SOME HYDROGRAPHIC CONDITIONS FOUND IN WINTER IN LOWER CHESAPEAKE BAY AND THEIR POSSIBLE EFFECTS ON THE BLUE CRAB (CALLINECTES SAPIDUS RATHBUN) POPULATION

BY

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INTRODUCTION

The State of Virginia produces about twenty-three million pounds of hard crabs annually (1935-1945 average). Approximately one-sixth of this total poundage is taken between December 1 and March 31 by the winter crab dredge fishery.

The catch of this fishery fluctuates to a large degree both throughout the season and from year to year. It has been suggested (Sette and Fiedler, 1925) (Pearson, 1948) that the year to year fluctuations are caused, at least in part, by crab abundance. The hydrographic conditions existing in the lower part of Chesapeake Bay, where the dredge fishery is pursued, could also influence migration, schooling tendencies, or the catchability of crabs and thus be a factor in determining the fluctuations throughout a season and perhaps the year-to-year fluctuations.

This present study was made to determine what hydrographic conditions existed in the winter of 1948-1949 in the deeper channels of lower Chesapeake Bay where the bulk of the winter crab dredging is done. Experiments were carried out also in the laboratory to study crab reactions to various simulated hydrographic conditions.

Acknowledgment is made to all persons who aided in this study. Special thanks are expressed to Mr. W. A. Van Engel and Mr. W. H. Massmann for their assistance with the project and to Mr. W. A. Van Engel, Dr. Nelson Marshall, and Dr. A. R. Armstrong for valuable criticism of the manuscript.

REVIEW OF THE LITERATURE

During the winter months mature females make up over ninety percent of the crab catch taken in the lower Bay (Newcombe, 1946) (Truitt, 1939), and there is a distinct excess of adult males over adult females in Maryland waters (Truitt, 1934). Fiedler (1930) and Truitt (1934) found evidence indicating that there is a mass migration of mature female crabs to the lower Bay for spawning. No definite migrational pattern exists for mature males except that they do move offshore to deeper waters for over-wintering. Truitt stated that crabs are rarely taken from Chesapeake Bay waters in less than fifteen feet of water during the winter. Immature males and females in equal number are abundant at depths of twenty to thirty feet while mature crabs seek deeper waters.

Truitt (1934) found that blue crabs do not occur very far out into the ocean. During the winter months crabs occurring in the lower Bay are mostly mature females capable of producing a sponge, and those found just outside of the Bay in ocean waters are mostly senile females, many of which die before the end of the winter.

In 1934 and 1935 five thousand adult crabs were tagged in Chesapeake Bay. On the basis of an eleven percent tag return of which only one tag was recovered outside of the Chesapeake Bay area (in North Carolina), Truitt (1936) concluded that the Chesapeake Bay blue crab population is separate and distinct from others along the Atlantic Coast.

There is ample evidence that mature female crabs school during the winter. This viewpoint is widely held by the commercial fishermen who dredge for crabs in the lower Bay.

In March 1933 Truitt (1934) located a school of adult female crabs in the lower Bay and found that they had moved inshore five hundred yards three days later. During the following three days a northeast storm occurred and the school disappeared, apparently having been broken up. Three other schools were located by him that winter, but he was unable to follow them due to weather or other adverse conditions. The above author mentions that when deep water winter bedding areas in Maryland are exposed to stormy weather, the crabs over-wintering there will leave for other localities. He also claims that the adult male crabs over-wintering in the deeper Bay waters do not school as do the adult females.

Churchill (1919) stated that there is a widely held belief among fishermen that crabs bury themselves in the bottom muds of the deeper waters and hibernate during cold weather. Dredging observations by Sette and Fiedler (1925) and Truitt (1934) do not support the theory.

In respect to hibernation it has been noted above that schools of crabs do move from one locality to another while over-wintering in the deeper waters of the lower Bay. In regard to winter activity of crabs Truitt (1934) states that the younger mature males taken in December and January are much more active and alert than the senile males taken in the same waters, and that in February and March many crabs in this latter group are frequently taken dead with the gills fouled by debris.

Although a fairly large number of papers containing information about some phase of the hydrography of parts of Chesapeake Bay has resulted from various studies in this region, there are comparatively few papers dealing with the subject on a larger scale. This is especially true of the more offshore waters of the Bay. The following references include only those which are most applicable to the present paper.

In 1915, 1916, and 1917 Lewis Radcliffe of the Bureau of Fisheries started a survey of Chesapeake Bay that was continued in 1920, 1921, and 1922 under the direction of Dr. R. P. Cowles of The Johns Hopkins University. Stations were set up in the Bay and plankton samples, water temperatures, and salinities were taken at each station at the surface, bottom, and intermediate depths. The fauna on or near the bottom was also sampled with a beam trawl and a dredge. The above stations were sampled at intervals throughout the years during which the survey was carried out. The results were published in several different papers some of which are mentioned in the following paragraphs.

The salinity and temperature data for about 2,500 water samples taken in the above study are presented in a paper by Wells, Bailey, and Henderson (1929). This paper also deals with the probable effects of some of the factors that determine salinity distribution in the Bay.

The analysis of seasonal, horizontal, and vertical salinity and temperature distribution in Chesapeake Bay, based on the above determinations, is given in a paper by Cowles (1930). This paper also correlates these hydrographic factors with the distribution of the invertebrate fauna sampled at each station.

Two U. S. Coast and Geodetic Survey (1945) (1947) publications include data from five stations in the Chesapeake Bay area. Four of these stations are in Maryland and one, Old Point Comfort, in Virginia. The former publication gives the average monthly density (at 15° Centigrade) of surface waters at each station, and the latter, the average monthly surface water temperature.

Much data on salinity and temperature of Chesapeake Bay waters exists, more or less scattered through the literature, and undoubtedly much has also been collected and discarded, forgotten or otherwise not made available. Data concerning other physical and chemical hydrographic factors are much less abundant. This is due, no doubt, to the comparative ease with which temperature and salinity may be determined. In addition to the importance of salinity and temperature in studying biological phenomena, these two factors are also of great value in identifying water masses in the study of water movements and other physical as well as chemical conditions.

Literature dealing with oxygen content of the Chesapeake Bay area is confined almost entirely to studies of the estuarine sections of a few of the rivers emptying into the Bay. The Patuxent River has been more intensively studied than the other rivers, undoubtedly due to the fact that the Chesapeake Biological Laboratory is located at the mouth of this estuary.

In 1948 the Chesapeake Bay Institute, a division of The Johns Hopkins University, was formed to carry out research activities on Chesapeake Bay. Data for a large number of stations throughout the Bay, on all main tributaries and on the ocean just outside the Bay, are available for July 1, 1949, to October 1, 1949, in the first Quarterly Report of the Institutes (1949). A number of different determinations (including salinity, temperature, and dissolved oxygen) at different depths are made at each station.

CHARACTERISTICS OF CHESAPEAKE BAY

Chesapeake Bay extends in a north-south direction from Havre de Grace, Maryland, at 39°33' North Latitude to the entrance to Lynnhaven Bay, Virginia, at 36°54½' North Latitude. This distance is 158½ nautical miles (182 statute miles or 292 kilometers). The entrance to the Bay, between Cape Charles and Cape Henry, is about 10 nautical miles wide, and the Bay itself varies in width from 5 to 25 nautical miles. The area of the Bay is about 2,800 square miles (Cowles, 1930), and the shoreline is very irregular.

Chesapeake Bay is a rather shallow body of water, 30 to 40 feet being about average for deep water but, beginning at about 39°01' North Latitude and extending southward to about 37°42' North Latitude is a narrow, deep channel between 90 and 156 feet in depth. This channel runs for its first 16 nautical miles close to the eastern side of the Bay, in mid-Bay for the next 51 nautical miles, and for the last 12 nautical miles, from Smith Point southward, closer to the western side of the Bay. It is generally believed that this deep-water channel is the old bed of the Susquehanna River before the subsidence of the coastal plain (Cowles, 1930).

A second deep channel, with depths between 65 and 110 feet, runs in a southerly direction down Tangier Sound. A third channel runs southward intermittently down Pocomoke Sound and disappears a few miles east of the southern end of the Tangier Sound Channel. A fourth channel, probably a continuation of the Tangier Sound and/or the Pocomoke Sound Channels in past geological times, runs intermittently along the Eastern Shore, generally between 55 and 80 feet deep with extreme depths of 100 to 150 feet appearing just off Cape Charles City. The last deep water is found about one nautical mile offshore from Butlers Bluff midway between Cape Charles City and Cape Charles. The water here is 85 feet deep. Two shallower channels 30 to 45 feet deep continue around the Cape but become lost in the shoal area across the northern three-quarters of the Bay where no through channel with water over 30 feet deep exists.

The Patuxent, Potomac, Rappahannock, York, and James Rivers also have deep channels near their mouths but not running into the Bay. These channels average between 70 and 90 feet in depth. The Bay waters just off the mouths of these rivers average 30 to 40 feet in depth.*

The bottom of Chesapeake Bay is generally a fairly thin layer of hard or soft mud over a lower layer of sand, clay, or shells. The mud layer becomes much thicker around the mouths of rivers. The shores are generally sandy (Cowles, 1930).

The Susquehanna River, originating in southern New York State and flowing into the head of the Bay, contributes 49% of the fresh water. Drainage from the west, from large and small rivers originating in the Alleghany Mountains and on the Coastal Plain, contributes 44% of annual freshwater inflow. The remaining 7% is contributed from

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* Above information from U. S. Coast and Geodetic Survey Maps #77, #78, and #1222.

the Eastern Shore (Wells, Bailey, and Henderson, 1929).

The salinity of the Bay increases from about 4 to 7 parts per thousand in the latitude of Baltimore to about 24 to 30 parts per thousand at Cape Henry (Newcombe, Horne, and Shepherd, 1939). The salinity also tends to increase from west to east due to the much larger amount of freshwater entering the Bay from the west and probably also to Coriolis effect. The salinity also generally increases with depth, believed to be caused by a slow inward movement of heavier (more saline) ocean waters under the lighter outflowing surface waters (Wells, Bailey, and Henderson, 1929). From the average cross section area and annual freshwater inflow of Chesapeake Bay, it has been calculated that there is an average outward current of 0.3 knots (Wells, Bailey, and Henderson, 1929). Although there are no very strong currents in the Bay (Cowles, 1930), the currents are very complicated.

LOCATIONS OF STATIONS

The selection of stations was based on winter crab dredging activity in the Bay. This dredging is almost entirely confined to the deeper channels of the lower Bay where the water is over thirty feet in depth. The greatest dredging activity is generally found in the lower James River channel from Thimble Shoal eastward to Cape Henry, in the lower York River channel from about two miles east of Tue Point to the Bay channel, and in the Bay channel itself from Cape Henry northward to Wolf Trap Light. The deep water area to the west of Cape Charles City appears to be a favorite crab dredging area. Some crab dredging is done north of Wolf Trap Light up to the Maryland State line.

Stations 1 to 4 are spaced about three and one-half nautical miles apart and make up a series starting about three nautical miles down the York River channel from the mouth of the York River and extending down this channel to station 4 located in the Bay channel opposite the mouth of the York River channel. (Figure 1, Table I)

Station 5, in the James River channel just north of Lynnhaven Roads, station 6, in the channel at the Bay entrance just north of Cape Henry, and station 7, about five nautical miles up the Bay channel from station 6 were occupied on the first trip, November 19 and 20, 1948, but were discontinued for the later cruises.

Stations 8 to 11 make up a series of stations running along the Eastern Shore channel from a point about two miles off Butlers Bluff to a point about three and one-half miles off Wescott Point. Station

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12, two-thirds of the way across the Bay to the west of station 11, was added on January 7, 1949, to obtain data for a station farther away from the influence of the very deep channel to compare with the series of stations located in this area.

Selection of the three deep-channel stations (9, 10, and 11) was influenced by the fact that the bathythermograph would record only to a maximum depth of 72 feet. Because of the lack of landmarks to pinpoint these stations, the exact locations were not occupied on successive trips. Due to the very abrupt slope from shallow to deep water along this section of the Eastern Shore, a comparatively small error in locating a station introduced a difference of up to 40 feet in depth for that station.

