

David C. Nutt

FROM THE

DARTMOUTH COLLEGE MUSEUM

HANOVER · NEW HAMPSHIRE

BLUE DOLPHIN LABRADOR

River Flow and Winter Hydrographic Structure
of the Hamilton Inlet-Lake Melville Estuary
of Labrador

by

Lawrence K. Coachman

30 October 1953

Approved for Distribution

Principal Investigator:

David C. Nutt

David C. Nutt

AD No. **21124**

ASTIA FILE COPY

ABSTRACT

This report covers: 1) river-flow studies of the four major tributaries to the Hamilton Inlet - Lake Melville estuary of Labrador and 2) a description and analysis of the basic winter structure of the estuary as observed in March 1953.

The method used by the Blue Dolphin parties in river-flow measurements, both summer and winter, is described, and a summary of the existing knowledge of river discharge into the estuary is presented.

Fresh water inflow to the Hamilton Inlet - Lake Melville estuary varies considerably with the season. Winter flow is about 20,000 - 25,000 C.F.S. and summer flow about 125,000 - 150,000 C.F.S. Spring freshet, occurring in late May, is nearly 500,000 C.F.S.

The source fresh water, entering the western end of the estuary, is close to 0° C. The source salt water is true Arctic water from the Labrador Current. Reduced fresh water inflow in winter is noted by salting of the surface layers. A stable density gradient is observed in the estuary in winter. The basic process of exchange remains the same throughout the year.

Introduction

A study of the winter structure of the Hamilton Inlet - Lake Melville estuary of Labrador was undertaken during the month of March, 1953. This work was performed under subcontract with the Arctic Institute of North America (Project ONR-90, Contract N-onr 367 (01)) and forms a part of the more extensive investigation of the coastal waters of Labrador carried out by the research vessel Blue Dolphin under the contracts N-onr 342 (00) and N-onr 367 (01) from 1949-1953.

The purpose of this report is to set forth the results of the field investigation performed under AINA Project ONR 90. It covers:

- 1.) River flow studies of the Hamilton, North West, Kenamu, and Goose Rivers of Labrador.
- 2.) A description and analysis of the winter hydrographic structure of the Hamilton Inlet - Lake Melville estuary as observed during March, 1953. Data obtained from this project will also be used in the over-all study of the coastal waters of Labrador now being carried out under Contract N-onr 1138 (02).

Throughout preparation for and carrying out the field investigations the utmost cooperation was received from the Arctic Institute of North America, the Office of Naval Research, the United States Air Force, Dartmouth College, the Woods Hole Oceanographic Institution, and the Grenfell Mission at North West River, Labrador. Appreciation is expressed to these institutions and agencies, and to the personnel involved. In connection with the preparation of this report I wish to thank Mr. G. K. Chiselm of the Engineering and Water Resources Branch of the Department of Resources and Development, who made available earlier Canadian flow data on the Hamilton River. Appreciation is also expressed

to Cdr. David C. Nutt, leader and director of the project, Dr. John C. Ayers, of Cornell University, and Dr. Richard H. Backus of the Woods Hole Oceanographic Institution, for their helpful advice in the preparation of the report.

HAMILTON INLET - LAKE MELVILLE ESTUARY

Hamilton Inlet indents the coast of Labrador at latitude 54° north. The bottom is very irregular, varying from shoals of three to ten fathoms to general depths of twenty to forty fathoms. The inlet narrows until at Rigolet, fifty miles westward from the outer islands, it is one mile wide with a sill depth of fourteen to fifteen fathoms. Southwestward of this point, called the Narrows, lies Lake Melville, a tidal lake eighty miles long, twenty miles wide near its western end and with depths of over one hundred fathoms.

The Backway is an arm of Lake Melville extending twenty miles eastward from the junction of the Narrows and the Lake, with depths of seventeen to ninety-five fathoms.

Goose Bay forms a fifteen-mile extension to the westward from the southwest corner of Lake Melville. The bay is thirty fathoms deep and connected to Lake Melville by a channel one-half mile wide and twenty feet deep. Terrington Basin is a small "dead-end" arm of Goose Bay ten to twelve fathoms deep and connected to the bay by a channel fifty yards wide and six fathoms deep (see fig. 1).

A large portion of the eastward drainage of the Ungava Peninsula flows into the estuary. Of the four principal rivers the North West and the Kenamu discharge directly into western Lake Melville, while the Hamilton and the Goose discharge into Goose Bay.

A description and analysis of the summer hydrographic conditions, the tidal problems, water transport through the Narrows, flushing time, and

certain aspects of water exchange within the estuary, have been made (Nutt and Backus 1951, Backus 1952, Nutt 1953). The purpose of the Blue Dolphin Winter Project, 1953, was to confirm the winter hydrographic structure of Terrington Basin, Goose Bay, and Lake Melville as observed during March, 1952, to extend observations to the Backway and Hamilton Inlet, and to obtain an estimate of the winter fresh water inflow to the estuary.

