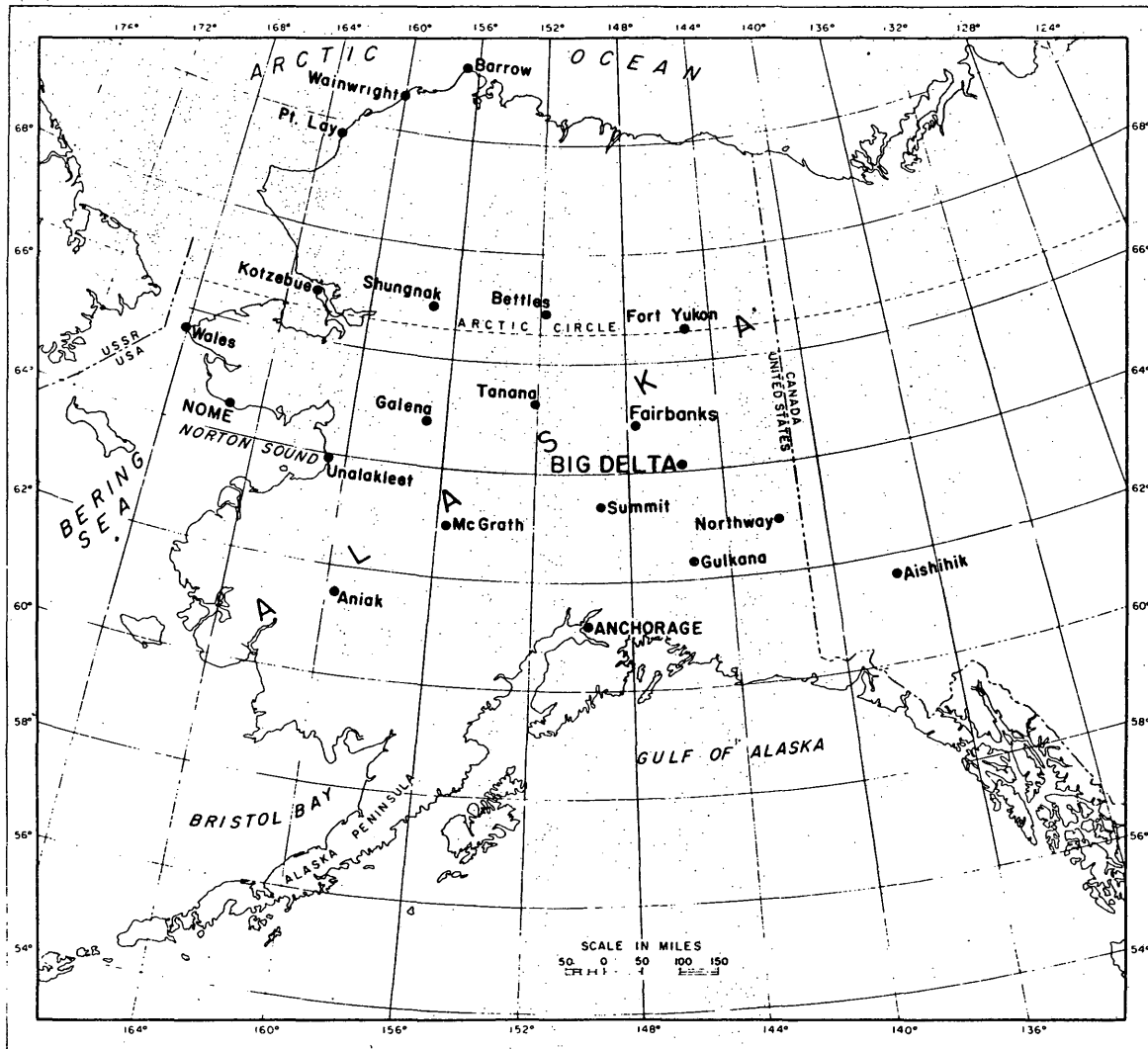
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SUMMARY

This report summarizes climatological, ground-temperature and soil data obtained at Big Delta, Alaska. The climatological data were taken from U.S. Weather Bureau records. Various periods-of-record were used with a minimum period of 10 years unless otherwise stated in the report. The ground-temperature data were obtained from daily observations during the years 1947-1960; and the soil data were obtained from samples taken when drilling the ground-temperature well in June 1946, and during the excavation of a test pit in May 1962.



Ground-temperature observation sites.

GROUND TEMPERATURE OBSERVATIONS

BIG DELTA, ALASKA

by

G. W. Aitken

INTRODUCTION

Purpose

The Big Delta, 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 investigational efforts.

Scope

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

The climatological data for Big Delta, Alaska were taken from U.S. Weather Bureau records. Ground-temperature observations were made on a daily basis from 1947 to 1960 by the 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 the temperature well in June 1946, and from a test pit excavated in May 1962.

DESCRIPTION OF SITE

Location

Big Delta is located in East Central Alaska, about 100 air miles southeast of Fairbanks at 64°00' north latitude and 145°44' west longitude (Fig. 1). It is situated between the Big Delta River and tributary, Jarvis Creek, at a point where they are separated by about one mile, approximately 1 1/2 miles south of their confluence. The site is accessible by air and by the Richardson Highway at all times of the year.

Terrain

Big Delta is located in the Tanana lowlands area of interior Alaska, just north of the Alaska Range. This area is characterized by a wide variety of terrain features varying from the heights of Donnelly Dome to the flat stream flood-plains of the Tanana and Delta Rivers.

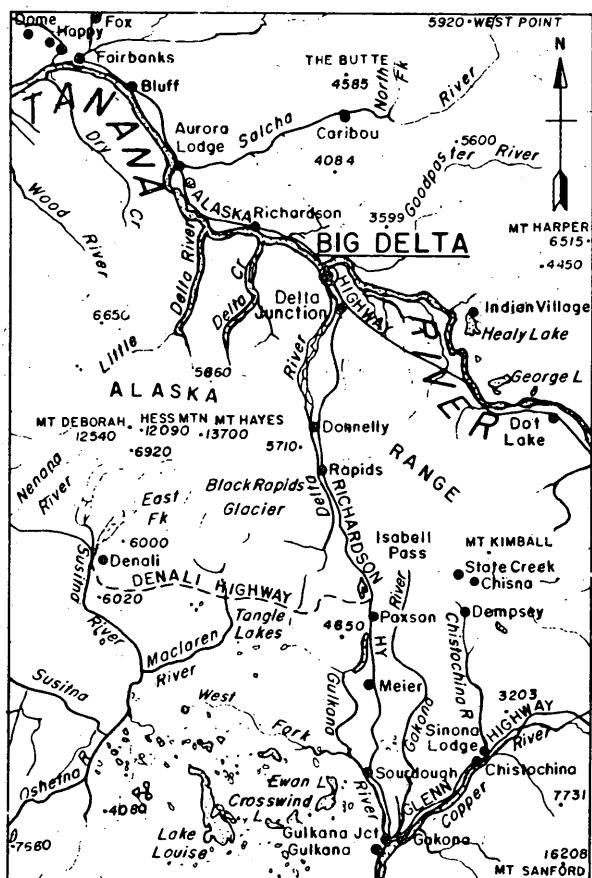


Figure 1. Vicinity map.