TABLE I

STATION LOCATIONS

Station Number	Latitude North	Longitude East
1	37° 13.7'	76° 18.8'
2	37° 11.1'	76° 15.2'
3	37° 08.5'	76° 12.2'
4	37° 06.8'	76° 08.2'
5	36° 57.7'	76° 05.9'
6	36° 57.3'	75° 59.1'
7	37° 01.3'	76° 02.6'
8	37° 10.1'	76° 01.4'
9	37° 12.8'	76° 02.9'
10	37° 16.6'	76° 05.5'
11	37° 18.3'	76° 05.4'
12	37° 18.0'	76° 09.7'

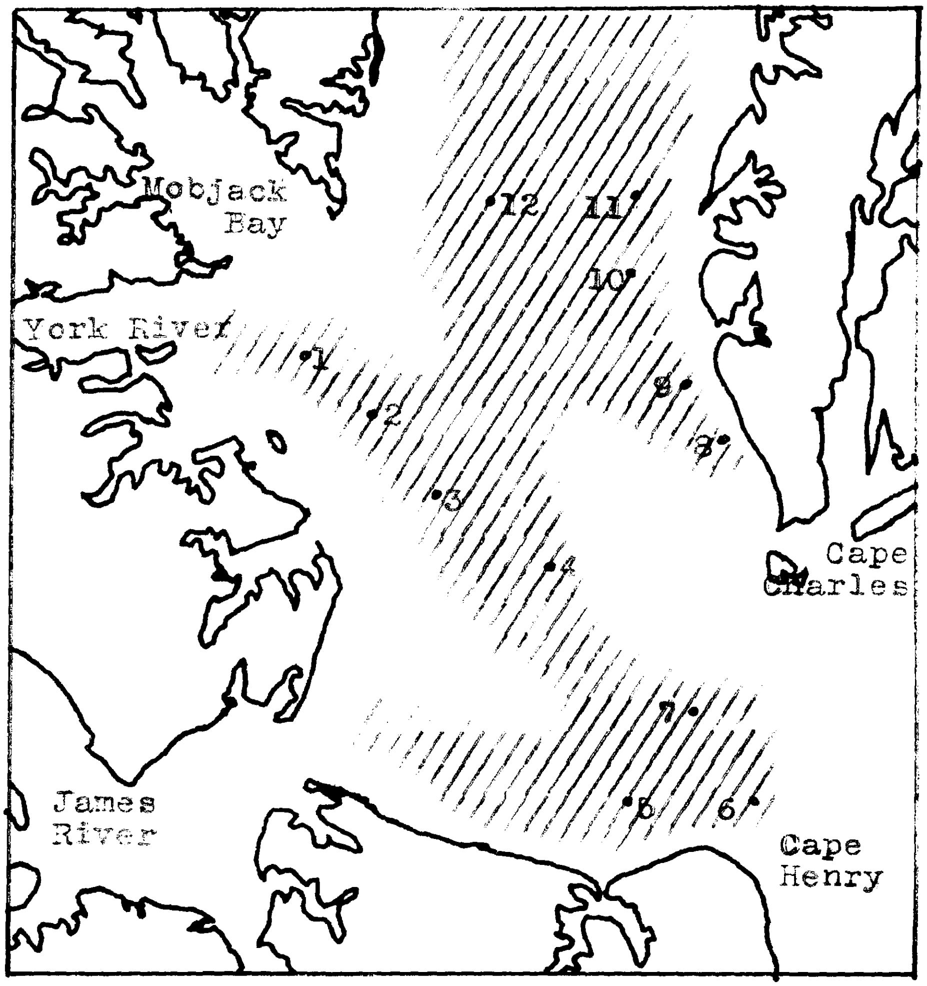


Figure 1. Map of Lower Chesapeake Bay Showing Station Locations (Cross-hatching indicates crab dredging grounds)

HYDROGRAPHIC METHODS

Temperature in relation to depth from surface to bottom was measured with a bathythermograph (Woods Hole Oceanographic Institute, number 203, recording to a maximum depth of seventy-two feet). Air and surface water temperatures were measured at each station with mercury thermometers.

Bottom water samples were collected by means of a three thousand cubic centimeter modified Kemmerer water bottle.

Salinity of surface and bottom samples was determined by titration with silver nitrate as described as Harvey (1928).

Oxygen content of the bottom samples was measured by the standard Winkler method. It was assumed that surface waters were near saturation values in dissolved oxygen.

HYDROGRAPHIC RESULTS AND DISCUSSION

TEMPERATURE

The water temperatures for all stations sampled on November 19 and 20 ranged from 60.0°F. to 62.0°F. for both surface and bottom waters. The lowest water temperatures were found on January 7 when surface and bottom temperatures ranged from 43.0°F. to 46.5°F. In February and March a gradual increase in surface water temperatures was found. On February 1 the mean surface water temperature was 47.0°F.; on February 9, 48.0°F.; and March 23, 50.0°F. During this same period mean bottom water temperature increased to 47.7°F. on February 1, and 48.3°F. on February 9, but decreased to 46.7°F. on March 23. (Figs. 2 to 14) The greatest variation from the mean was in no case greater than 1.6°F.

On November 19 there was little or no difference between the surface and bottom water temperatures at the four York River channel stations. During December, January, and February the bottom temperatures were, in all but two cases, higher than surface temperatures. This was most noticeable at station 4 and least at station 1. It was also more marked in December than in later months. In March surface temperatures were higher than bottom temperatures for these four stations.

Along the Eastern Shore there was no difference between surface and bottom water temperatures on November 20. On December 11, all Eastern shore stations had bottom temperatures either colder than or the same as surface temperatures. This same condition was found for stations 8, 9, and 10 during January and February, but during this same period stations 11 and 12 had bottom temperatures that were either warmer than or the same as surface temperatures. The differences between surface and bottom water temperatures were in most cases very small for Eastern Shore stations throughout the winter, but on March 23 stations 8 to 12 had surface temperatures that were from 1 to 6.2°F. higher than the bottom temperatures at these stations. During January and February temperature inversions were fairly common especially at Eastern Shore stations. In most cases the surface and bottom waters were warmer than the intermediate water layers.

Virginia air temperatures were above normal during the winter of 1948-49. February was the warmest on record in 59 years, January, the fourth warmest, and November, the sixth warmest. December air temperatures were also above normal (U. S. Weather Bureau, 1949). In order to determine to what extent this condition affected the waters of lower Chesapeake Bay, records of water temperatures and air temperatures for other winters are compared with those found during the winter of 1948-49 in Table II.

Station 10 was selected to compare with station 29 of Wells, Bailey, and Henderson (1929) located in the same general area in 1919-22. These two stations were chosen because they are near the Eastern Shore and, therefore, not subject to the full impact of the drainage of the large rivers along the western shore of the Bay which may cause large day-to-day fluctuations in water temperatures in that area.

The surface water temperatures of stations 8, 9, and 11 were nearly the same as those of station 10 on each sampling date, the average difference being less than one-fourth of a degree Fahrenheit. Although Table II gives surface water temperatures, these values may also be considered as representative of bottom temperatures as the average temperature difference between surface and bottom at both stations 10 and 29 was, in most cases, 1°F.

The only U. S. Coast and Geodetic Survey (1947) station in the lower Bay gives records for average monthly surface water temperatures at Old Point Comfort for 1943-1946. Although this station is located near the mouth of the James River, large day to day fluctuations in water temperature caused by the river flow are not apparent in the monthly averages. These data are also included in Table II.

The air temperature data in Table II are given as plus or minus deviations of the average monthly air temperatures from the 59-year average for each month for the State of Virginia. Average winter air temperatures for the Tidewater section of Virginia are about 3 to 5°F. higher than for the whole state.

It is apparent from the data given in Table II comparing station 10 with station 29 that December-January-February air temperatures were lowest in the winter of 1919-20, second lowest in 1921-22, somewhat higher in 1920-21, and highest in 1948-49.

Although no precise numerical correlation can be made with these data, it seems that winter air temperatures for the State of Virginia do influence the surface water temperatures of lower Chesapeake Bay to a rather large extent and probably also influence bottom water temperatures.

TABLE II

SURFACE WATER TEMPERATURES OF LOWER CHESAPEAKE BAY
AVERAGE MONTHLY AIR TEMPERATURES OF THE STATE OF VIRGINIA FOR WINTER MONTHS OF VARIOUS YEARS

Month	Wells, Bailey and Henderson[1] Station Number 29						U. S. Coast and Geodetic Survey[2] Old Point Comfort						Station Number 10[3]	
	1919-1920		1920-1921		1921-1922		1943-1944		1944-1945		1945-1946		1948-1949	
	Water[4]	Air[5]	Water[4]	Air[5]	Water[4]	Air[5]	Water[4]	Air[5]	Water[4]	Air[5]	Water[4]	Air[5]	Water[4]	Air[5]
October Average		+ 8.1		+ 2.8		- 0.2	62.4	- 1.5	64.8	- 0.8	65.7	- 1.0		- 3.1
November Average		+ 1.0		- 1.0		+ 3.2	53.2	- 0.8	53.4	- 1.0	57.9	+ 1.7		+ 4.1
November 19													61.0	
December 5			50.4											
December 11													54.2	
December Average		- 3.1		+ 1.3		+ 1.9	42.4	- 0.8	40.5	- 4.3				+ 2.4
January 7													46.0	
January 12	35.0													
January Average		- 2.9		+ 1.7		- 2.6	38.3	+ 1.2	38.1	- 3.2				+ 7.7
January 22					38.8									
January 23			41.0											
February 1													47.5	
February 9													48.0	
February Average		- 3.4		+ 3.4		+ 3.5	42.1	+ 2.3	39.7	2.0				+ 7.0
March 11	37.8													
March Average		- 0.3		+10.0		+ 1.6	46.4	- 2.1	51.3	+ 9.8				+ 0.1
March 23													49.0	
March 26					46.2									

1 - Wells, Bailey and Henderson, 1929.
2.- U. S. Coast and Geodetic Survey, 1947.
3 - Present Survey
4 - Surface water temperature in degrees Fahrenheit.
5 - Deviation of the average monthly air temperature for the State of Virginia from the 59-year average for that month in degrees Fahrenheit. U. S. Weather Bureau, 1949.