I. THE FRESHWATER INFLOW OF THE RIVERS

Volume measurements of the four major tributaries to the estuary were made in late July 1950, early July and late August 1952, March 1953, and May 1953. The general method employed during the summer season was as follows: At a suitable site along one river bank a base line was measured with a surveyor's chain. From one end of the base line a cross section line was established perpendicular to the course of the river and marked on each bank. A boat was then anchored at various stations on this cross section line and its position determined by transit angle from the opposite end of the base line. Six to twelve stations were established at convenient intervals depending on the width of the river. At each station a hand lead sounding and a surface current measurement with a Price current meter were taken. (In 1950 a current pole or float was used and station positions were determined by estimate). To obtain the median velocity of the vertical column the surface velocity was multiplied by the rapid stream factor of 0.9, and the discharge was then calculated by the rectilinear formula (Hoyt and Grover, 1912). The 1950 data (Backus, 1952) was computed by a slightly modified rectilinear method.

The method employed during March 1953 varied from river to river depending on depth and ice conditions.

The North West River remains open most of the year. A base line was established on the ice foot at the outflow of Grand Lake; and the summer method was used.

On the ice-covered Hamilton, Goose and Kenamu rivers measurements of current and depth were made through holes in the ice on line across the river. Distances were determined by chaining. In the Hamilton, adequate depths made a vertical series of current measurements possible and the median velocity of each station was calculated by the ten-segment method (Hoyt and Grover, 1912); in the Goose and Kenamu only mid-depth velocities were obtained and the median velocity was calculated by applying the factor of .88 (Hoyt and Grover, 1912).

During the March 1953 measurements of the Hamilton a large tidal effect was observed and velocities were obtained at the calculated time* of low water and .8 high water. The .8 high water flow was reduced to high water and the mean discharge calculated:

$$\text{Discharge (mean)} = \frac{\text{LW} + \text{HW}}{2}$$

* Canadian Hydrographic Service, Tide Tables for the Atlantic Coast of Canada. Tidal Publ. No. 1, Dept. of Mines and Technical Surveys, Ottawa.

With the inclusion of Canadian flow data, Table I summarizes the existing knowledge of river discharge in the Hamilton Inlet - Lake Melville estuary.

TABLE I

Discharge of the Four Major Tributaries to the Hamilton Inlet - Lake Melville Estuary. Cubic feet per second.

Month and Year	Hamilton		North West		Kenamu		Goose	
	Day	c.f.s.	Day	c.f.s.	Day	c.f.s.	Day	c.f.s.
7-48	10	105,800						
7-48	15	96,740						
9-48	29	52,600						
1-49	31	18,550*						
4-49	18	9,800(ice)						
9-49	3	60,000						
9-49	5	64,900						
7-50	27	96,375	29	44,597	26	6,325	28	4,760
7-52	8	98,032	9	22,072	8	5,676	7	1,504
8-52	20	68,353	22	23,647	20	24,461	19	10,723
3-53	20	8,000(ice)	27	12,941	18	232(ice)	26	173(ice)
5-53	28	385,830	27	63,613	27	10,250	26	18,789

*Estimate- slush ice

** Mean discharge computed from low water and .8 high water measurements.

The total fresh water inflow to the estuary through the four major tributaries and the percentage contributed by each is given in Table II for each season of observation.

TABLE II

Date	Total Fresh Water		Percent		
	Inflow	c.f.s.	Hamilton	North West	Goose & Kenamu
7/50	152,057		63.4	29.6	7.0
7/52	127,284		77.0	17.5	5.5
8/52	127,184		53.7	18.6	27.7
3/53	21,346		37.5	60.6	1.9
5/53	478,482		80.6	13.3	6.1

Discussion Of River Flow

Although these data are fragmentary, the order of magnitude of discharge can be ascertained and certain conclusions about these rivers may be drawn. The Hamilton drains a large area of the Labrador plateau. In winter the water of the plateau and the lower tributaries is largely frozen and the resulting discharge is very low (8,000-10,000 c.f.s.). The advent of warm weather in late May and early June rapidly melts the ice and snow of the interior, releasing the water in a freshet, at which time the river flow increases thirty to forty times (385,000 c.f.s.). Normal summer flow is quite regular and of the order of 100,000 c.f.s. during July, tapering off to 60,000 c.f.s. during September. During the spring, summer and fall the Hamilton contributes fifty to eighty percent of the total fresh water inflow to the estuary but during the winter its contribution is less than forty percent.

The Goose and Kenamu have much smaller drainage basins. Their flow is quite irregular, apparently directly reflecting local meteorological conditions. Normal summer discharge is of the order of 1500 to 6300 c.f.s. as observed in July 1950 and 1952, about 5.5% to 7% of the total fresh water flow, but after the storm of August 16th to 18th, 1952, five to six times as great a flow was observed and these two smaller rivers contributed nearly thirty percent of the fresh water inflow to the estuary. The flow during spring freshet appears to be of the same order of magnitude as that of a severe storm. During midwinter the flow becomes negligible.