Climate

Climatological data for Big Delta are given in Table I and Figures 2 and 3.

Table I gives air temperatures, amounts of precipitation, snowfall and snow cover, and the freezing and thawing indexes. The air temperatures were obtained in accordance with standard Weather Bureau procedures. The snow cover measurements were made in the vicinity of the FAA building and are believed to be representative of the area where the ground-temperature assembly is located.

Figure 2, a climograph (also called a hythergraph) gives: mean monthly values of precipitation versus temperature; direction and force of prevailing winds; amount of cloud cover; number of days of precipitation (rain and/or snow); and fog data for the area.

Figure 3 presents meteorological data and ground isotherms for a typical year (October 1949 to October 1950). The meteorological data include average daily air temperatures, degree days of thaw and freeze (cumulative on the last day of each month), daily precipitation (rain and/or snow) and depth of snow on the ground.

GROUND TEMPERATURE OBSERVATIONS

Table I. Climatological data
for
Big Delta, Alaska

Air temperature - °F

Mean annual		27.6
Recorded high	7/4/58	91
Recorded low	1/30/47	-63

Precipitation - inches

Mean annual		11.6
Max. annual	(1955)	16.9
Max. monthly	(July 1945)	6.2

Snowfall - inches

Mean annual		36.9
Max. annual	(1955)	63.9
Max. monthly	(Dec 1955)	29.0

Freezing index (degree-days, F, below 32)

Average	(1947 - 1954)	5063
Minimum	(Oct 52 - Apr 53)	3888
Maximum	(Oct 50 - Apr 51)	5798

Thawing index (degree-days, F, above 32)

Average	(1947 - 1954)	3184
Minimum	(Apr 47 - Oct 47)	2057
Maximum	(Apr 53 - Oct 53)	3675

Average date start freeze season	- 14 Oct
Average date start thaw season	- 22 Apr
Average length of freeze season (days)	- 192
Average length of thaw season (days)	169

Snow cover in inches

first day of month for 1948-1958

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Maximum recorded	0	2	9	10	49	54	50	13	12	0
Minimum recorded	0	0	1	1	2	2	6	3	1	0
10-year average	0	T	4	5	10	16	17	11	3	0

T = Trace

CONVERT OF-days → °C-lws
 OF-days * 1.8 → (5063 °F-days) * 1.8 = 9113.4 °C-lws
 24 lws

→ 2812.07 °C-days

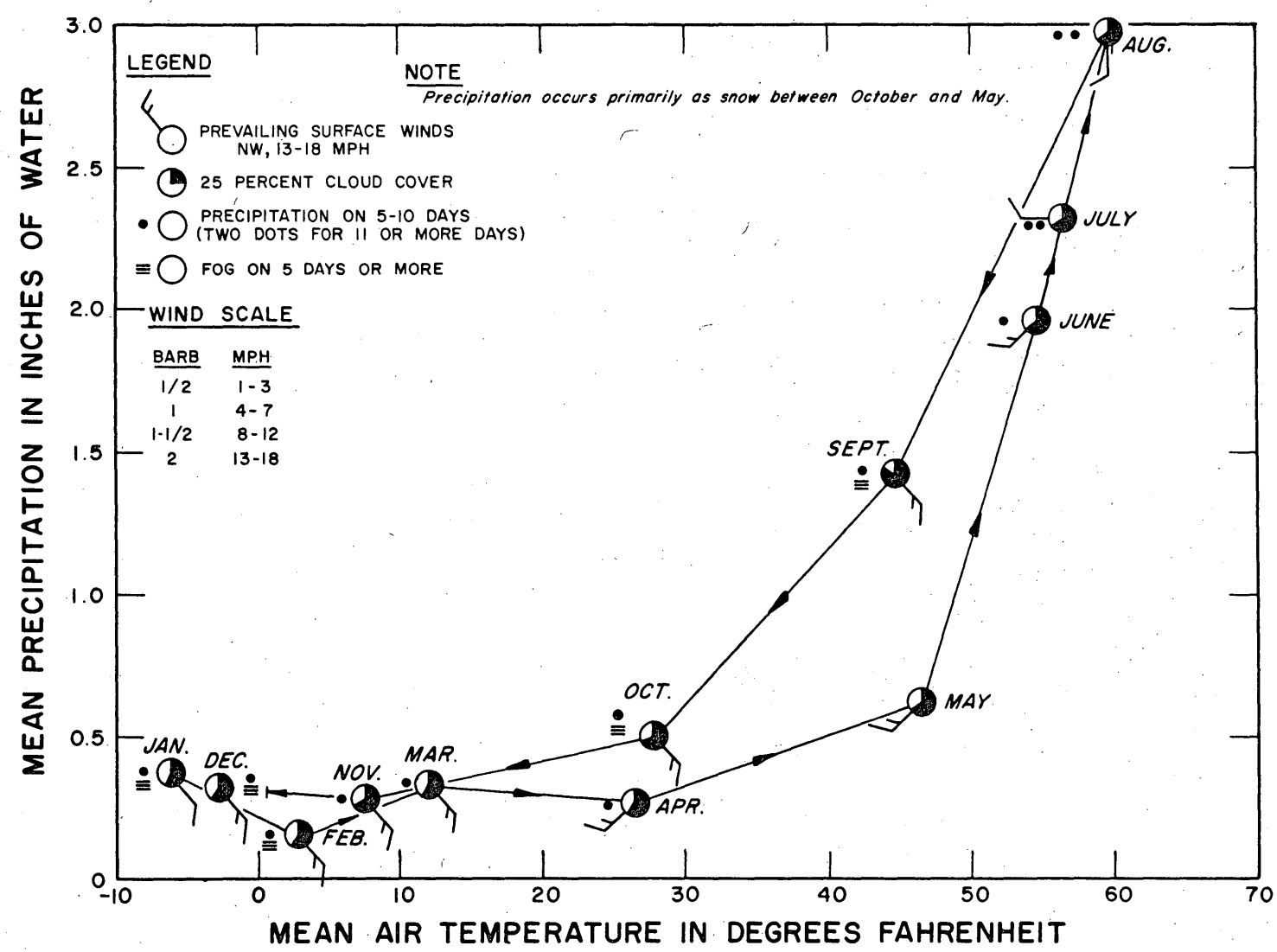


Figure 2. Climograph.

GROUND-TEMPERATURE ASSEMBLY

Location

The ground-temperature assembly was installed 111 feet northeast of the FAA control building, about 300 feet northwest of the south end of the main runway, and about 120 feet east of a taxiway (Fig. 4).

The location of the temperature assembly in such close proximity to a paved runway and taxiway should be considered when interpreting the ground temperature data.