Figure 2
BATHYTHERMOGRAPH DATA
November 19, 1948

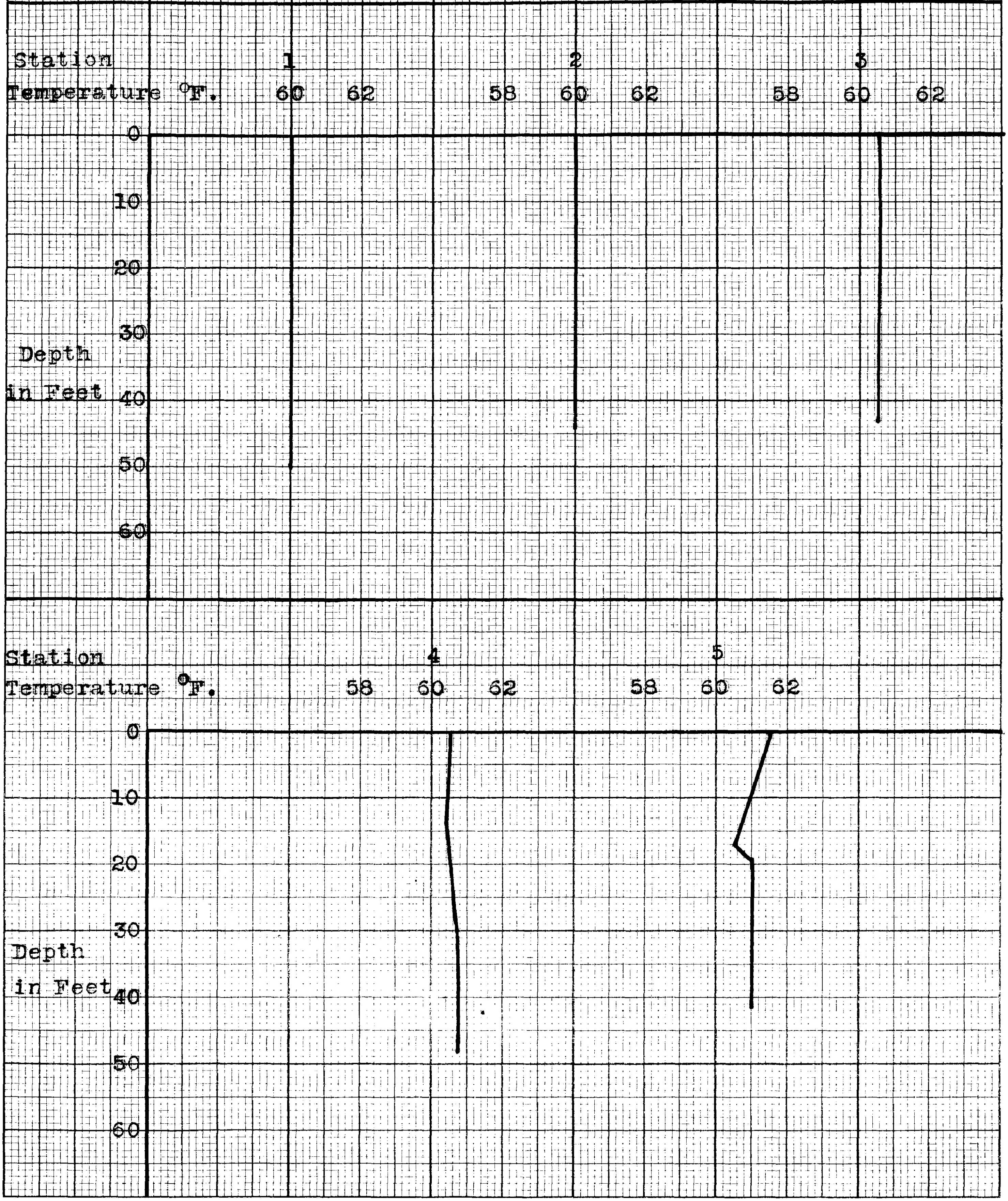


Figure 3

BATHYTHERMOGRAPH DATA

November 20, 1948

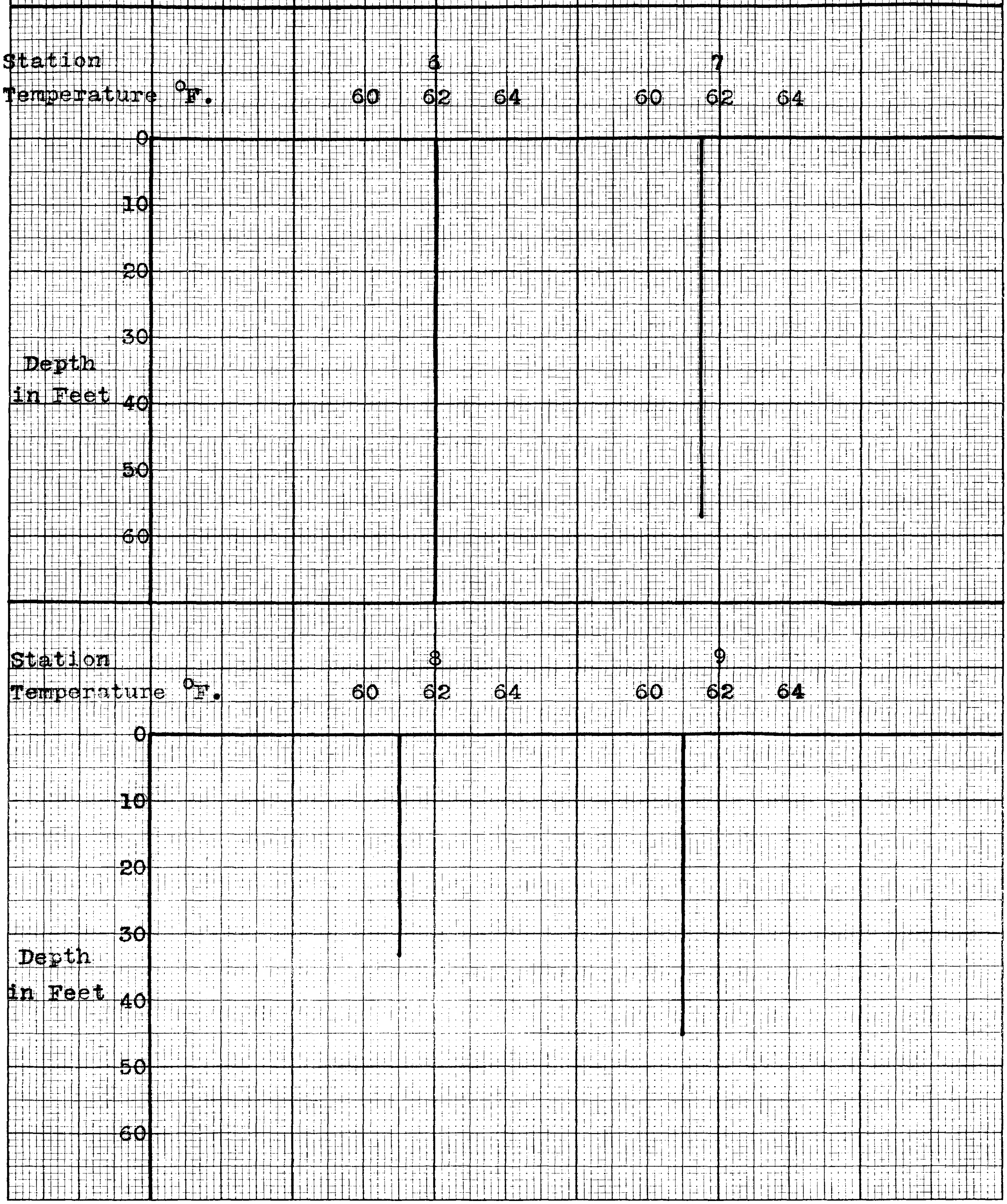


Figure 4
BATHYTHERMOGRAPH DATA
December 11, 1948

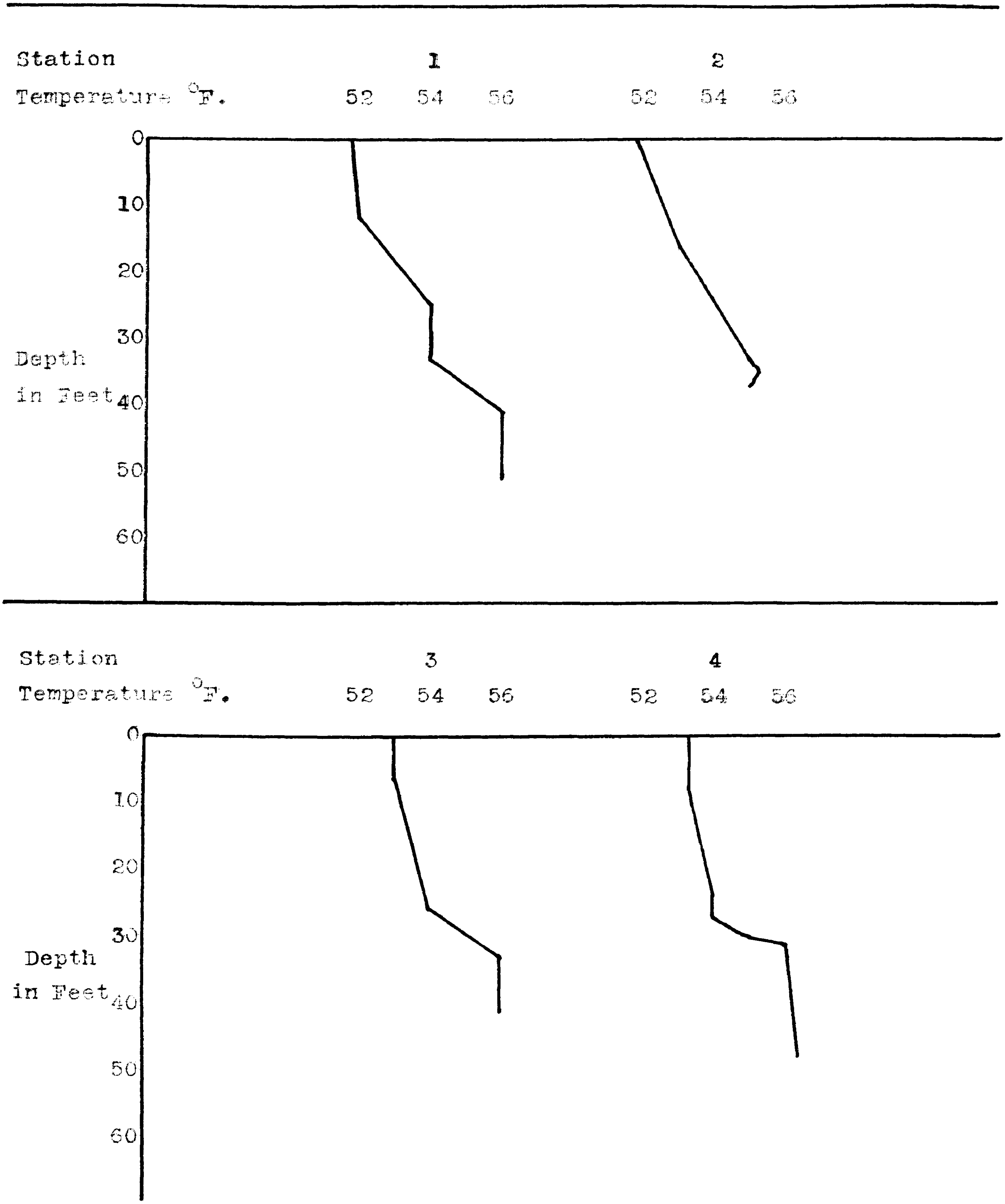


Figure 5
BATHYTHERMOGRAPH DATA
December 11, 1948

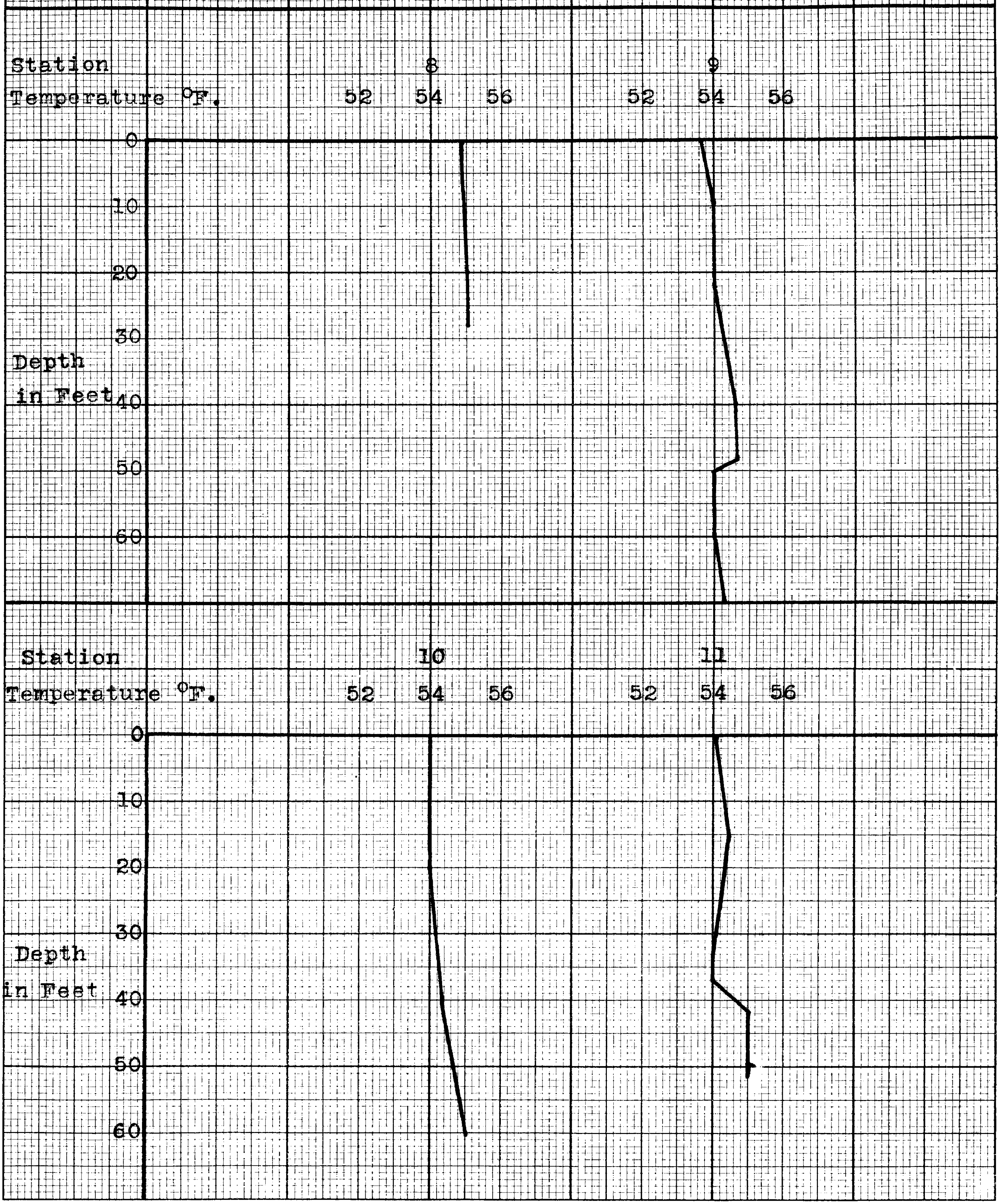


Figure 6
BATHYTHERMOGRAPH DATA
December 21, 1948

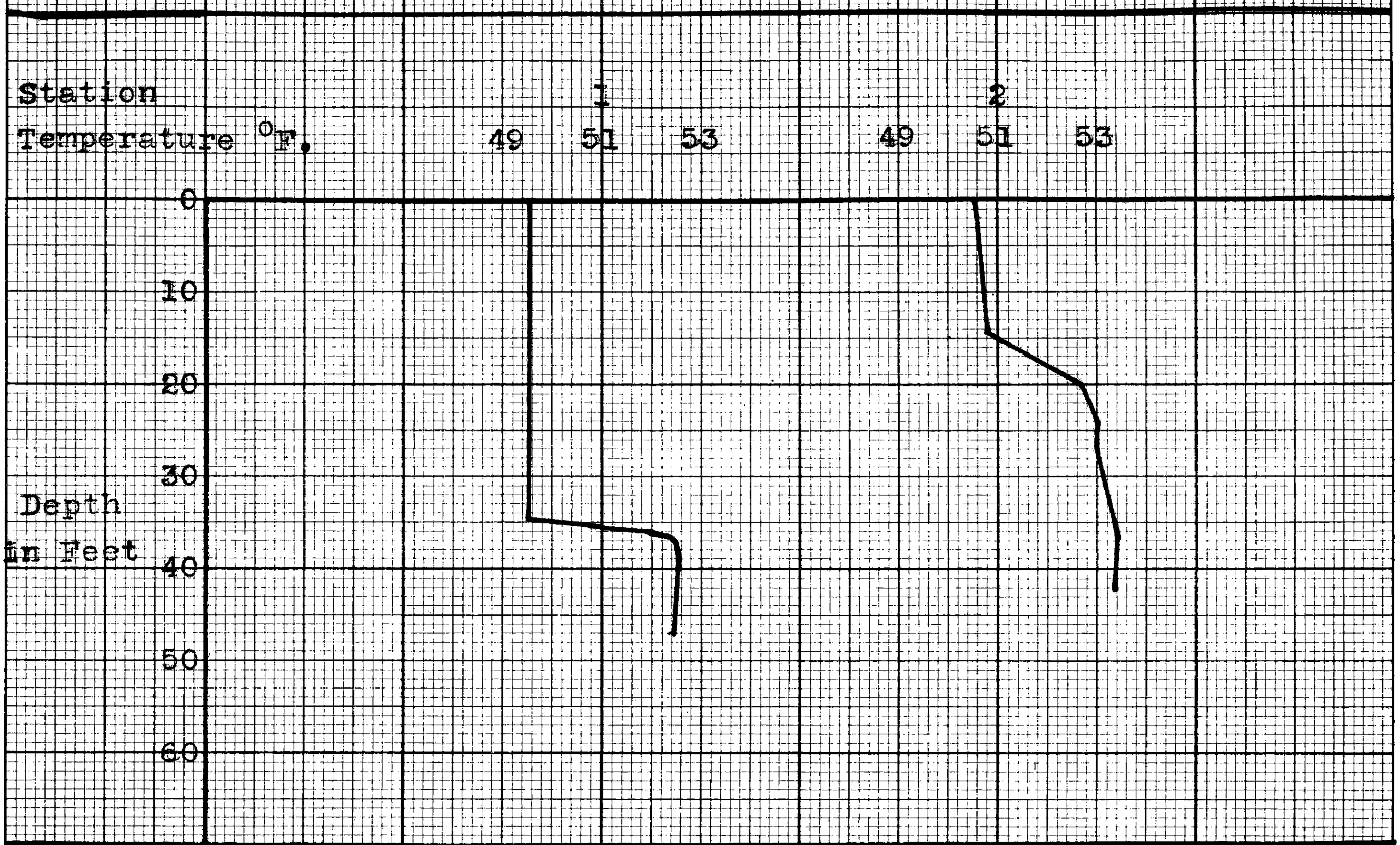


Figure 7
BATHYTHERMOGRAPH DATA
January 7, 1949

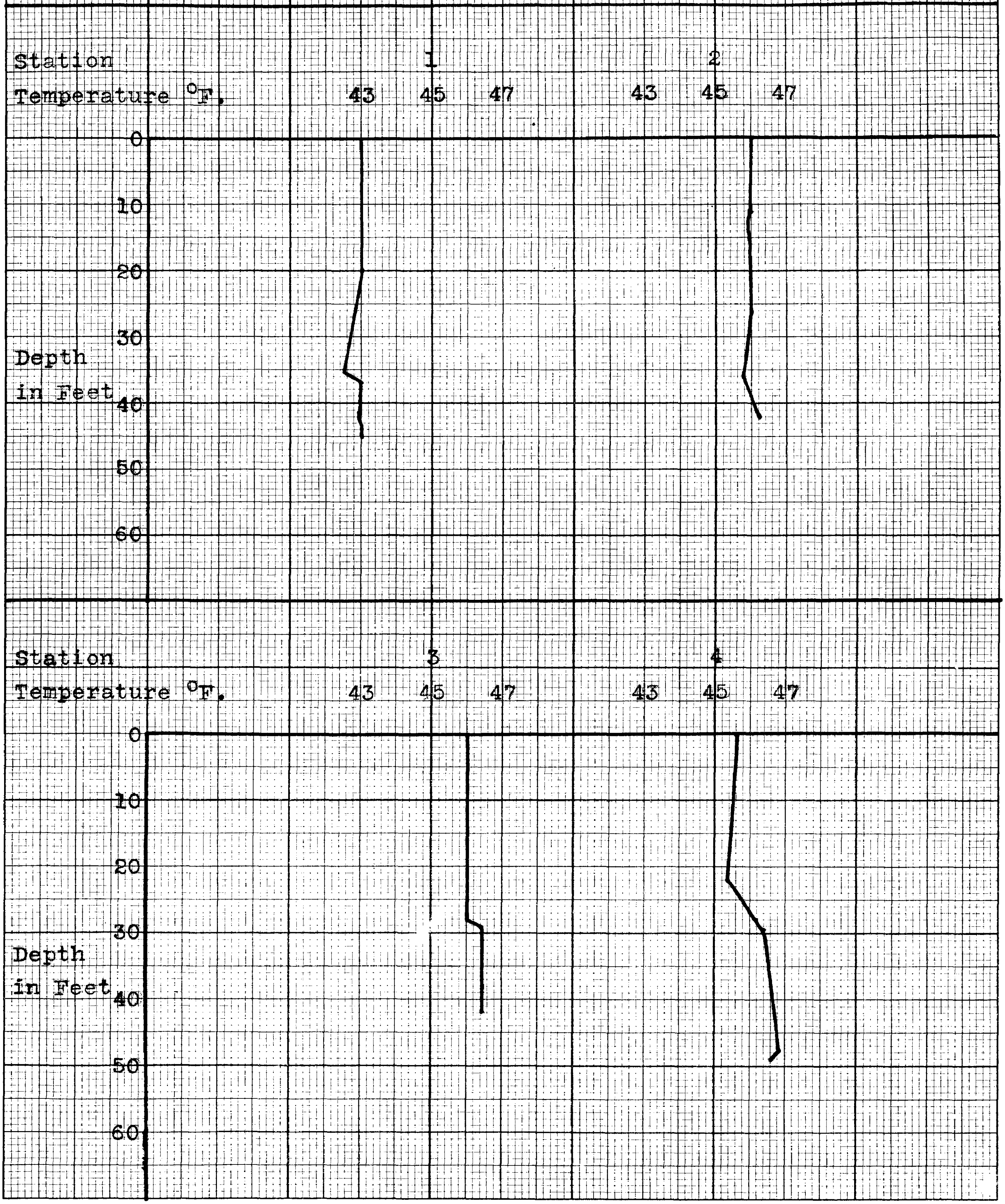


Figure 8

BATHYTHERMOGRAPH DATA

January 7, 1949

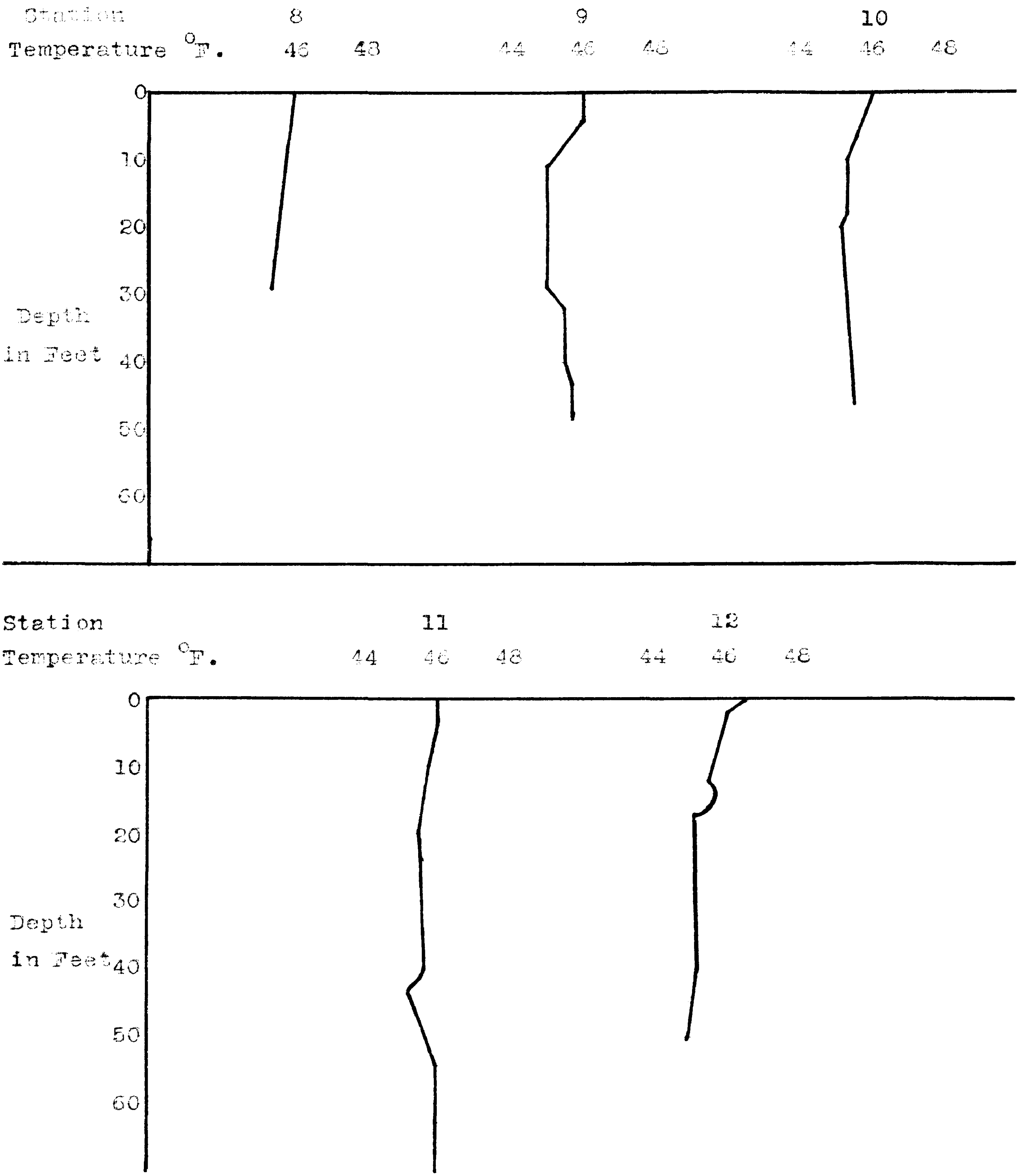


Figure 9

BATHYTHERMOGRAPH DATA

February 1, 1949

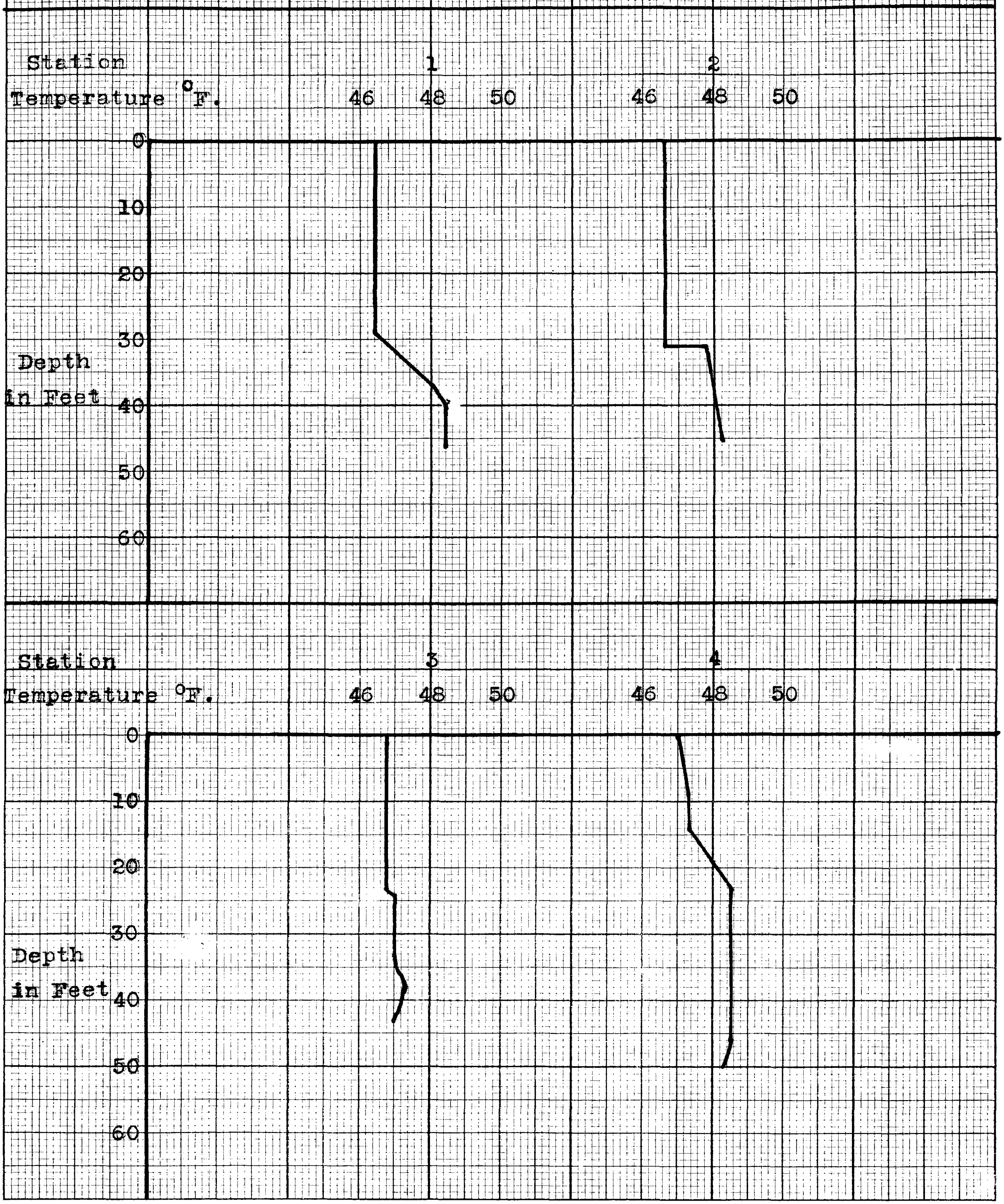