Large, deep Grand Lake, out of which flows the North West River, appears to act as a reservoir with a stabilizing influence on the flow. The spring freshet flow in the North West River is only five times as great as the mid-winter flow, while it was observed to be thirty to

forty times as great in the Hamilton and fifty to one hundred times as great in the Goose and Kenamu rivers. In fact during the winter the largest contribution to the estuary, representing sixty percent of the total, is made by the North West River, while at other seasons its contribution was observed to be only thirteen to thirty percent.

The annual picture of fresh water inflow to the Hamilton Inlet - Lake Melville estuary through the four major tributaries shows the considerable seasonal variation typical of higher latitudes where winter cold stores the precipitated moisture as snow and ice to be rapidly released with the advent of spring thaw. The minimum flow of midwinter would appear to occur during mid or late March just prior to the occurrence of above freezing temperatures at mid-day, and may be considered as being in the neighborhood of 20,000 - 25,000 c.f.s. Within six to eight weeks, by late May, the river discharge increases twenty fold to nearly 500,000 c.f.s. The peak of the freshet must pass rapidly, for by early July the total flow is reduced to about 125,000 - 150,000 c.f.s., which is believed fairly typical of midsummer conditions. The September observations of 1949 of the Hamilton River seem to show a gradual reduction in river discharge which likely continues throughout the fall and winter until the minimum flow is reached in late March.

II. WINTER HYDROGRAPHIC STRUCTURE

To determine the winter hydrographic structure of the Hamilton Inlet - Lake Melville estuary a skeleton grid of oceanographic stations was occupied through the ice, or, in the case of the Hamilton Inlet station, from a motorboat (see fig. 1). Observations of temperature and salinity were made with Nansen bottles, reversing thermometers, and bathythermograph, in a routine manner. The water samples were stored in six oz. plastic bottles so that they could be allowed to

freeze in the field without damage to the sample bottles. These bottles, first tested at the Woods Hole Oceanographic Institution, proved satisfactory for the storage of salinity samples, but in those tests the samples were not frozen. In analysis of the material from operation "Ski Jump" and T-3 and in later tests at the Institution where the samples had been frozen, the results have proven unreliable in some cases. Individual errors of from 0.5 to 3 o/oo, too low a salinity, were observed in certain frozen samples while others were perfectly normal.* At the present state of our experience and knowledge with these bottles, no satisfactory explanation can be offered for these discrepancies; but all salinity values, anomalies, in particular, must be examined carefully and treated with caution.

The results from the winter samples from Labrador appear in general to be satisfactory, as is shown by the regular and stable haloclines observed, particularly in the lower layers. However, two isolated anomalies were obtained (30m at BD-38, 50m at BD-50) and these values have been discarded.

Station data as determined by Nansen bottle and reversing thermometer for the twelve stations occupied during March 1953 are given in Table 3 (see fig. 1 for station location). Stations BD-113 and BD-129, in the Hamilton River and Grand Lake respectively, were made primarily to determine the winter temperature structure of the principal fresh water affluents. Station BD-52 in the Hamilton Inlet was occupied to establish the winter hydrographic structure of the source salt water to the estuary. The remaining stations are spread throughout greater Lake Melville (Terrington Basin, Goose Bay, Lake Melville proper, and the Backway).

Longitudinal profiles of temperature and salinity have been constructed from Terrington Basin through Goose Bay and Lake Melville (along

*Personal communication. L. V. Worthington.

the south shore in the deeper water) and into the Backway. The site of exchange of water between Hamilton Inlet and Lake Melville through the Narrows and each side of Henrietta Island is indicated (figures 2 and 3).

To give a more detailed picture of the winter temperature structure the individual bathythermograms for all on the Hamilton River and Grand Lake stations are submitted in figure 4. In all cases except the Goose Bay station (BD-34), where faulty bathythermograph operation is suspected, good adjustment of BT traces to the temperatures from the reversing thermometers was possible.

Discussion of Winter Hydrographic Structure

The fresh water inflow to the estuary is uniformly cold at approximately the freezing point. Data for BD 113 (Hamilton River) shows the temperature to be very nearly 0° C. BD 129 (Grand Lake) shows temperatures close to 0° C. at the surface, increasing to nearly 3° C. at 150 meters. However only the upper eight meters of the Lake flow through the rapids at North West River and the fresh water contribution from Grand Lake through the North West River may be considered at or within a fraction of a degree of 0° C.

Station data for BD-52, Ticoralak section, Hamilton Inlet (figure 1 and table 3) indicates that during the winter season true Arctic water from the Labrador Current is present in all but the upper twenty meters just outside the Narrows.

Thus during mid-winter both the fresh and salt water being contributed to the estuary have reached their maximum cold and lie within a fraction of a degree of their theoretical freezing points. The fresh water inflow has been reduced from one-fifth to one-sixth of the summer and about one-twentieth of the spring freshet flow. The Hamilton Inlet water from the Labrador Current has reached a higher salinity due to the

reduced fresh water inflow and to the formation of ice.