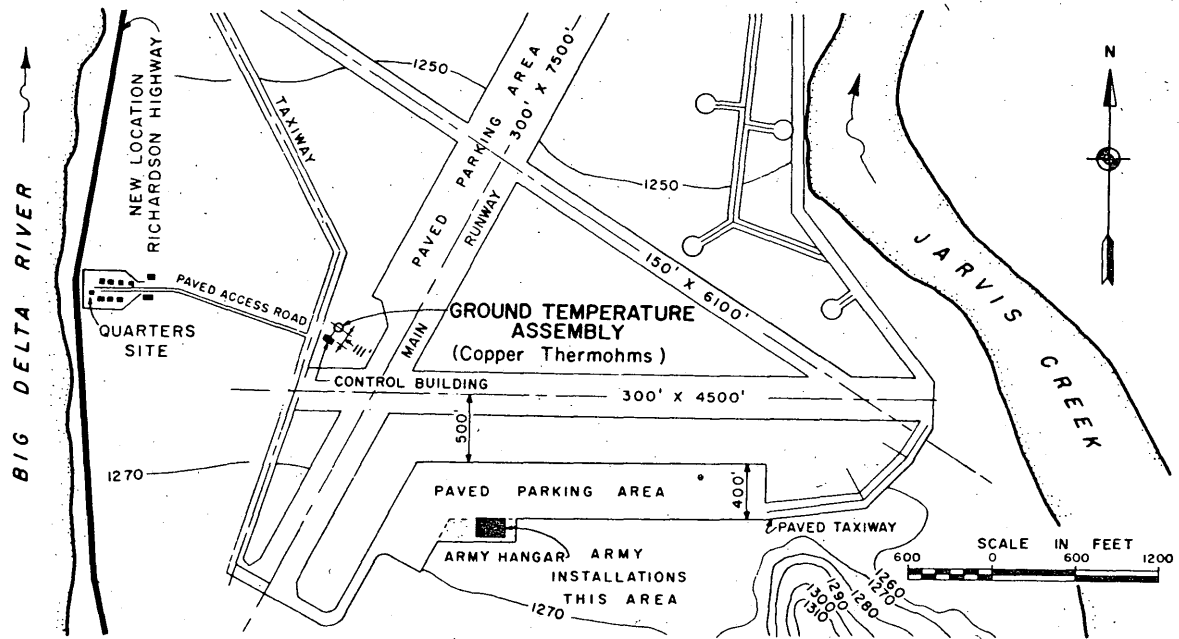


Figure 4. Site location.

Drainage and vegetation

At the temperature assembly, the ground surface elevation is about 1260 feet above mean sea level and slopes gently to the west. The site is slightly above the elevation of the adjacent runway and taxiway, and is believed to have been entirely free of surface water during the period of record.

The surface cover during the observational period consisted of a sparse growth of grass (Fig. 5).

Temperature well drilling

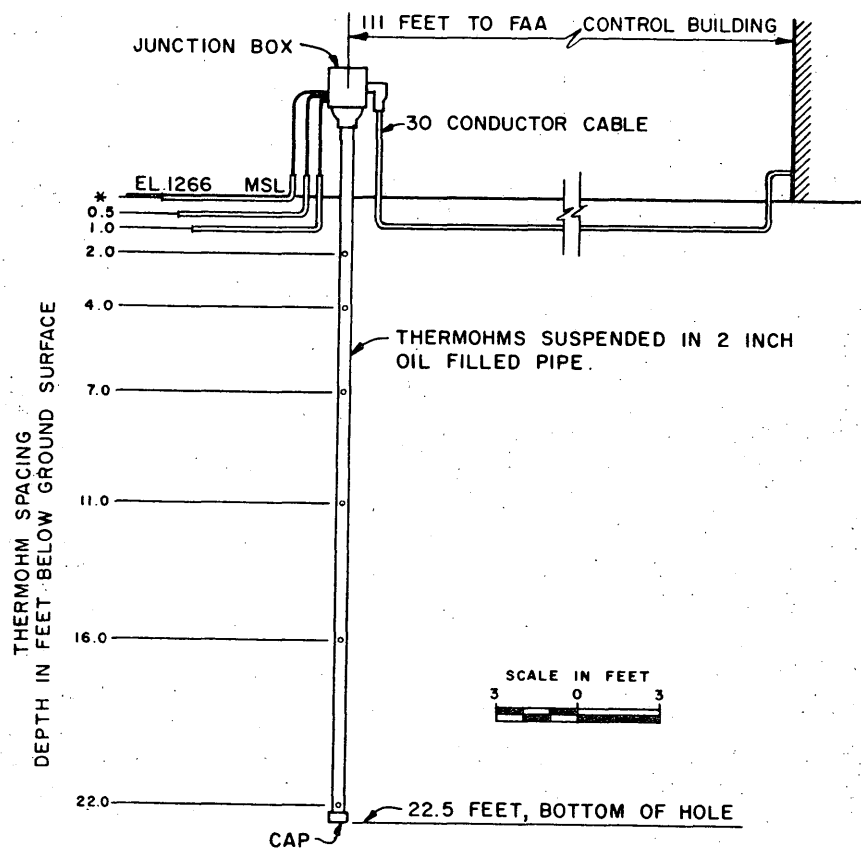
Drilling operations for the temperature well were started on 18 January 1946. Large and closely spaced boulders were encountered and the crew was unable to drill beyond a 9-ft depth in any of several attempted locations with the available equipment, and was forced to suspend operations. The drilling was resumed on 15 June 1946, with a heavier churn drill; progress was slow and the 22.5-ft deep temperature well was not completed until 18 June.

Instrumentation

The ground-temperature measuring equipment installed at Big Delta consisted of nine copper resistance thermometers (thermohms); the top three thermohms were individually encased in $\frac{3}{4}$ -in. diam steel tubing and the other six thermohms were suspended in a 2-in. oil-filled pipe. The thermohms extended from 0.0 to 22.0 feet below the ground surface and were spaced as shown in Figure 6. It should be noted that the 0.0-ft thermohm was actually installed $\frac{1}{8}$ to $\frac{1}{4}$ -in. below the ground surface.



Figure 5. Surface cover in area of ground-temperature assembly.



* Thermohm located $\frac{1}{8}$ to $\frac{1}{4}$ inch below ground surface.

Figure 6. Resistance thermometer installation.

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

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 involved.

SOIL INVESTIGATIONS

Exploration

In conjunction with drilling observations for the temperature well, representative soil samples were obtained with a 4-in. hand auger after each drill run. In May 1962, in connection with the termination of ground-temperature observations at the station, a 10-ft-deep test pit was excavated to obtain supplementary soil data, with one wall of the test pit located 6-in. from the temperature well.

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. Density determinations in the test pit below 6 feet were made in-place using a Washington Densometer. The boring log and soil data for the temperature well are shown in Figure 7, and the log and soil data for the test pit are shown in Figure 8.

GROUND TEMPERATURES

Observed ground temperatures

Ground temperatures were recorded daily at Big Delta from February 1947 through June 1960. The maximum, minimum, and the average of the temperatures recorded the first day of each month are shown in Table II. The actual ground temperatures recorded the first day of each month for the 1947-1960 period of observation are shown in Table III.

Ground-temperature gradients and maximum-minimum curves

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

The end-of-thaw gradient indicates the maximum temperatures recorded (at each depth greater than 4 feet) during the 1951 thawing season; the end-of-freeze gradient shows the minimum subsurface temperatures recorded (at depths greater than 4 feet) for 1950-1951 freezing season. It should be noted that the maximum and minimum temperatures shown for the various depths do not represent January-Sept 1951 period as do the gradients; rather, they are the maximum and minimum temperatures recorded at each depth during the years 1947 to 1960.

