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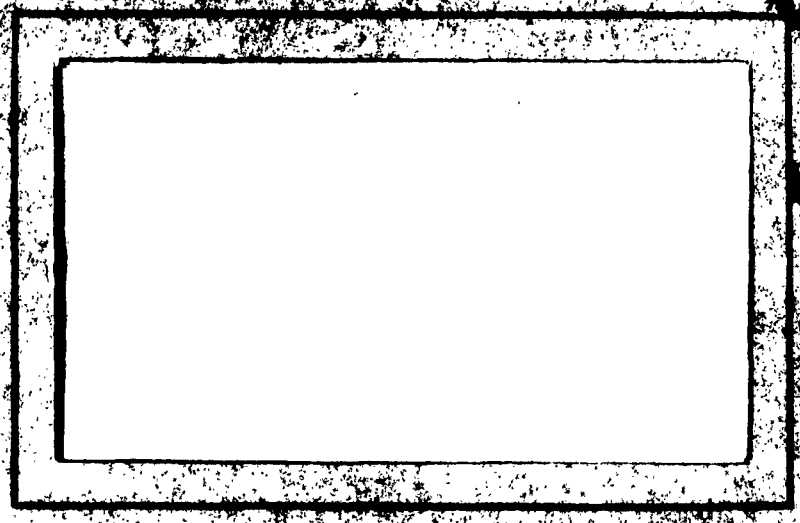

WOODS HOLE, MASSACHUSETTS

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole, Massachusetts

Reference No. 52-19

Hydrographic Survey in the Boston Area

Results of HAZEL III - Cruise 8

Prepared by D. F. Bumpus

Interim Report No. 6
Submitted to Geophysics Branch, Office of Naval Research
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APPROVED FOR DISTRIBUTION _____
Director

The Contractor shall furnish the necessary personnel and facilities for and, in accordance with any instructions issued by the Scientific Officer or his authorized representative, shall conduct an oceanographic investigation of Boston Harbor.

Introduction

Temperature, salinity, and transparency measurements were made in the Boston Harbor area during the period 20-28 November 1951. Similar observations in this area during other periods were reported in our Interim Reports 1, 4, and 5; WHOI Reference Nos. 51-62, 51-93, and 51-94, respectively.

Bathythermograms and surface salinity samples were taken in Cape Cod and Massachusetts Bays along the two sections indicated in Figure 1. Measurements of temperature, salinity, and transparency were made at the points of observation indicated by letters in Figure 1. The area was characterized by a high degree of horizontal and vertical homogeneity in temperature and considerably less of a vertical salinity gradient in the harbor approaches than was observed during the cruises at other times of the year. A relatively strong vertical salinity gradient was present in the Inner Harbor due to high precipitation and runoff in November.

Temperature and Salinity at the Surface

The distribution of temperature at the surface, 20-28 November 1951, is shown in Figure 2. The temperature ranged from about 45°F. in certain parts of Boston Harbor and along the coast between Nahant and Marblehead to slightly more than 50°F. at the station occupied farthest up the Mystic River and in Cape Cod and Massachusetts Bays. A puddle of low temperature water (< 46°F.) was observed between Point Allerton and Minots Light. This occurred only at the surface as section II, Figure 4, will show. This is probably transitory, apparently being the effluent from the previous ebb current which had been pinched off by the succeeding flood current.

The surface salinity in Cape Cod and Massachusetts Bays (Figure 3) lay between 31.8 and 32.23 °/oo. The minimal salinities occurred near shore and the maximum values at the greater distances from shore. A 32.0 °/oo isohaline extended from off Scituate Neck inshore of the lightship, thence to south of Nahant. Inshore of this line, the salinity decreased to 31.0 °/oo from North Channel across to Hull with a puddle of lower salinity water offshore of Point Allerton coincident with the low temperature puddle mentioned above.