Examination of the station data (table 3) and the longitudinal temperature and salinity profiles (figs. 2 and 3) within greater Lake Melville reveals at once that a stable density gradient is maintained through the midwinter season. This precludes any overturn due to surface cooling and salting. Thus essentially the same basic process of exchange and mixing that occurs during the summer regime occurs during the winter also. This is primarily a vertical circulation with a fresh water surface overflow mixing with salt water below, which in turn is maintained by the saline water of Hamilton Inlet. (Nutt and Backus, 1951).

The effect of the reduced fresh water inflow and the more saline character of the Hamilton Inlet water is seen in the salting of the upper twenty meters of the lake. Although the surface water remains very fresh, the sharp halocline of summertime between ten and twenty meters (Nutt and Backus, 1951) is now noted between the surface and five meters (fig. 3).

The warm surface layer and sharp thermocline of summer has been destroyed by winter cooling, but a temperature inversion with a wedge of warm water, 2° to 3° C. in Terrington Basin and Goose Bay, and 1° to 2° C. in Lake Melville, extends as far eastward as BD-50, ten miles inside the Narrows. It is this wedge of warm water that permits further insight into the mechanics of exchange in winter.

Since all water, whether fresh or salt, which is contributed to the estuary during the winter is colder than this wedge by several degrees, this warm water must be residual summer heat that has not been completely removed by cooling. The stable density gradient in the upper layers inhibits any rapid downward cooling. Once the ice has formed and a snow cover fallen, usually in the latter part of November, a certain

amount of insulation is provided for the water beneath and any abstraction of heat atmospherically is further retarded.

Grand Lake is a deep fresh water lake (140 fathoms) requiring a vertical overturn prior to the formation of ice which occurs usually in late December or early January. Although no definite measurements are available to permit a firm conclusion, we can speculate that fresh water with slightly above freezing temperatures is likely flowing through the North West River until after freeze-up of Lake Melville; and this may contribute to the maintenance of the warm water wedge.

The year around warm water in Goose Bay and Terrington Basin is maintained by the Goose Bay bar (6½ meters) which prohibits entrance of any colder water of a saline character to the lower layers and by the stable density gradient which inhibits cooling from the surface down.

The cold saline water of Hamilton Inlet, after mixing in the Narrows, feeds the bottom layers of Lake Melville. The temperature data for the eastern end of the lake shows the distinct warm water wedge absent east of BD-50 and in the Backway, where special conditions apply (see below). The cooling of the lower layers at BD-50 indicates the westward penetration of the cold saline water.

Comparison of the data from BD-38 and BD-40 in the Epinette Point section, and BD-47 and BD-49 in the Charley Point section (fig. 1 and table 3) reveals no greater tendency toward a rotary circulation than was noted under summer conditions (Nutt and Backus, 1951). The five meter level at BD-38 is two and one-half parts fresher than BD-40 but it is so near the source of fresh water from river discharge which dominates this upper layer that the difference cannot entirely be attributed to a rotary circulation. The low surface salinity at BD-40 is likely due to melt-water rather than true surface water, since a heavy thaw was in progress at the time of occupation. In Bd-49 there appears

to be indication of colder water along the north shore but any circulation this might indicate is not supported by the salinity determinations.

Examination of the bathythermograms (figs. 4 and 5) reveals a very uniform temperature structure at all stations except those of the Charley Point section (BD-47 and BD-49). In this section many small "wiggles" and minor irregularities from 100 meters to the surface in the temperature plot must indicate a certain turbulence and movement of water. At BD-50, however, where an even greater turbulence and movement might be expected, there is uniform vertical temperature structure. The significance of this condition is not apparent. To a lesser degree irregularities in the bathythermograms of BD-105 and BD-106 indicate turbulence and mixing in the upper 30 meters of the Backway.

The hydrographic conditions in the Backway are different from those in Lake Melville and in the lower layers are a result of sill depth control. The only source water is mixed water from the Narrows and lake, as there is no appreciable fresh water inflow. Exchange is carried on by tidal action from the Narrows eastward.

That flushing in the Backway is more advanced in winter than in the rest of Lake Melville is indicated by the less marked temperature inversion and reduced halocline. The density gradient at the eastern end of the Backway, though stable, is quite weak and vertical convection below 30 meters appears possible.

TABLE III

Blue Dolphin Labrador Expedition - Winter Project 1953

Station DataBD-113 3/20/53L. 53°20.9' N
Lo. 60°11.7' W

Depth	T°C.	S	o/oo
0	0.1	1.00	
5	0.00	1.00	
10	-0.01	1.00	

BD-129 3/24/53L. 53°38.4'
Lo. 60°23.6'

Depth	T°C.	S	o/oo
0	0.1	1.00	
50	1.46	1.00	
100	1.03	1.00	
150	2.95	1.00	
200	2.92	1.00	

BD-62 3/21/53L. 53°20.9' N
Lo. 60°22.5' W

Depth	T°C.	S	o/oo
0	0.1	1.00	
5	2.66	15.35	12.30
10	3.07	19.05	15.24
15	2.77	19.49	15.58
20	2.66	19.68	15.74