Figure 10
BATHYTHERMOGRAPH DATA
February 1, 1949

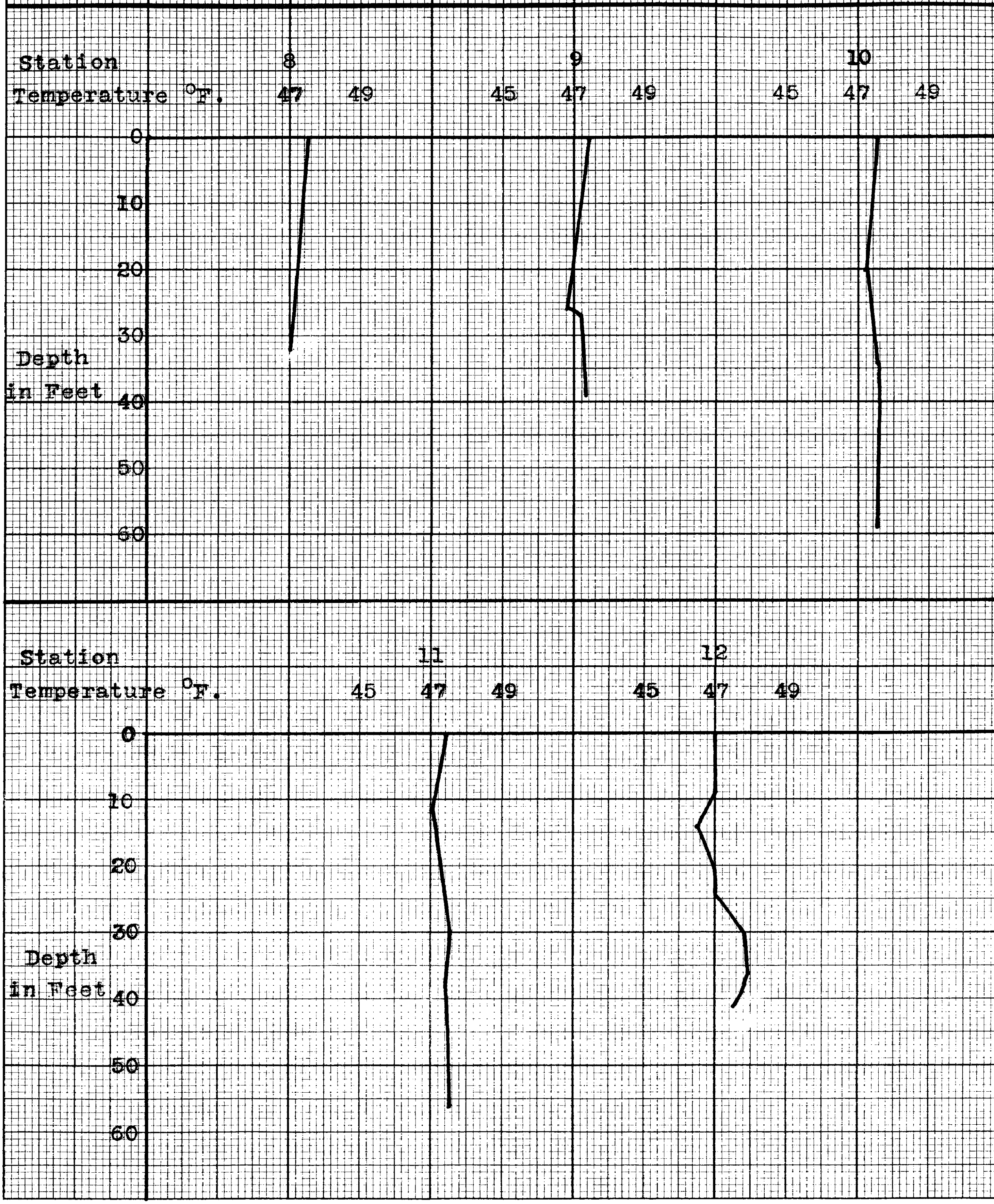


Figure 11
BATHYTHERMOGRAPH DATA
February 9, 1949

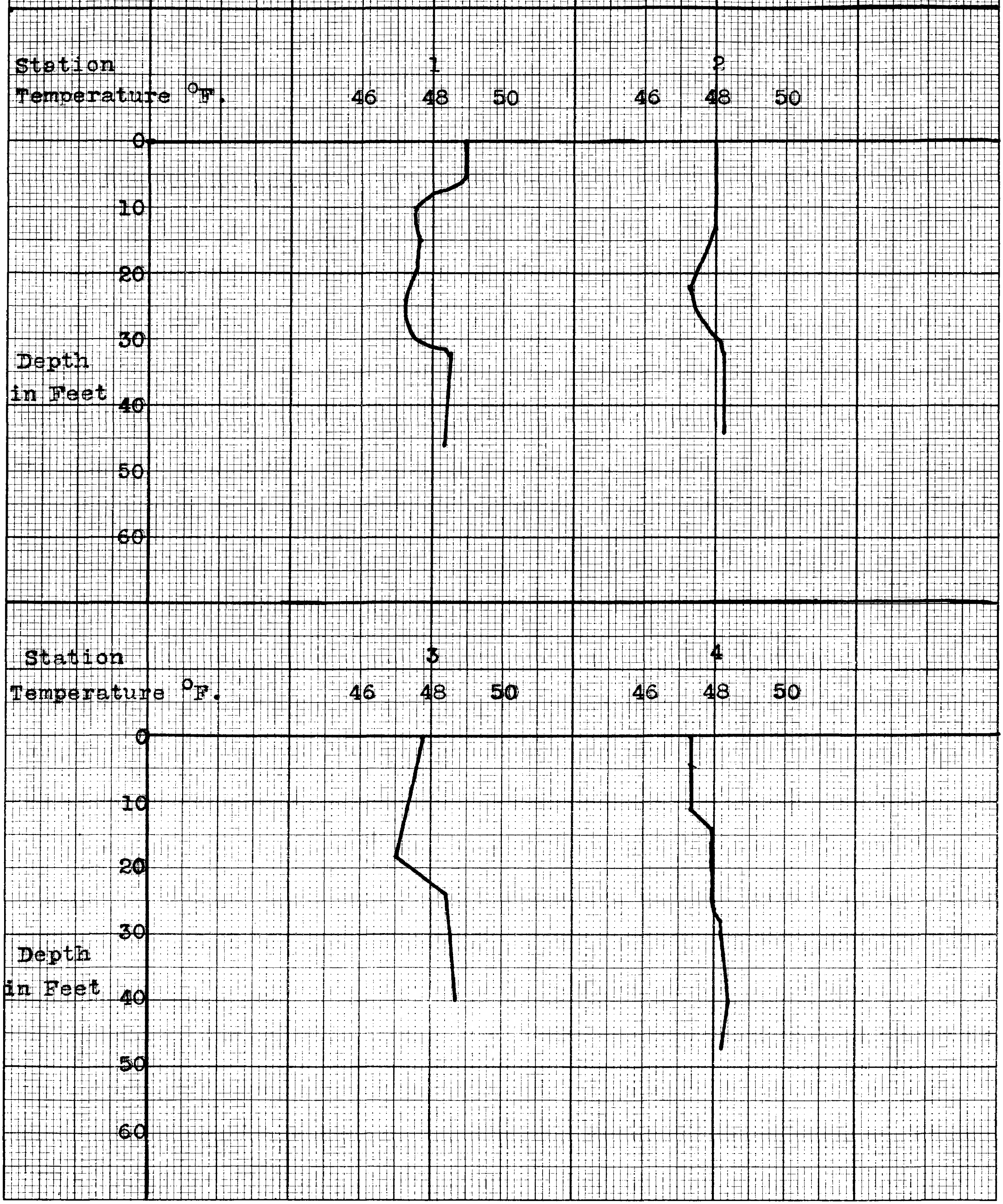


Figure 12
BATHYTHERMOGRAPH DATA
February 9, 1949

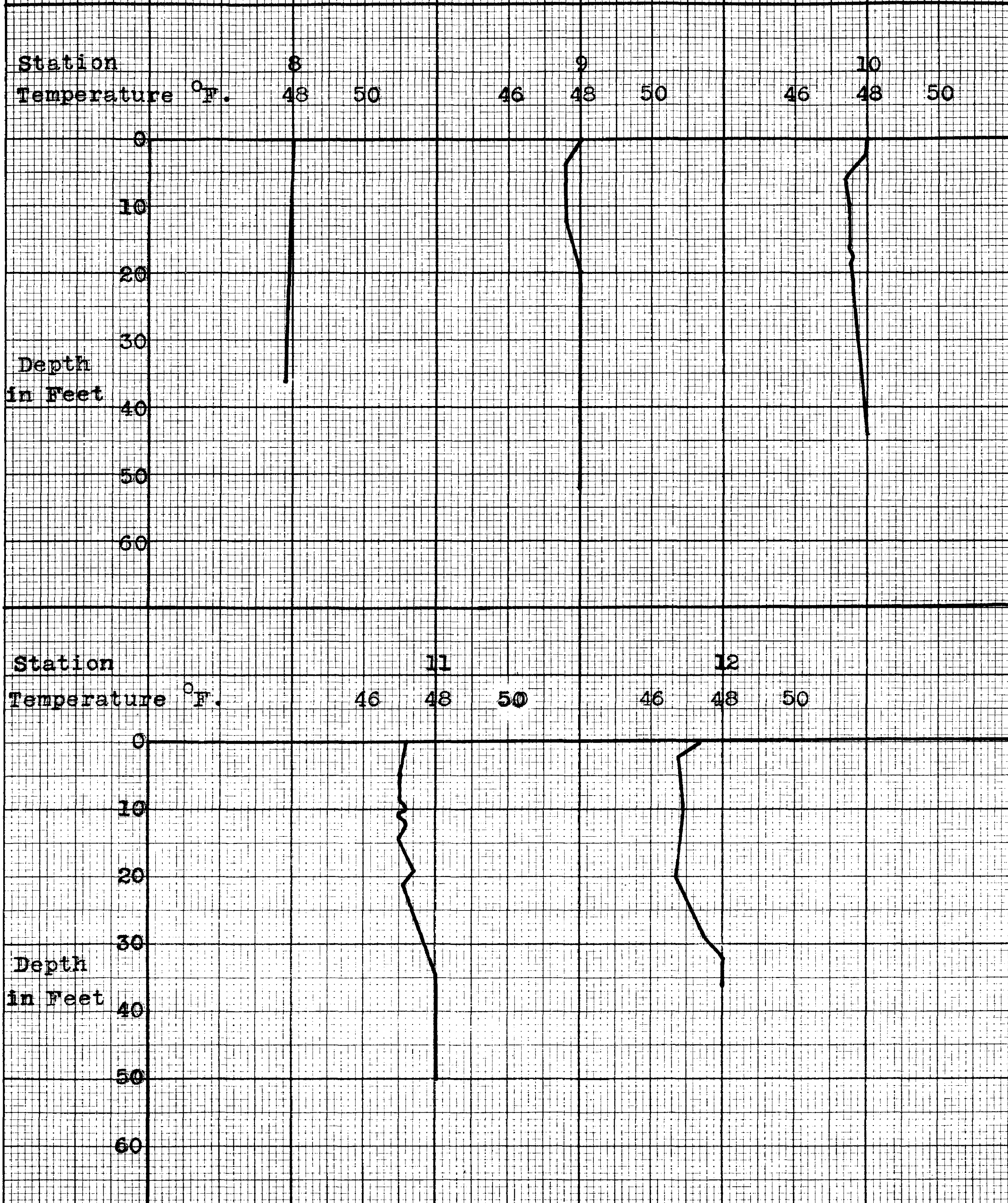
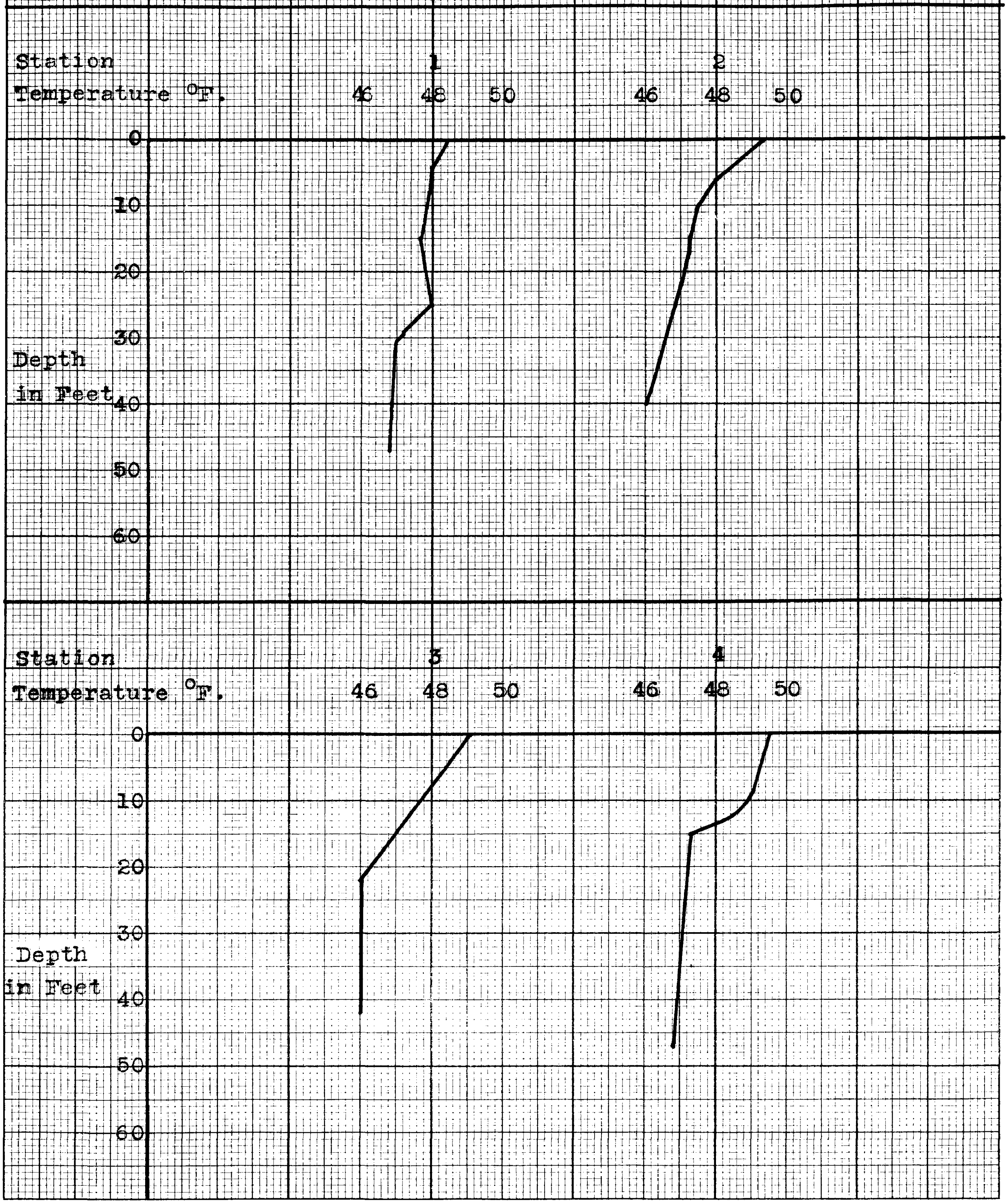


Figure 13
BATHYTHERMOGRAPH DATA
March 23, 1949



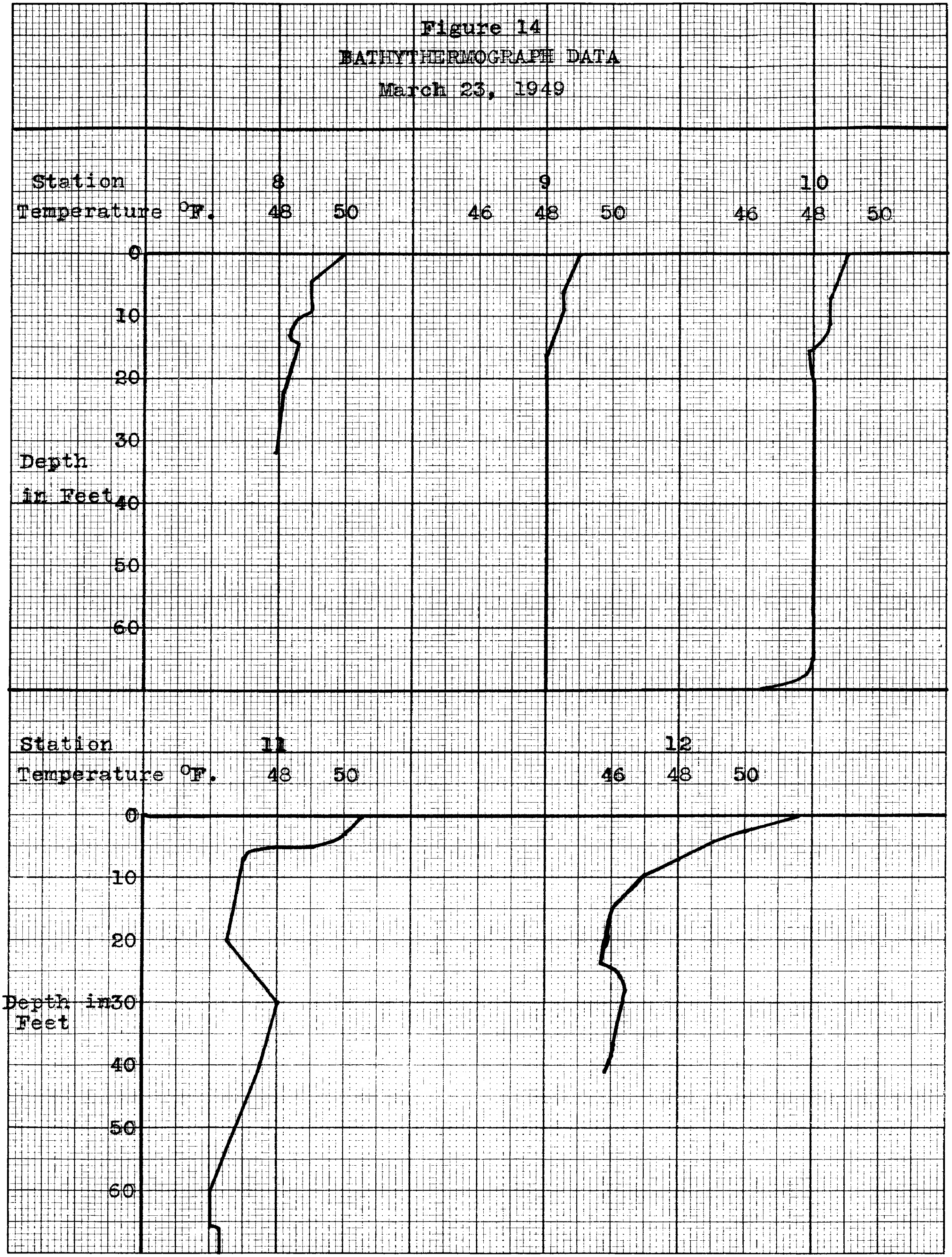


Figure 14
BATHYTHERMOGRAPH DATA
March 23, 1949
Station
8
9
10
Temperature °F.
48
50
46
48
50
46
48
50
0
10
20
30
Depth
in Feet
40
50
60
Station
11
12
Temperature °F.
48
50
46
48
50
0
10
20
Depth in
Feet
30
40
50
60

SALINITY