Seasonal frost

The ground-temperature data obtained at Big Delta show that there is no permafrost at the site to a depth of 22 feet. These data are corroborated by the 22.5-ft-deep hole drilled in June 1946. The average depth of seasonal frost penetration shown by the ground temperature data was about 14 feet during the period of record.

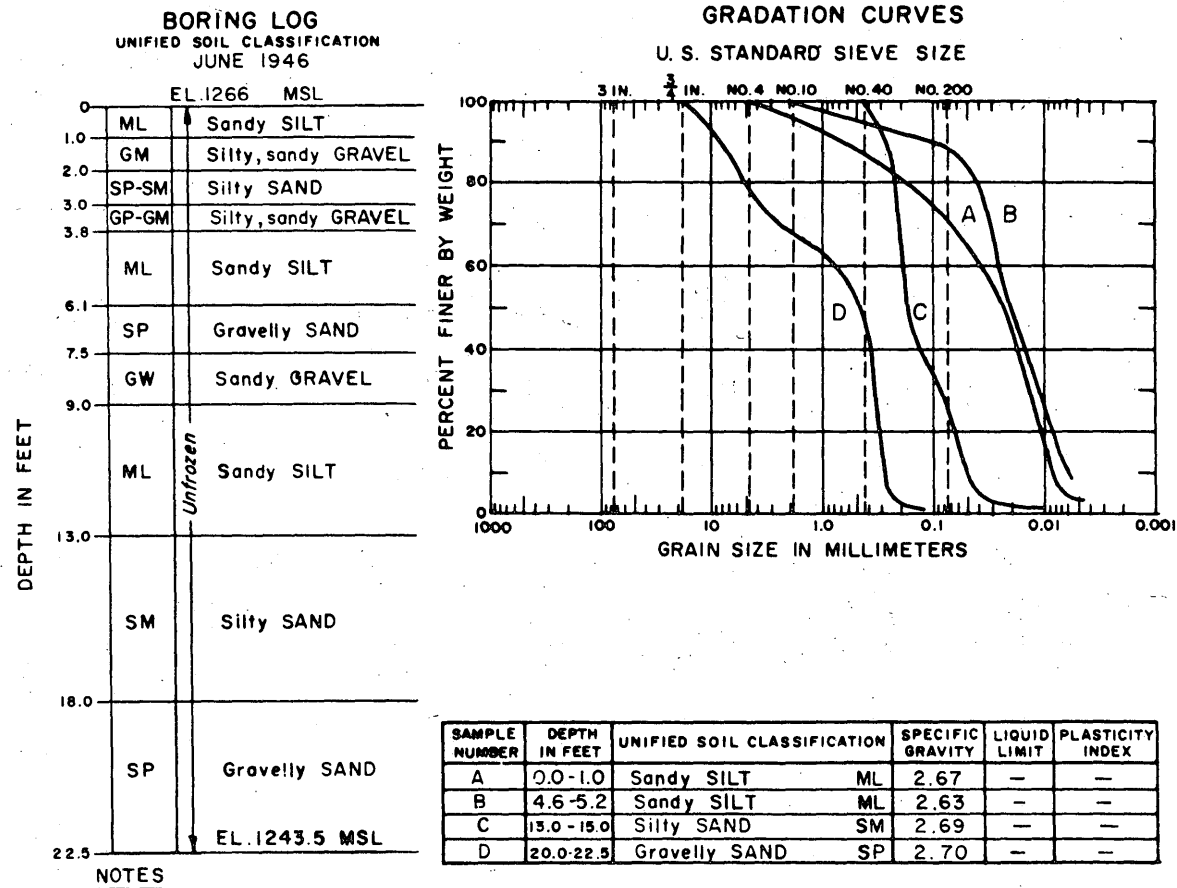
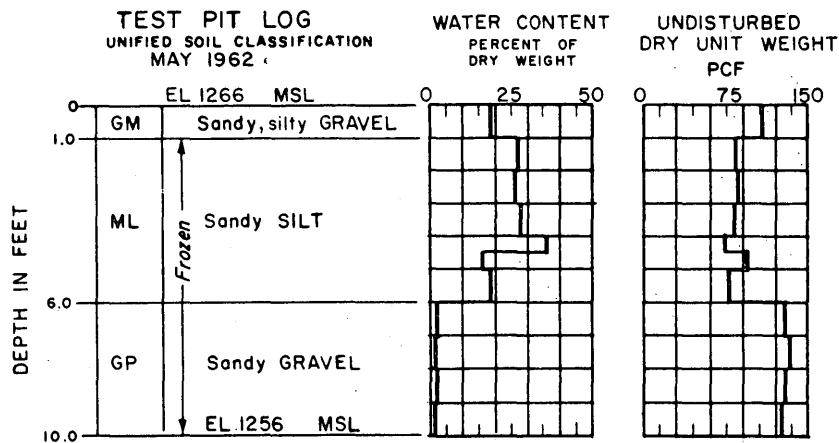
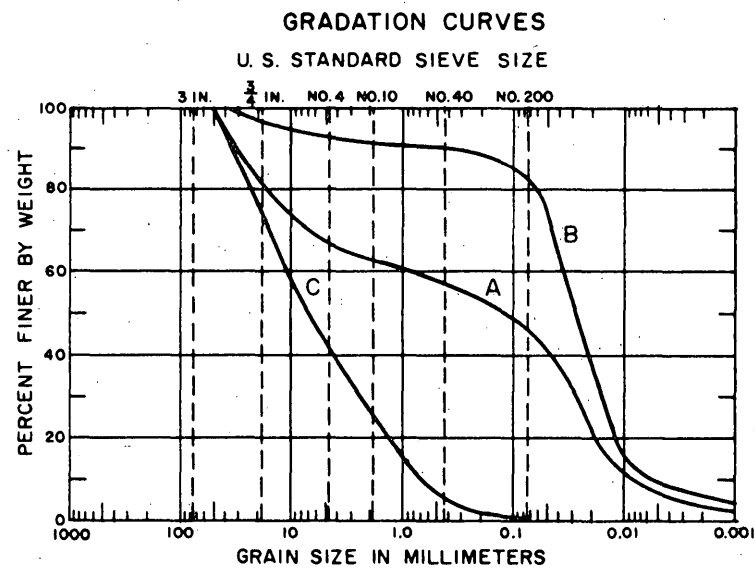


Figure 7. Boring log and soil data, ground-temperature well.



NOTES

Exploration by test pit.
Densities below 6 feet taken in place using a Washington Densometer.



SAMPLE NUMBER	DEPTH IN FEET	UNIFIED SOIL CLASSIFICATION	SPECIFIC GRAVITY	LIQUID LIMIT	PLASTICITY INDEX
A	0.0-1.0	Sandy, silty GRAVEL GM	2.70	28.9	2.5
B	3.0-4.0	Sandy, SILT ML	-	-	-
C	7.1-7.9	Sandy GRAVEL GP	-	-	-

Figure 8. Boring log and soil data, test pit.