BD-34 3/19/53L. 53°24.0' N
Lo. 60°04.7' W

Depth	T°C.	S	o/oo
0	0.3	1.00	
5	0.97	13.56	10.90
10	1.81	18.17	14.57
20	1.97	20.37	16.32
30	1.59	20.92	16.78
50	1.46	21.2*	17.0

BD-38 3/16/53L. 53°34.1' N
Lo. 59°53.5' W

Depth	T°C.	S	o/oo
0	0.0	2.03	1.56
5	1.40	18.93	15.18
10	1.72	24.09	19.30
20	1.23	25.34	20.32
30	0.75	26.05*	20.9
50	0.35*	26.83	21.55
100	-0.17	27.57	22.15
140	-0.24	27.72	22.28

BD-47 3/19/53L. 53°51.9' N
Lo. 58°59.8' W

Depth	T°C.	S	o/oo
0	-0.2	6.99	5.57
5	1.40	20.01	16.05
10	1.35	23.80	19.08
20	0.33	25.37	20.37
30	0.19	26.12	20.98
50	0.03	26.79	21.52
100	-0.22	28.01	22.50
150	-0.69	28.19	22.65
200	-0.99	28.33	22.78

*value from station plot

TABLE III (Cont.)

BD-40 3/30/53L. 53°45.4' N
Lo. 59°48.8' W

Depth	T°C.	S	o/oo
0	0.2	1.00	
5	1.55	21.04	16.87
10	1.69	23.71	19.00
20	1.11	25.34	20.32
30	0.31	26.18	21.02
50	0.20	27.08	21.74

BD-49 3/19/53L. 53°56.0' N
Lo. 59°03.2' W

Depth	T°C.	S	o/oo
0	-0.1	5.67	4.51
5	0.70	19.28	15.48
10	0.30	24.52	19.69
20	0.48	25.49	20.46
30	-0.45	25.97	20.86
50	-0.18	26.75	21.49
80	-0.27	27.71	22.27

BD-50 3/20/53L. 53°59.3' N.
Lo. 58°40.7' W.

Depth	T°C.	S	o/oo
0	-0.5	15.57	12.49
5	1.33	21.54	17.28
10	0.35	24.62	19.77
20	-0.30	25.74	20.68
30	-0.71	26.27	21.12
50	-0.97	26.99	21.70
100	-0.51	27.75	22.31
175	-1.22	28.31	22.77

BD-52 3/27/53L. 54°14.6' N
Lo. 58°08.9' W

Depth	T°C.	S	o/oo
0	-0.6	26.15	21.02
5	-1.09	28.68	23.06
10	-1.48	31.73	25.54
19.6	-1.69	32.66	26.30
29.4	-1.73	33.03	26.60
48.9	-1.73	33.13	26.68
73.3	-1.76	33.23	26.77

BD-105 3/22/53L. 54°07.3' N
Lo. 58°08.1' W

Depth	T°C.	S	o/oo
0	-0.9	19.25	15.47
5	-0.74	20.39	16.38
10	-0.45	22.81	18.32
20	-0.41	25.27	20.30
30	-0.57	25.74	20.69
50	-1.08	26.27	21.12
100	-1.12	26.43	21.24

BD-106 3/23/53L. 54°05.2' N
Lo. 57°54.1' W

Depth	T°C.	S	o/oo
0	0.0	2.77	2.16
5	-0.80	20.48	16.45
10	-0.50	21.43	17.22
20	0.24	25.45	20.44
30	-0.23	25.86	20.77
50	0.21	25.94	20.83
100	-0.68	25.95	20.86
150	-0.68	25.98	20.88

References

Backus, R.H. 1952.

Water transport and flushing time in the
Hamilton Inlet - Lake Melville estuary of
Labrador. Contracts N-onr 342(00) and N6-
onr 264(15). 20 May 1952. Ithaca, N.Y.,
PP. 1-15 (Technical Report)

Hoyt, J.C. and N.C. Grover. 1912.