Salinity data for the winter of 1948-49 are given in Table IV. Surface salinity was highest on November 19-20 and lowest on February 9 at all stations. The mean difference in surface salinities between these two dates was about 9.0 parts per thousand.

The highest or second highest bottom salinities were recorded in most cases on February 9 and March 23. The lowest bottom salinities at all stations occurred on February 1. The mean range between highest and lowest was about 6.0 parts per thousand.

Salinity stratification as indicated by bottom-surface salinity difference (Table III) was weakest on November 19-20 and strongest on February 9.

Bottom salinities were in most cases highest at station 4, and surface salinities at station 8. Neither bottom nor surface salinities were consistently lower at any particular stations.

According to Cowles (1930) the seasonal surface salinity pattern for Chesapeake Bay consists of rising salinities during the summer to a late fall and winter maximum followed by decreasing salinities to a spring minimum. This trend was not followed in the winter of 1948-49. A possible explanation is that November and December 1948 were the wettest and fifth wettest, respectively, in Virginia in 58 years. November precipitation was 6.03 inches and December, 5.06 inches compared with 58-year averages of 2.52 inches for November and 3.06 inches for December. It is probable that this unusual rainfall caused below normal surface salinities throughout the lower Bay for the rest of the winter although this condition was not yet apparent on November 19 and 20.