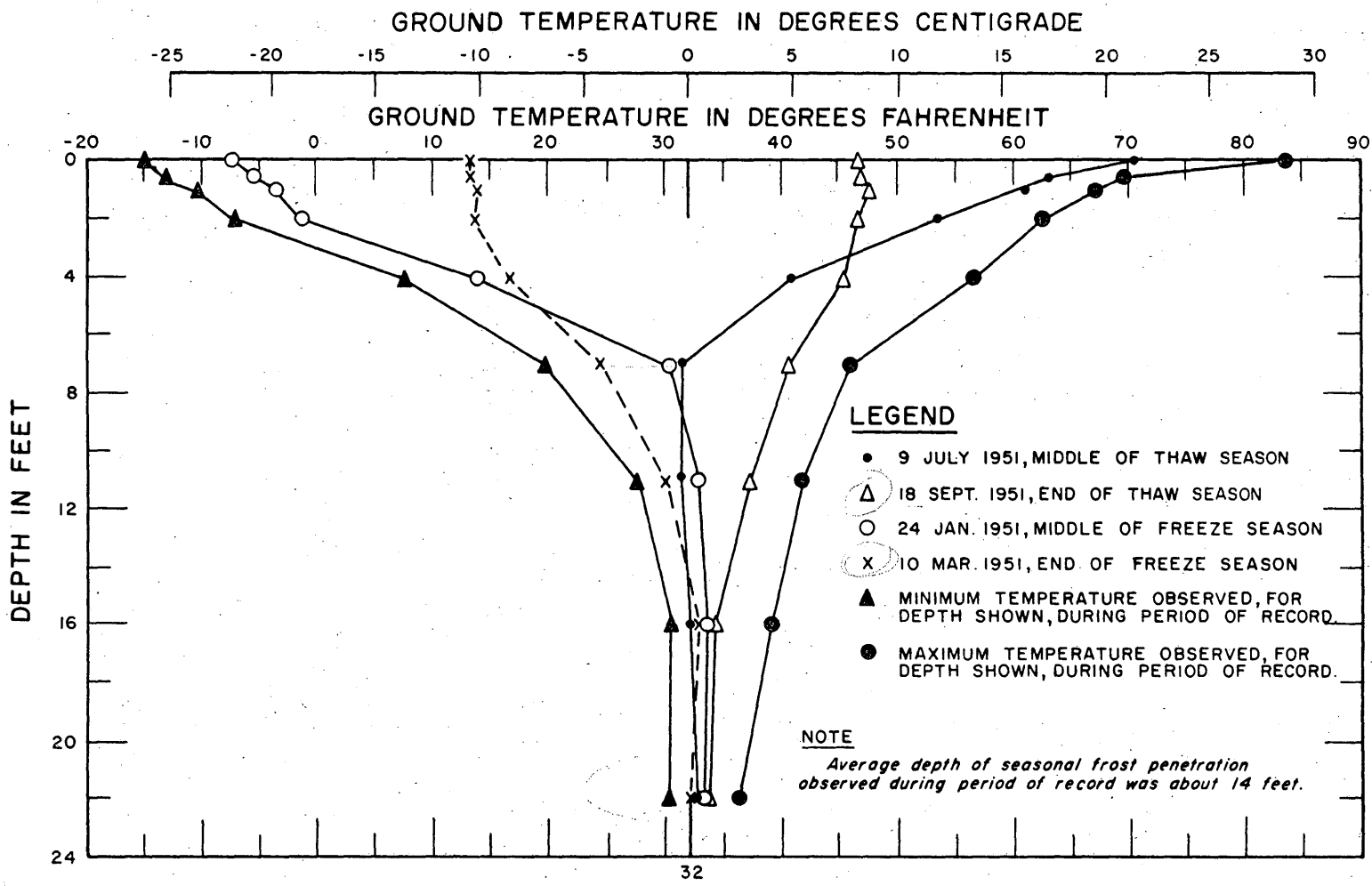


Figure 9. Ground-temperature gradients and maximum-minimum curves.

GROUND TEMPERATURE OBSERVATIONS

Table II. Ground temperatures, °F, maximum, minimum and average recorded first day of month, 1947-1960

DEPTH IN FEET	MONTH																	
	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE		
	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
0.0*	26.2	-0.2	14.2	22.6	-18.0	10.8	29.1	-5.4	14.3	30.7	9.1	20.4	56.5	24.4	43.0	75.4	46.8	60.9
0.5	22.8	7.5	16.9	24.8	-15.0	11.8	24.8	2.3	13.9	25.7	9.5	19.4	39.8	23.9	32.6	54.5	42.8	48.2
1.0	27.7	11.3	19.5	24.6	-12.1	13.5	24.4	5.0	15.1	26.0	11.7	19.8	36.0	23.9	31.4	52.2	40.8	45.8
2.0	28.6	14.4	21.7	27.3	-7.2	15.6	24.4	9.1	16.6	27.3	13.5	21.0	33.1	22.6	30.3	45.5	34.3	40.0
4.0	32.4	27.5	30.2	30.7	6.8	24.1	29.5	14.5	21.3	30.2	18.1	23.5	31.5	22.8	27.6	38.3	23.9	31.2
7.0	34.9	32.2	33.7	33.8	23.2	31.4	32.7	21.7	28.7	32.5	24.1	27.7	32.0	25.3	29.2	37.2	28.6	31.1
11.0	36.2	33.1	34.5	35.6	32.5	33.4	35.2	27.7	32.2	33.4	28.0	31.0	33.4	28.1	30.7	32.5	27.3	30.6
16.0	38.0	33.6	35.3	36.7	33.2	34.4	36.7	32.7	34.0	34.9	31.6	33.1	34.2	31.1	32.7	34.3	31.3	32.5
22.0	37.4	33.6	35.0	36.8	33.4	34.6	37.0	32.2	34.4	35.6	32.7	33.6	35.2	31.8	33.3	34.0	30.4	32.7

DEPTH IN FEET	MONTH																	
	JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
0.0*	79.5	53.6	64.6	79.2	44.2	62.4	55.9	48.0	52.6	41.7	22.4	35.4	32.0	20.8	25.7	27.2	10.6	20.6
0.5	68.5	44.8	55.9	65.8	50.0	56.6	54.0	45.5	50.2	39.6	31.3	35.8	31.8	24.8	29.0	27.5	15.6	22.1
1.0	63.0	45.2	54.2	63.5	48.4	55.6	54.6	47.7	51.1	39.9	33.1	37.3	32.7	19.6	30.8	31.3	19.0	25.5
2.0	56.6	41.6	50.5	60.4	51.1	54.8	54.5	45.7	50.5	42.0	36.3	38.6	33.2	29.5	31.9	31.1	15.4	27.3
4.0	44.2	34.3	38.9	51.6	44.8	47.5	52.9	35.7	47.9	42.6	36.5	40.2	35.6	30.4	34.6	34.2	29.5	33.0
7.0	32.4	30.5	31.3	41.2	32.2	36.4	45.2	38.5	41.4	41.4	37.8	39.5	38.6	34.3	36.5	36.8	32.9	34.8
11.0	33.1	30.5	31.5	37.4	25.0	32.1	41.6	33.6	37.1	40.1	25.9	36.2	39.6	34.3	36.9	38.1	33.8	35.7
16.0	34.2	31.3	32.5	36.3	30.7	32.4	39.9	31.6	34.3	37.6	33.1	35.3	39.4	33.1	36.3	38.5	33.8	35.8
22.0	34.0	32.0	32.8	33.4	32.0	32.6	34.2	29.0	32.7	35.4	32.4	33.7	35.6	32.7	34.4	37.6	29.5	34.2

* Thermohm installed $\frac{1}{8}$ inch to $\frac{1}{4}$ inch below ground surface.