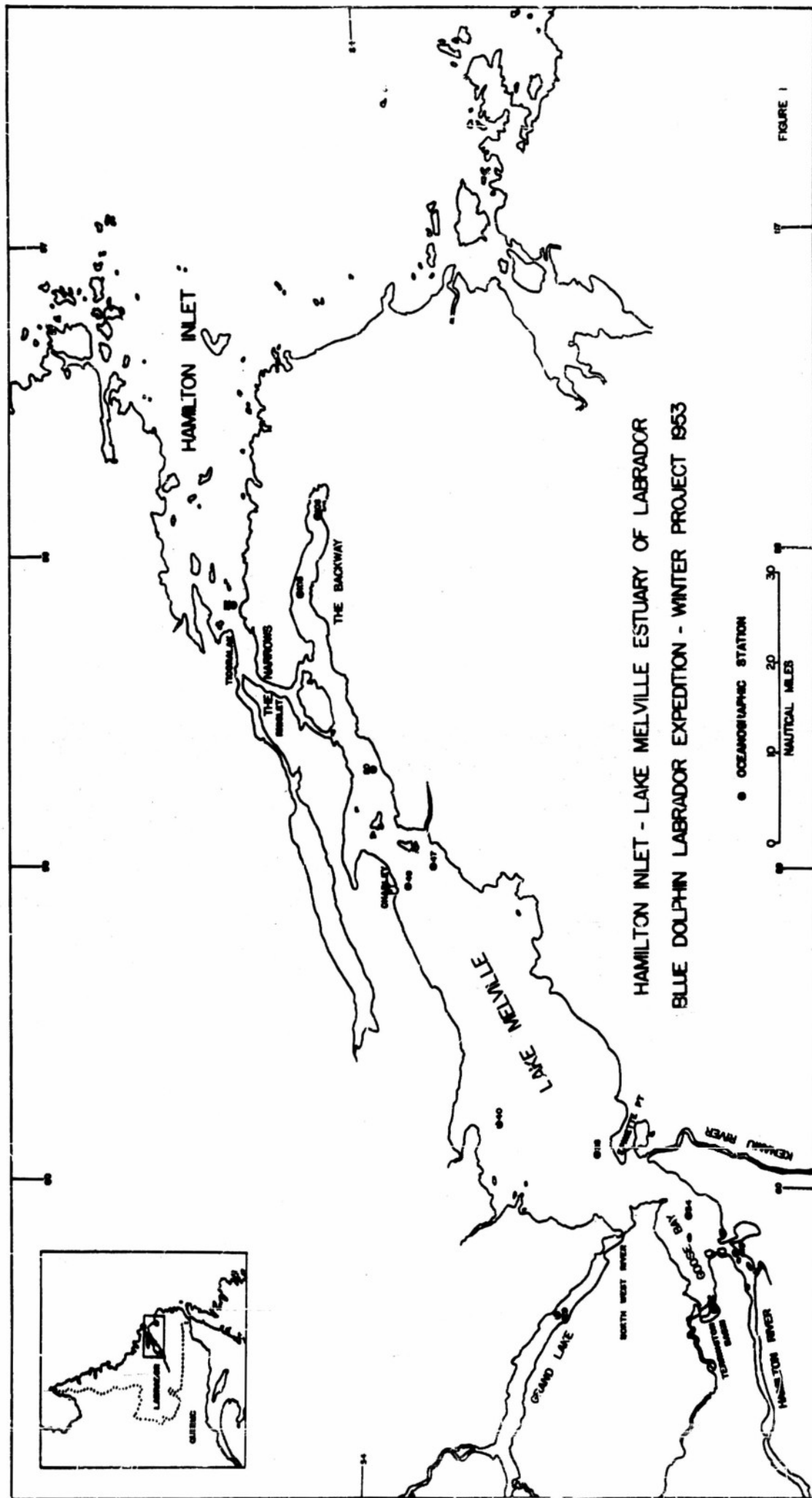
River Discharge.
John Wiley and Sons, New York. 1-173.

Nutt, D.C. 1953.

Certain aspects of oceanography in the
Coastal waters of Labrador. Jour. Fish. Res.
Bd. Canada 10(4).

Nutt, D.C. and R.H. Backus. 1951.

Blue Dolphin Labrador Expeditions. Oceanographic
Report No. 1, 15 June 1951, Hanover, N.H.
PP. 1-30 Figs. 1-28 (Technical Report)