Figure 15 compares Virginia rainfall for the winter of 1948-49 with the surface salinities of stations 9 and 10, and for the winters of 1919-20, 1920-21, and 1921-22 with the surface salinities of stations 29 and 30 of Wells, Bailey, and Henderson (1929). These four stations were selected for comparison because they are in the same general locality, and they are near the Eastern Shore away from the mouths of the large rivers. Precipitation in the winter of 1920-21 was much like that in 1948-49, with heavy precipitation in November and December declining to below average in February and March. Surface salinities during these years decreased from late fall highs to winter lows and increased in early spring.

For the winters of 1919-20 and 1921-22 precipitation followed a more nearly normal* trend with lower late fall and early winter precipitations increasing toward late winter. The surface salinity trends for stations 29 and 30 show decreases from January highs to March lows which, as mentioned above, Cowles (1930) believes to be the expected condition.

The greatest average change in surface salinities between any two sampling dates was the decrease between November 19 and 20 and December 11. These decreases in salinity were undoubtedly due to the increase in river discharge resulting from the heavy rains of the

* Fifty-eight year average monthly precipitation for the State of Virginia is: November, 2.52"; December, 2.83"; January, 3.28"; February, 3.04"; March, 3.62" (U. S. Weather Bureau, 1949).

preceding month. U. S. Weather Bureau (1949) records show that there was a major flood in the lower James River from December 3 to 7. The crest, 21.6 (13.6 feet above flood stage), at Richmond on December 6 was the eighth highest stage recorded at this city in fifty-five years. The Mattaponi River, which joins with the Pamunkey River at West Point, Virginia, to form the York River, was also in flood at this time.

COMPARISON OF VIRGINIA MONTHLY PRECIPITATION WITH SURFACE SALINITIES AT FOUR CHESAPEAKE BAY SAMPLING STATIONS WINTERS OF 1948-49, 1919-20, 1920-21, 1921-22

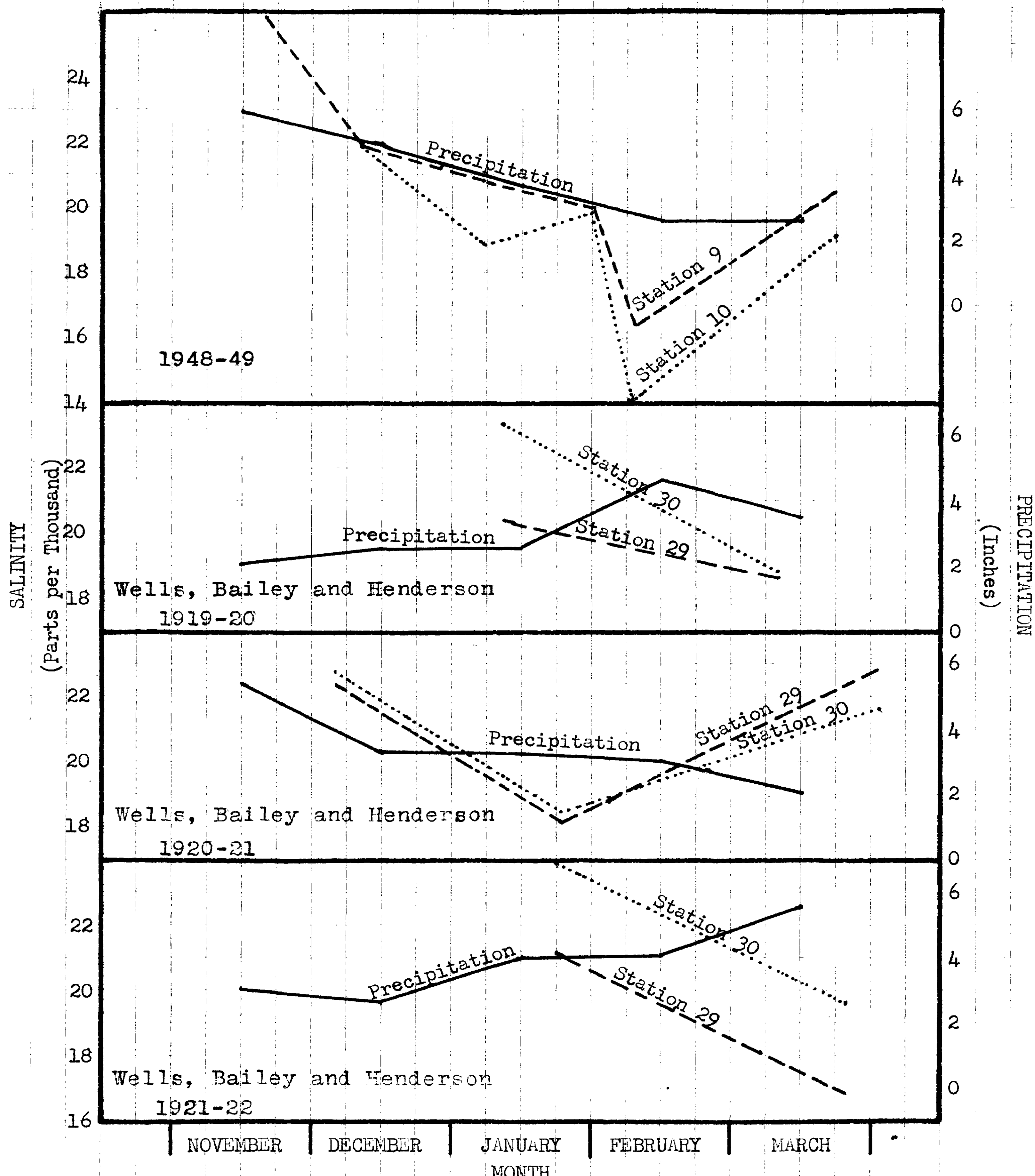


Figure 15

TABLE III

SALINITY STRATIFICATION
AS INDICATED BY BOTTOM-SURFACE SALINITY DIFFERENCE
(Parts per Thousand)

Station Number	Date 1948-1949 11/19	11/20	12/11	12/21	1/7	2/1	2/9	3/23
1	0.5	---	7.2	2.8	3.0	1.1	12.1	3.9
2	0.0	---	2.9	5.5	1.4	2.6	11.3	6.6
3	1.6	---	3.2	---	5.5	3.5	11.3	8.8
4	1.2	---	5.9	---	5.5	4.7	13.4	9.8
5	3.1	---	---	---	---	---	---	---
6	---	3.6	---	---	---	---	---	---
7	---	0.8	---	---	---	---	---	---
8	---	0.2	0.9	---	0.9	0.9	7.1	3.4
9	---	-0.1	0.7	---	1.9	0.2	8.9	5.9
10	---	---	1.2	---	3.2	1.0	10.6	6.9
11	---	---	0.8	---	4.7	2.9	11.0	6.6
12	---	---	---	---	3.1	2.9	10.1	6.0

TABLE IV

SALINITY
(Parts per Thousand)

Date

Station Number		11/19/48 11/20/48	12/11/48	12/21/48	1/7/49	2/1/49	2/9/49	3/23/49
1 -	Surface	21.9	15.5	18.7	18.3	16.7	15.1	19.0
	Bottom	22.4	22.7	21.5	21.3	17.8	27.2	22.9
2 -	Surface	22.9	17.3	19.7	19.7	16.8	15.7	19.6
	Bottom	22.9	20.2	25.2	21.1	19.4	27.0	26.2
3 -	Surface	24.0	19.5	----	19.8	17.1	15.5	19.2
	Bottom	25.6	22.7	----	25.3	20.6	26.8	28.0
4 -	Surface	26.2	21.2	----	20.1	19.4	14.7	18.9
	Bottom	27.4	27.1	----	25.6	24.1	28.1	28.7
5 -	Surface	23.7	----	----	----	----	----	----
	Bottom	26.8	----	----	----	----	----	----
6 -	Surface	26.2	----	----	----	----	----	----
	Bottom	29.8	----	----	----	----	----	----
7 -	Surface	25.4	----	----	----	----	----	----
	Bottom	26.2	----	----	----	----	----	----
8 -	Surface	28.5	22.2	----	22.0	20.5	17.3	20.0
	Bottom	28.7	23.1	----	22.9	21.4	24.4	23.4
9 -	Surface	25.8	22.2	----	21.0	20.2	16.5	20.4
	Bottom	25.7	22.9	----	22.9	20.4	25.4	26.3
10 -	Surface	----	22.1	----	18.9	20.1	14.1	19.1
	Bottom	----	23.3	----	22.1	21.1	24.7	26.0
11 -	Surface	----	22.3	----	18.3	18.0	13.8	18.3
	Bottom	----	23.1	----	23.0	20.9	24.8	24.9
12 -	Surface	----	----	----	18.3	16.5	14.2	18.6
	Bottom	----	----	----	21.4	19.4	24.3	24.6

OXYGEN

Dissolved oxygen content of bottom waters is given in Table V.

In general, fairly high oxygens in November decreased slightly by December 11, increased to winter maxima on February 1, and decreased to generally low values by late March. The minimum oxygen content observed was 1.8 millileters per liter at station 9 on March 23, and the maximum 7.8 milliliters per liter at station 9 on February 1. The greatest range in oxygen content, 1.8 at station 9 to 7.1 at station 12, occurred on March 23, and the least range, 7.0 at station 4 to 7.8 at station 9, on February 1.

The fact that on February 1 bottom oxygens were higher and bottom salinities lower at all stations than on any other sampling date indicates that fairly intensive mixing had recently taken place. It is known that rough weather prevailed on lower Chesapeake Bay for several days preceding this sampling date. Small craft warnings were displayed in this area on January 28, 29, and 30 and southwest storm warnings on January 31. On February 1 the lower Bay was still fairly rough in the morning but had moderated by afternoon. The combination of hydrographic conditions found on that date were undoubtedly caused, at least in part, by the weather conditions prevailing during the previous few days.

TABLE V

BOTTOM OXYGEN
(Milliliters per liter)

Date

Station Number	11/19/48	11/20/48	12/11/48	12/21/48	1/7/49	2/1/49	2/9/49	3/23/49
1	4.5	---	5.0	5.6	2.1	7.6	5.5	7.0
2	5.6	---	5.6	6.4	6.4	7.5	4.5	1.9
3	5.3	---	5.1	---	6.7	7.3	5.9	2.0
4	5.5	---	3.0	---	6.8	7.0	6.1	3.8
5	5.4	---	---	---	---	---	---	---
6	---	4.9	---	---	---	---	---	---
7	---	5.5	---	---	---	---	---	---
8	---	5.8	2.0	---	5.4	7.7	4.7	1.9
9	---	6.0	4.6	---	4.6	7.8	6.5	1.8
10	---	---	3.4	---	5.8	7.5	4.8	5.1
11	---	---	4.5	---	6.1	7.4	6.0	5.5
12	---	---	---	---	5.8	7.5	4.5	7.1

DISTRIBUTION OF CRAB DREDGE BOATS

Excluding adverse weather the major factor controlling the day-to-day fluctuations in catch of the winter crab dredge fishery is undoubtedly the absence of presence of beds or schools of crabs.

The number and distribution of crab dredge boats seen during the cruises taken in the winter of 1948-1949 was recorded. On November 19 and 20 the crab dredging season had not yet started, but on December 11, fifty-one crab dredge boats were seen. Nine of these boats were in the lower York River channel distributed halfway between stations 2 and 3 to about one mile southeast of station 3. Although the bottom waters of station 4 were found to be low in oxygen (3.0 milliliters per liter) on that date and could conceivably drive crabs toward the station 3 area, the number of boats seen were scarcely large enough to indicate a very heavy concentration of crabs.

Of the remaining crab boats, thirty were concentrated around and to the west of station 11 and working over the area as close together as was possible without fouling each others' dredge lines. Low oxygens were recorded at stations 8 and 10 on this date. Oxygen content of bottom waters at stations 9 and 11 were markedly higher. The remaining twelve boats in the vicinity of station 12 were more scattered than those at station 11.

On December 21 stations 1 and 2 were occupied, but the trip was discontinued due to extremely rough weather.