DEPTH IN FEET	1947											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	-18.0	29.1	30.7	56.5	49.8	67.5	59.9	48.0	34.5	20.8	19.4	
0.5	-15.0	24.8	17.0	39.6	48.8	50.5	54.3	45.5	34.0	26.6	21.9	
1.0	-12.1	24.4	19.0	35.2	50.4	51.8	57.4	47.7	36.2	30.5	23.9	
2.0	-7.2	21.2	24.4	31.3	44.6	49.1	58.3	49.1	38.3	32.4	29.3	
4.0	6.8	19.6	25.3	29.5	32.4	40.1	50.9	46.0	39.2	34.6	33.1	
7.0	23.2	21.7	25.5	28.4	29.8	30.9	37.4	39.0	37.8	35.4	33.6	
11.0	31.4	27.7	28.0	29.1	30.2	30.5	31.4	34.9	35.8	35.6	34.3	
16.0	33.4	32.7	31.6	31.1	31.3	31.3	31.4	31.6	33.4	35.2	34.5	
22.0	34.2	33.8	33.1	32.7	32.5	32.0	32.0	32.2	32.4	33.8	34.2	

DEPTH IN FEET	1948											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	4.3	14.0	-5.4	14.0	24.4	46.8	70.3	49.3	--	40.4	25.9	14.0
0.5	7.5	12.9	2.3	14.0	23.9	45.3	52.3	53.6	-	37.6	29.8	16.5
1.0	11.3	13.4	5.0	13.8	23.9	45.3	52.2	55.2	-	38.3	32.0	19.4
2.0	18.1	17.4	9.1	14.7	22.6	34.3	46.4	52.7	-	38.0	32.4	25.3
4.0	29.8	24.8	15.4	18.1	22.8	30.0	36.2	45.2	-	38.8	33.8	32.4
7.0	32.9	31.6	26.0	24.1	25.3	28.6	30.5	34.2	-	37.8	34.3	32.9
11.0	33.8	33.1	32.0	29.6	28.8	29.3	30.5	31.2	-	35.8	34.3	33.8
16.0	34.3	33.8	33.2	32.4	32.0	31.6	31.4	31.6	-	33.1	33.8	33.8
22.0	34.2	34.0	33.8	33.2	32.9	32.7	32.5	32.4	-	33.4	33.2	33.4

DEPTH IN FEET	1949											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	1.4	13.1	10.4	17.9	41.0	75.2	61.5	67.8	55.6	32.0	30.0	10.6
0.5	9.3	12.4	10.0	18.3	31.6	50.0	44.8	54.3	52.7	37.0	31.8	15.6
1.0	11.7	13.1	10.4	19.9	31.8	49.3	45.2	55.8	54.6	39.2	32.5	19.0
2.0	16.7	13.8	10.4	22.1	30.4	38.3	41.6	52.5	53.1	42.0	33.1	26.8
4.0	28.2	20.5	14.5	24.5	29.0	31.1	34.3	44.8	46.6	42.6	35.2	33.1
7.0	32.2	29.8	24.0	26.4	28.2	30.0	30.9	32.4	38.5	39.4	36.2	34.3
11.0	33.1	32.5	31.3	29.5	29.6	30.5	30.9	30.1	33.6	36.3	36.2	34.9
16.0	33.6	33.2	32.5	32.0	31.8	31.6	31.6	31.4	31.8	33.6	35.2	35.0
22.0	33.6	33.4	33.2	32.7	32.5	32.5	32.2	32.4	32.4	32.7	33.8	34.3

DEPTH IN FEET	1950											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	-0.2	20.5	12.0	19.0	50.6	51.4	57.4	54.0	54.0	38.8	30.4	27.2
0.5	9.3	21.2	9.5	20.8	32.2	44.0	57.6	54.8	49.6	38.6	31.1	27.5
1.0	13.1	22.3	9.7	21.6	32.4	43.9	59.0	55.8	50.2	37.0	32.7	29.0
2.0	17.0	23.4	11.3	22.3	30.2	36.5	52.5	51.1	50.4	36.5	32.9	30.2
4.0	29.1	27.5	18.5	24.0	29.1	31.1	37.8	46.0	49.8	36.5	35.4	33.4
7.0	33.1	32.0	28.4	26.9	28.8	30.5	31.1	34.2	39.8	39.8	36.3	35.0
11.0	34.2	32.9	32.5	31.3	30.5	31.1	31.5	31.4	34.3	36.7	36.3	35.6
16.0	34.7	33.8	33.6	32.9	32.2	32.2	32.2	32.2	32.0	34.5	35.4	35.6
22.0	34.5	34.0	34.0	33.4	33.1	32.9	32.5	32.9	32.5	33.1	34.2	34.9

19.80C
0.380C

Table III. Ground temperatures, °F, recorded first day of month, 1947-1960.

DEPTH IN FEET	1951											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	20.5	10.8	12.2	17.2	34.9	57.0	64.4	60.4	51.1	31.6	29.1	17.2
0.5	21.2	10.4	12.7	16.3	34.2	52.7	58.3	56.5	52.3	33.6	29.6	19.8
1.0	23.0	11.7	14.0	16.5	32.2	52.2	57.9	54.7	53.4	36.3	31.6	23.2
2.0	25.0	13.6	14.7	16.5	30.4	39.6	51.6	55.6	52.5	39.8	32.5	28.6
4.0	31.3	24.4	19.9	18.5	29.3	32.0	38.5	48.6	48.9	42.4	35.2	33.1
7.0	33.4	32.4	28.8	24.4	28.8	30.9	31.3	36.3	40.6	40.1	37.0	35.0
11.0	34.0	33.1	30.7	30.6	28.1	27.3	31.3	25.0	35.6	25.9	37.4	36.0
16.0	35.0	33.8	33.4	32.9	32.4	31.8	32.0	31.6	31.8	35.6	36.5	36.0
22.0	34.5	34.2	33.4	33.4	32.5	33.2	32.7	32.9	32.0	33.4	34.9	35.2

DEPTH IN FEET	1952											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	14.9	-2.4	15.8	9.1	52.1	66.9	53.6	68.4	49.6	37.0	31.5	22.1
0.5	14.7	-0.9	14.4	9.5	31.6	46.6	55.2	55.8	48.6	36.2	29.8	24.6
1.0	16.0	1.6	14.4	11.7	32.4	43.3	55.9	55.8	49.3	38.5	32.7	30.9
2.0	17.0	5.2	14.7	13.5	33.1	38.6	52.7	54.2	48.9	39.6	32.9	30.6
4.0	27.5	14.5	16.5	20.1	29.0	38.3	39.4	47.1	45.7	41.0	35.0	33.6
7.0	33.4	29.0	24.4	25.2	28.0	37.2	31.1	35.2	39.0	38.3	35.6	34.3
11.0	34.7	33.1	30.9	29.1	29.1		31.3	31.8	34.7	36.0	36.0	34.9
16.0	35.2	34.5	33.4	32.4	32.0	31.8	31.8	32.0	32.0	33.8	35.2	35.0
22.0	35.0	34.9	34.9	33.4	33.1	32.9	32.5	32.5	32.4	33.1	34.0	34.3