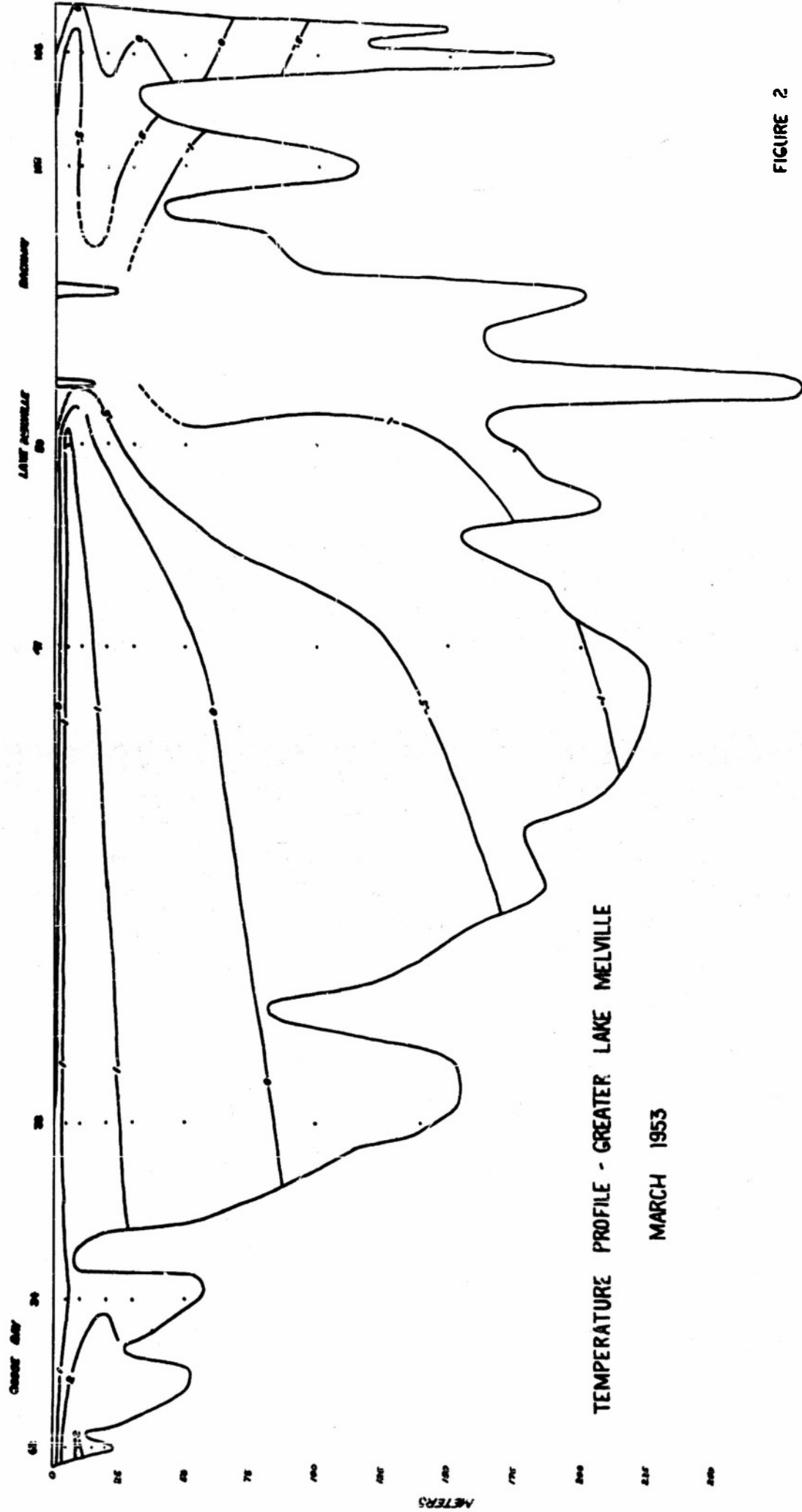
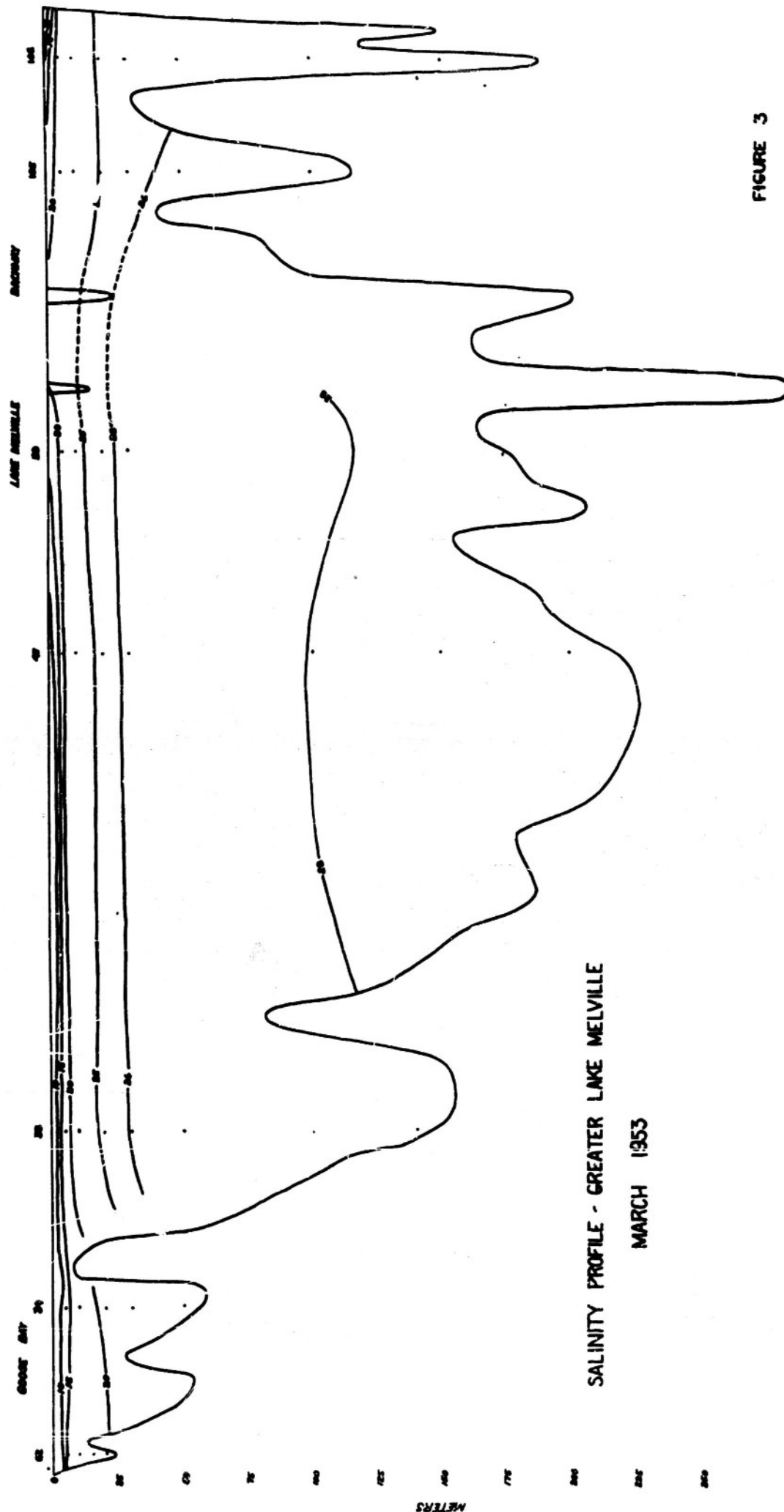