On January 7, 1949, forty-nine crab boats were seen in the lower

York River channel distributed from about one mile southeast of station 1 to about one mile northwest of station 3 with the greatest concentration (twenty-one boats) in the immediate vicinity of station 2 and the remaining boats tapering in numbers up and down channel. No other crab boats were seen for the remainder of the cruise. It is noteworthy that on this date a low bottom oxygen of 2.1 milliliters per liter existed at station 1 and all other stations were fairly high in bottom oxygen content. As on December 11 no weather or surface conditions prevailed that would influence the distribution of crab boats.

On February 1, when oxygen values of all bottom waters sampled were very high, twenty-four of the forty-eight crab boats seen were scattered from about one mile southwest of station 1 to two or three miles south of station 4, and the remaining twenty off the Eastern Shore with no large concentration of crab boats at any particular position.

On February 9 thirty-eight crab boats were seen, ten in the shallower waters (twenty-five to thirty feet deep) about one to one and one-half miles west of station 2, twenty-two more or less spread out to the west of station 9, and six scattered one to one and one-half miles west of station 12. Although on these two February dates there was enough grouping of the crab boats to indicate possible schooling of crabs, there were no very large concentrations of crab boats such as were found on December 11 around station 11 nor on January 7 in the lower York River channel.

On March 23 only 9 crab boats were seen. These were scattered in the shallower waters to the west of the York River channel between stations 2 and 3. By late March crab dredge catches had generally fallen off, and most dredgers had turned to other pursuits.

EXPERIMENTS WITH CRABS IN RELATION TO TEMPERATURE

The lowest bottom water temperatures observed in the Bay during the winter of 1948-49 occurred on January 7. On this date bottom water temperatures ranged from 43.0 to 46.5°F. although it is known that lower bottom water temperatures in winter are not unusual (Wells, Bailey, and Henderson, 1929) (see Table II).

In order to observe crab activity at low temperatures, 13 immature crabs, ranging from 50 to 90 millimeters in width, were kept in a large aquarium supplied with a constant stream of York River water. The bottom of the aquarium was covered with about 3 inches of sand.

No water temperatures below 50.0°F. were found in the aquarium until December 31 when the temperature was 47.5°F. It remained at this value over January 1, dropped to 45.5°F. on January 2, rose to 46.5°F. on January 3 and to 50.0°F. on January 4. During the four day period when temperatures were below 50.0°F., the crabs walked and swam, and some of them fed on small clusters of crab eggs that were dropped into the aquarium as food.

From January 5 to January 29 water temperatures ranged between 51.0 and 61.0°F., and the crabs remained active. On January 30 the water temperature dropped to 44.5°F. On this date all the crabs except one were buried (i.e. no part of carapace visible) or partly buried (i.e. only the front part of carapace visible). The one that remained on the surface of the sand moved around on the sand and fed on crab egg clusters that were dropped near it, but its movements while feeding were slow.

Another group of crabs, which was being held in the laboratory during January in a large tub to which running York River water was piped, was also seen to move about freely by walking or swimming during that month. The water temperatures in the tub were generally two or three degrees higher than those in the aquarium. When the water temperature in the tub was lowest, 48.0°F. on January 3, two mature crabs in the tub accepted and fed on crab egg clusters.

It is a rather widely held belief that crabs bury themselves in the bottom mud or sand during cold weather. The number of crabs that would or would not bury in the aquarium sand did not seem to be related to the temperature of the water. Twelve had buried themselves in the sand on January 30 when the lowest water temperature was found, and twelve were found buried on January 7 when the temperature was 53.5°F., but on several occasions, at temperatures between 44.5 and 53.5°F., none of the crabs were buried.

The above mentioned crabs were held at reduced temperatures throughout most of the winter, and although on two occasions the water temperature became about as low as the lowest bottom water temperatures observed in the lower Bay, no complete cessation of activity was seen at any time among the crabs held in the aquarium. There was no time at which at least one crab would not feed when food was made available to it.

To observe differences in reactions to low temperatures when different bottom materials were available for burying, three mature and twelve immature crabs (48 to 90 millimeters in width) were isolated in individual jars in a refrigerated constant temperature bath (Aminco, 50 gallon capacity). Five jars had no bottom material, five contained three to four inches of sand, and the remaining five, three to four inches of mud. The water in the jars had a salinity of 15.8 parts per thousand. The temperature was reduced from 50.0°F. to 40.0°F. over a period of four days and held at the latter temperature for eight days. On the third day of confinement at 40.0°F. one immature crab, in a jar containing no bottom material, was found dead. On the last day the mature crab in the jar containing no bottom material appeared to be dead but revived rapidly when removed to water having a temperature of 62.5°F. The remaining crabs held at a 40.0°F. temperature moved when they were prodded and also were able to right themselves when turned on their backs. Throughout the experiment the crabs showed no tendency to bury in one bottom material more than another. What caused the deaths of four of the crabs is not known.

To further investigate temperature burying relationships, an aquarium was set up in the constant temperature bath. One half of the bottom of the aquarium was set up in the constant temperature bath. One half of the bottom of the aquarium was covered with mud and the other with sand. A rubber tube, through which water flowed continously, was coiled under the mud and sand to raise the temperature of the bottom material slightly. The aquarium was filled with water of 17.4 parts per thousand salinity, and stocked with ten crabs ranging in size from 35 to 50 millimeters. The crabs were kept in the aquarium for eighteen days during which time the water temperature ranged from 45.5 to 46.5°F., and the bottom material temperature from

46.5 to 48.0°F. On the fourth day of the experiment one crab was found dead and partly consumed by the others, but the remaining crabs were active and apparently healthy throughout the eighteen days and fed whenever food was available. There was no sign of any tendency for the crabs to bury themselves in mud in preference to sand or vice-versa, and the number of crabs buried at different times ranged from one to eight with no apparent trend or pattern.

In the next experiment 20 small crabs (15 to 27 millimeters wide) were placed in fingerbowls half of which had mud bottom material and half sand. Water having a salinity of 15.8 parts per thousand was added. The fingerbowls were placed in a refrigerator. These crabs were examined after four days exposure at a temperature of from 37.5 to 39.0°F. None of the 10 crabs in the fingerbowls having sand bottom material was buried. All were active and able to right themselves easily when turned on their back and 8 of them fed readily on crab eggs which were placed in the fingerbowls. Three of the ten crabs in the fingerbowls containing mud were not buried, three were partly buried, and four were completely buried. All ten crabs were active, but only one fed readily.

The above crabs were left in the refrigerator for two more days at the same temperature and again examined. At the end of this period it was found that none of the crabs on sand was buried; one was dead, and the remaining 9 were active. Two of the crabs on mud were buried and 8 were not. One crab (not buried) was dead and the remaining 9 were active.

It had been noticed that a consistently large percentage of crabs kept in reserve in fingerbowls in the laboratory at room temperature were found buried in the sand or mud during the daytime, but during the night the majority of these crabs would not be buried.

To test the effects of light in relation to burying, 20 crabs (15 to 27 millimeters wide) were placed in fingerbowls containing mud bottom material and 20 in fingerbowls containing sand. These 40 crabs were placed in a refrigerator containing a lighted bulb. The following day it was found that the heat of the light bulb had kept the refrigerator temperature up to 52.5°F. All of the 20 crabs on mud bottom were completely buried, 16 of the 20 crabs on sand bottom were completely buried, one crab was partly buried, and 3 were not buried. One of the latter was a crab which had shed and died as a soft crab.

The light in the refrigerator was turned off for the following 24 hours and the crabs examined at the end of this period. With the light off the temperature had dropped to 39.0°F. Of the 19 crabs on sand 16 were not buried, 3 were partly buried and one of the former was dead. Of the 20 crabs on mud, 12 were buried, 2 partly buried and 6 were not buried. After 3 additional days in darkness at 36.5 to 39.0°F., it was found that all 18 crabs on sand were not buried, half of the 20 on mud were buried, and the other half were partly buried.

The experiment was repeated using 20 small (15 to 27 millimeters wide) crabs, 10 on mud bottom and 10 on sand. They were kept in a dark refrigerator at 35.5 to 37.5°F. for 2 days. At the end of this period they were examined and it was found that the 10 crabs on sand were not buried, 8 of the 10 on mud were not buried and the remaining 2 on mud were buried. After exposure to light from a 3-cell flashlight (which did not increase the refrigerator temperature) for 6 hours, all of the crabs on mud were found to have buried themselves. One crab on sand was not buried, 3 were partly buried, and 6 were completely buried.

In summing the five observations on crabs kept in the refrigerator in darkness and the two in light, it was found that on the sand bottom in darkness the ratio of observations of crabs not buried to those partly buried to those completely buried was 62:3:0 while on sand in light it was 3:4:22. For the crabs on mud the same ratio in darkness was 24:15:30, while in light it was 0:0:30.

The above information indicates rather strongly that, at least under the conditions of the experiment, the presence or absence of light is the principle factor controlling the crab's burying tendencies. It also appears that mud bottom material induced more burying than sand among the size group of crabs used. This tendency was not noticed in the previous experiments using larger crabs, and it may merely indicate that the smaller crabs have more difficulty burying themselves in sand than in mud.

In order to observe crab reaction to low temperature at different salinities 120 small (15 to 75 millimeters in width) crabs were placed in fingerbowls containing washed sand as bottom material. Sixty crabs were held in a refrigerator at 37.5 to 41.0°F. Of these 60 crabs, 20 were in water having a salinity of 21.2 parts per thousand, 20 in water having a salinity of 5.2 parts per thousand, and 20 were in fresh water. The remaining 60 crabs were held at room temperature (about 70°F.) and divided into 3 groups of 20 at salinities corresponding to those used for the refrigerated crabs. At the end of 48 hours 3 crabs in fresh water in the refrigerator had died. When this experiment was terminated at the end of 72 hours, a total of six crabs in this same group had died, but there were no deaths in any of the other groups. The dead crabs constituted no particular size group.

It was noticed that in the above experiment all of the dead crabs were males so several experiments were set up to determine whether or not a differential death rate existed between males and females. Small crabs (15 to 75 millimeters in width) were placed in fingerbowls containing fresh water and about one-inch of washed sand as bottom material and were held in a refrigerator at 37.5 to 41.0°F. for varying lengths of time. The combined results of these experiments are given below:

TABLE VI

Length of Time Held (Hours)	Number of Crabs Used	Number of Crabs Found Dead	Percentage Mortality
	Males		
24	37	0	0
48	37	10	27
72	18	8	44
	Females		
24	37	0	0
48	37	0	0
72	23	3	13
96	12	2	17
120	23	11	48

Although the numbers of crabs used were too small to give accurate percentage mortality figures, the above figures do indicate that immature female crabs were more resistant than males to the conditions set up in the experiments. Fatalities were not confined to any particular size group.

SUMMARY

1. Hydrographic conditions found in lower Chesapeake Bay during the winter of 1948-49 were probably atypical due to above normal air temperatures and abnormal precipitation.

2. Bottom water temperatures were found to be generally higher than surface water temperatures during December, January, and February at the York River channel stations. This condition did not prevail at the Eastern Shore stations. During January and February temperature inversions were fairly common especially at the Eastern Shore stations. On March 23, 1949, surface water temperatures were higher than bottom water temperatures at all stations.

3. Salinity stratification as indicated by bottom-surface salinity difference was least on November 19 and 20 and greatest on February 9. Surface salinities were highest on November 19 and 20 and lowest on February 9. Bottom salinities were highest at stations 1 and 2 on February 9, at stations 3, 4, 9, 10, 11, and 12 on March 23, and at station 8 on November 20. Bottom salinities were lowest at all stations on February 1.

4. Occasional low values for the dissolved oxygen content of bottom waters were found during the winter. Low oxygen values were more widespread on March 23.

5. The distribution of crab boats noticed during the hydrographic

cruises indicated possible schooling of crabs.

6. Crabs kept in an aquarium supplied with cold water (down to 44.5°F.) throughout most of the winter walked, swam, and fed at all times.

7. Low temperatures did not seem to induce small crabs, 15 to 90 millimeters in width, to bury themselves in mud or sand bottoms in laboratory experiments. The presence of light seemed to induce burying regardless of temperature.

8. Low salinity (5.2 parts per thousand) with low temperature (37.5 to 41.0°F.) did not seem to cause undue mortality among small crabs (15 to 75 millimeters in width). Fresh water with low temperatures did cause an increase in mortalities. Small male crabs appeared to be less resistant than small female crabs to fresh water at low temperatures.

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