DEPTH IN FEET	1953											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	19.8	0.0	21.9	24.3	55.4	75.4	62.2	69.4	54.0	32.9	29.0	25.2
0.5	21.9	2.7	19.9	22.6	39.8	53.4	54.5	63.7	50.4	35.0	29.6	26.9
1.0	25.3	7.9	22.1	22.8	36.0	49.3	52.9	63.5	51.4	37.6	32.0	28.8
2.0	27.9	12.2	23.4	22.8	32.0	45.5	51.2	60.4	50.5	38.8	31.6	28.4
4.0	32.4	26.2	26.0	25.0	30.6	32.7	41.6	51.2	48.4	41.0	35.6	33.8
7.0	33.8	32.7	31.3	29.1	30.6	31.2	32.0	38.1	42.2	41.4	37.8	35.6
11.0	34.5	33.4	32.5	32.2	31.8	32.0	32.4	33.1	38.5	40.1	38.3	36.5
16.0	34.9	33.8	33.8	33.2	32.7	32.7	32.9	31.1	34.2	37.6	37.4	36.7
22.0	34.5	34.2	34.2	33.8	33.6	33.4	33.6	32.9	33.2	35.2	35.6	35.8

DEPTH IN FEET	1954											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	21.0	18.1	7.2	21.6	34.7	62.6	57.9	62.6	53.2	40.8	31.8	25.2
0.5	21.9	18.9	8.2	21.4	32.0	50.5	55.0	54.7	49.4	37.0	31.6	25.3
1.0	23.7	20.8	9.3	21.7	31.6	47.5	54.3	54.3	50.5	39.4	32.5	27.9
2.0	24.4	21.6	12.9	22.6	29.1	41.9	45.8	51.6	50.4	40.1	33.2	29.1
4.0	29.5	29.6	23.4	24.4	29.1	29.0	38.5	46.8	47.5	40.8	35.2	33.1
7.0	34.7	33.4	32.2	29.1	29.6	30.9	31.3	36.2	40.8	39.9	36.5	34.9
11.0	35.8	34.3	33.2	32.4	31.4	31.6	31.3	31.8	37.0	38.5	36.8	35.8
16.0	36.3	35.4	34.5	33.8	33.1	32.7	32.4	32.7	34.3	36.7	36.0	35.8
22.0	36.2	35.6	35.0	34.5	33.8	33.4	33.4	33.2	31.6	34.3	34.3	30.2

Table III. (Cont'd) Ground temperatures, °F. recorded first day of month, 1947-1960.

DEPTH IN FEET	1955											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0.0	9.0	12.6	9.0	18.9	37.0	58.3	63.0	70.7	54.0	41.7	21.2	22.1
0.5	10.8	13.8	10.6	19.4	30.2	42.8	50.5	57.6	48.6	36.5	25.5	22.3
1.0	13.3	16.2	12.4	20.5	31.3	40.8	49.3	56.5	48.6	37.8	31.6	27.3
2.0	14.4	17.6	14.0	21.2	30.2	36.2	46.6	53.8	47.7	38.8	31.6	27.2
4.0	28.8	26.2	19.6	23.0	28.1	30.9	36.0	45.0	45.0	40.1	34.5	32.9
7.0	34.0	32.5	28.4	26.6	28.4	30.2	30.7	32.2	38.8	38.3	36.0	34.2
11.0	35.0	33.6	32.4	31.3	30.4	30.9	30.9	31.4	34.7	36.5	36.5	34.9
16.0	36.0	34.9	34.0	32.7	32.4	32.2	33.1	30.7	33.4	33.6	35.6	35.2
22.0	34.9	34.7	34.5	33.6	33.4	33.4	32.4	-	34.2	-	34.9	34.9

DEPTH IN FEET	1956											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0.0	26.2	21.0	17.8	26.0	48.2	60.6	74.5	61.5	55.0	32.4	27.9	24.6
0.5	26.9	21.9	18.0	25.7	35.6	46.4	58.4	54.0	48.2	33.1	28.6	26.9
1.0	27.7	22.8	21.0	26.0	33.2	44.2	55.2	55.0	49.8	34.2	29.8	31.3
2.0	28.6	22.8	20.7	25.5	31.6	39.0	50.7	54.7	50.5	36.3	30.9	31.1
4.0	32.0	29.8	24.6	27.5	30.9	31.6	37.4	48.2	48.9	41.4	34.9	33.8
7.0	33.2	32.9	31.8	31.6	31.4	31.3	31.3	37.0	42.1	41.0	37.0	35.8
11.0	34.2	33.6	32.5	32.7	32.5	32.2	32.2	32.9	38.1	39.6	37.8	36.7
16.0	34.5	34.3	33.4	33.4	33.6	32.9	32.7	32.9	35.2	37.4	37.4	37.0
22.0	34.5	34.3	32.2	33.8	34.2	33.4	33.4	33.4	33.8	34.2	35.8	36.2

DEPTH IN FEET	1957											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0.0	22.6	22.6	22.8	25.2	42.4	56.3	71.4	79.2	55.9	22.4	32.0	20.1
0.1524	22.8	24.8	23.0	25.5	29.3	46.9	60.2	65.8	53.0	31.3	29.8	19.9
0.3048	24.1	24.6	23.4	25.7	30.7	45.2	58.8	60.6	52.0	33.1	31.6	23.0
0.6096	25.9	27.3	24.4	27.3	31.3	41.2	55.8	58.1	45.7	34.7	30.0	25.5
1.2192	31.6	30.7	29.5	30.2	31.5	31.8	42.1	51.6	52.9	37.2	30.4	34.2
2.1336	34.9	33.4	32.7	32.5	32.0	31.6	32.0	41.2	45.7	39.8	38.6	36.8
3.3528	35.2	34.7	34.2	33.4	33.4	32.5	32.2	37.4	41.4	34.2	39.6	38.1
4.8768	36.0	35.2	34.9	34.2	33.8	33.4	33.4	34.5	37.6	36.8	39.4	38.5
22.0	35.6	35.4	35.6	34.9	31.8	34.0	34.0	33.4	35.2	-	32.7	37.6

DEPTH IN FEET	1958											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0.0	16.3	17.2	16.7	22.3	40.6	73.9	79.5	64.4	51.8			
0.5	19.2	18.3	10.2	24.1	32.7	54.5	68.5	60.8	54.0			
1.0	21.6	19.8	12.0	24.1	30.2	42.6	63.0	49.3	54.0			
2.0	24.1	20.1	20.1	24.4	31.3	46.6	56.6	58.6	54.5			
4.0	31.8	28.6	25.5	25.5	30.9	23.9	44.2	45.3	52.7			
7.0	34.9	33.8	33.4	31.3	31.3	31.3	32.4	41.7	44.6			
11.0	36.2	35.6	35.2	33.2	32.7	27.9	33.1	36.7	40.8			
16.0	38.0	36.7	36.7	34.9	34.2	34.3	34.2	36.3	37.8			
22.0	37.4	36.8	37.0	35.6	35.2	30.4	32.0	28.8	29.0			