FIGURE 2



SALINITY PROFILE - GREATER LAKE MELVILLE
MARCH 1953

FIGURE 3

BATHY THERMOGRAMS

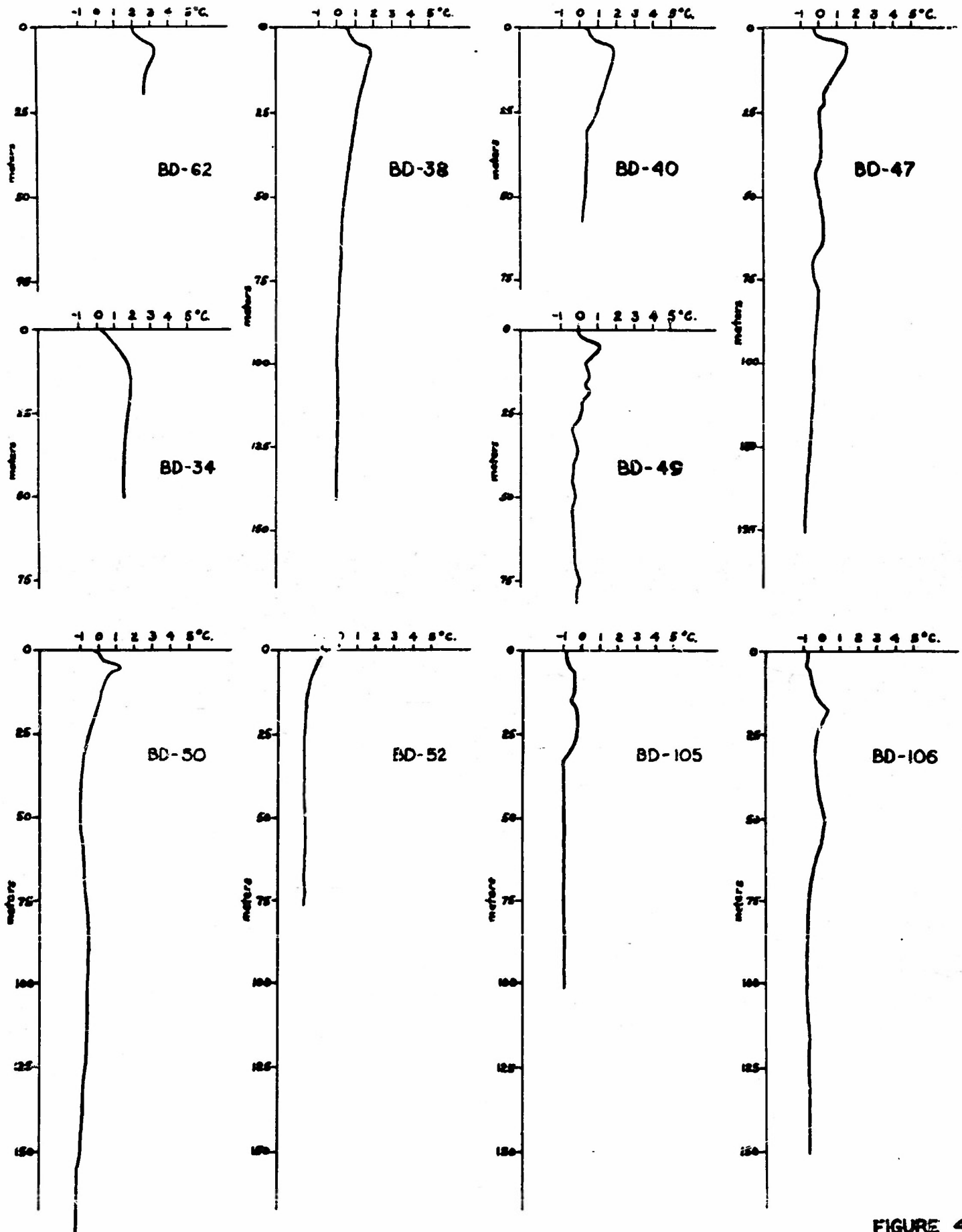


FIGURE 4