IN
Meters
0
0.1524
.3048
.6096
1.2192
2.1336
3.3528
4.8768

Oct '57.
0.0 -5.33
0.5 -0.39
1.0 0.61
3.0 1.50

0C
0.0 -5.33
0.5 -0.389
1.0 0.611
2.0 1.15

M
0 0.0 -8.72
0.15 0.1524 -7.11
1.0 0.3048 -5.78
2.0 0.6096 -4.39
4.0 1.2192 -0.111
7.0 2.1336 +1.611
11.0 3.3528 2.333
16.0 4.8768 3.33

OF -> 0C

Table III. (Cont'd) Ground temperatures, °F, recorded first day of month, 1947-1960.

DEPTH IN FEET	1959											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0			16.4	18.6	40.7	57.6	56.8	54.2	48.6	40.1	24.9	19.8
0.5			16.9	17.7	33.2	45.2	50.4	50.8	49.7	39.6	24.9	18.0
1.0			17.8	14.8	26.4	41.6	48.6	51.3	51.9	39.9	19.7	22.7
2.0			18.8	16.0	30.2	38.2	55.8	51.5	53.0	40.7	29.5	15.5
4.0			23.8	18.9	28.6	31.0	39.9	46.6	52.2	42.0	34.8	29.5
7.0			30.6	28.0	29.1	31.0	31.6	47.4	45.2	40.6	47.4	34.8
11.0			33.2	30.2	31.1	31.8	32.0	33.5	41.6	39.4	38.3	36.9
16.0			35.4	34.2	33.2	33.5	32.9	32.8	39.9	37.4	40.6	37.0
22.0			36.0	34.8	34.3	33.5	34.0	33.9	34.2	35.4	35.6	34.5

DEPTH IN FEET	1960											
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0	14.0	10.0	15.9	10.0	57.2	55.5						
0.5	15.1	5.0	11.2	9.7	22.7	45.4						
1.0	16.8	12.6	16.9	12.6	27.3	46.0						
2.0	18.9	16.0	19.6	15.0	29.6	35.6						
4.0	28.0	23.8	17.5	19.8	29.1	32.2						
7.0	33.8	34.2	29.5	26.4	28.6	30.6						
11.0	35.4	35.6	31.3	31.6	29.5	31.0						
16.0	36.4	37.0	35.0	33.8	32.9	32.5						
22.0	36.2	35.4	33.8	35.0	34.6	34.4						

DEPTH IN FEET												
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0												
0.5												
1.0												
2.0												
4.0												
7.0												
11.0												
16.0												
22.0												

DEPTH IN FEET												
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
0.0												
0.5												
1.0												
2.0												
4.0												
7.0												
11.0												
16.0												
22.0												

Table III. (Cont'd) Ground temperatures, °F, recorded first day of month, 1947-1960.

GROUND TEMPERATURE OBSERVATIONS

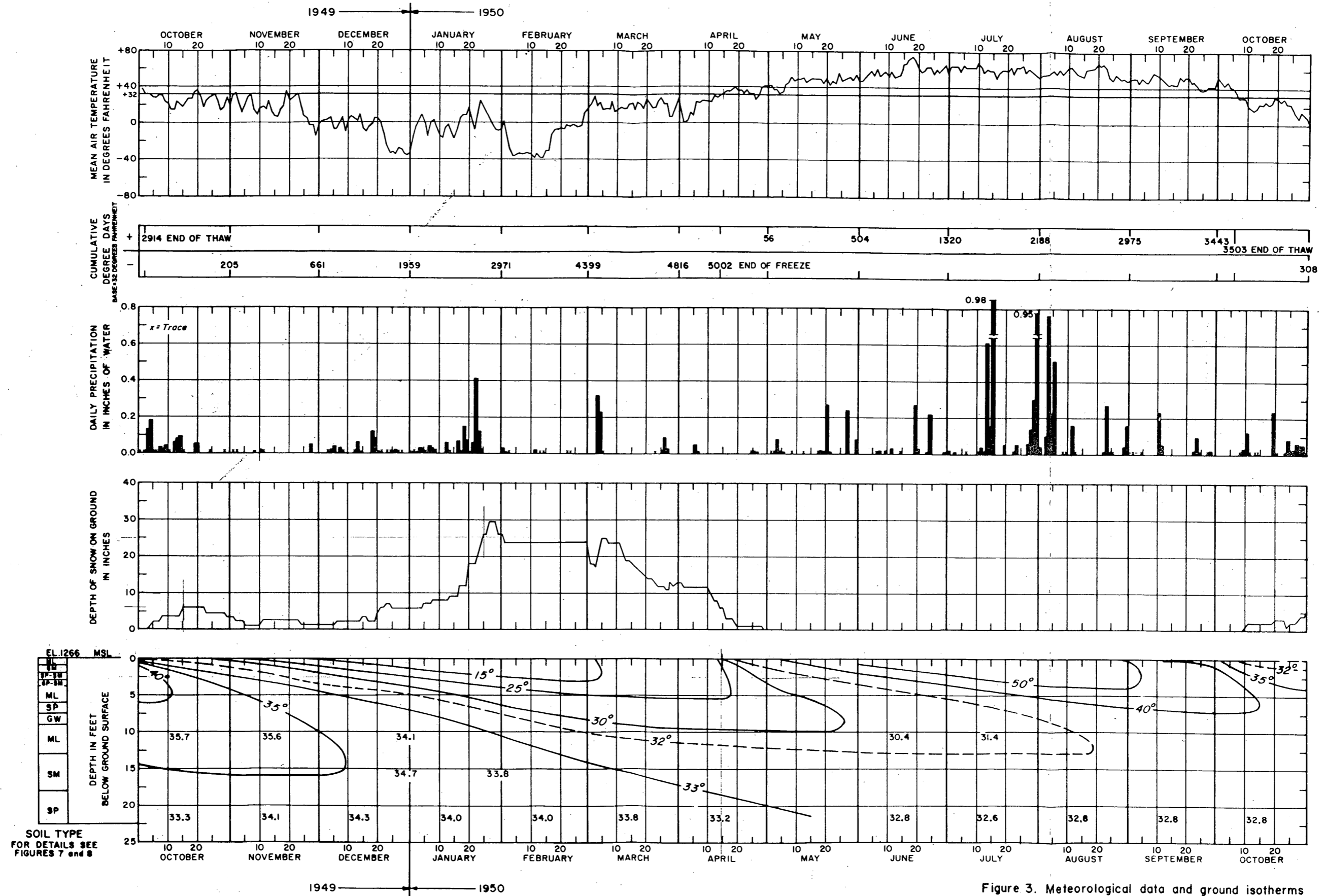


Figure 3. Meteorological data and ground isotherms