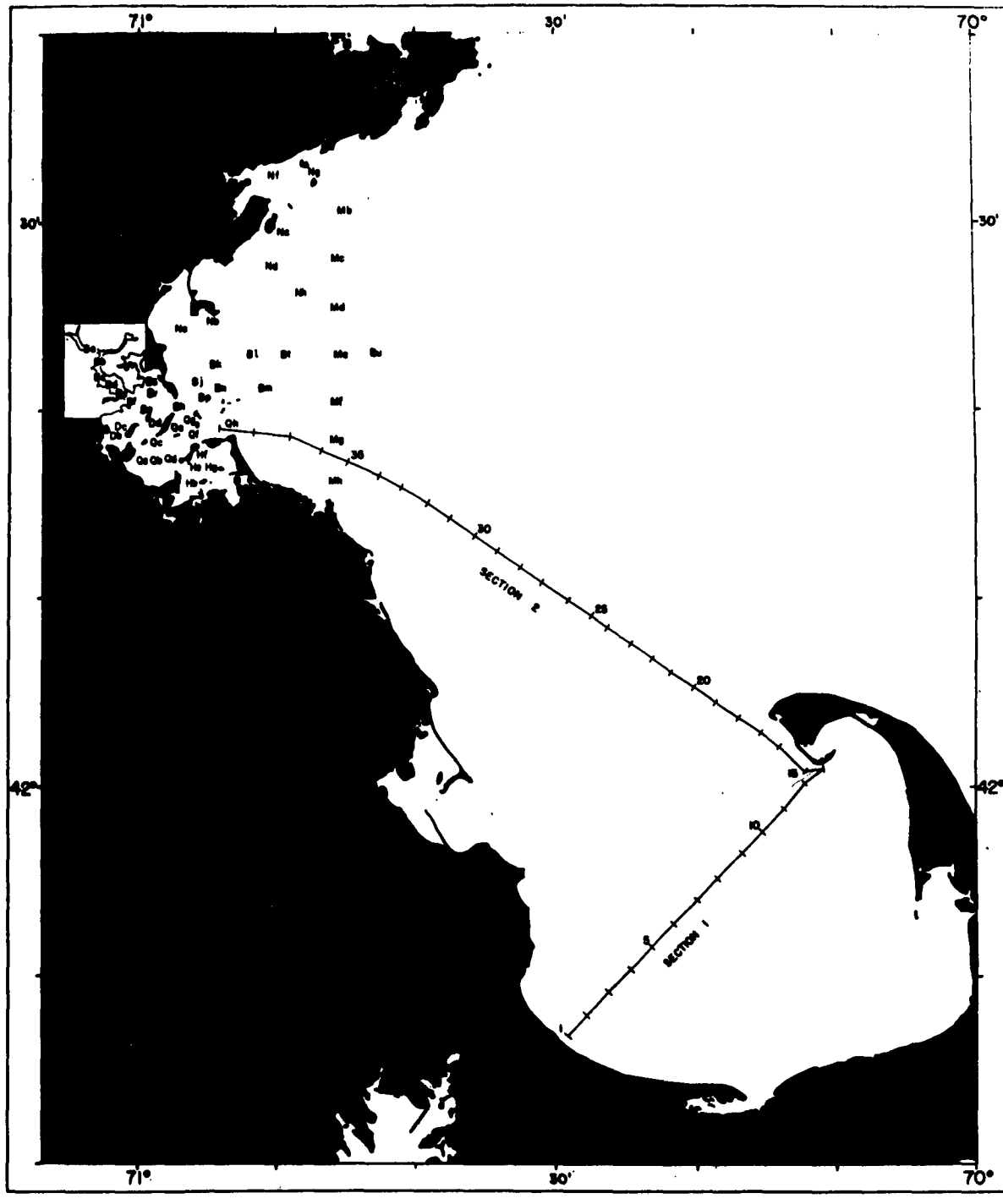

Fig. 1 Track chart and station locations, HAZEL III - Cruise 8, November 1951.

Fig. 2 Distribution of temperature (°F.) at the surface, HAZEL III - Cruise 8, November 1951.

Fig. 3 Distribution of salinity ($^{o}/_{oo}$) at the surface, HAZEL III - Cruise 8, November 1951.

The inner parts of Hingham and Quincy Bays contained water of salinity less than 30.0 °/oo, as did most of Dorchester Bay and the inshore part of President Roads. The surface salinity decreased up the Inner Harbor to a minimum of 22.4 °/oo just south of the Charles River. Further upstream, the salinity increased to 27.5 °/oo in the Mystic River. The salinity is further discussed in the section of temperature and salinity profiles.

Temperature Sections across Cape Cod and Massachusetts Bays

The distribution of temperature along the sections in Figure 1 are shown in Figure 4. The water in Cape Cod and Massachusetts Bay was virtually isothermal vertically and nearly so horizontally throughout the area. The only departure from this situation was between Minots Light and Point Allerton (slides 34 to 38 in Section II) where a positive temperature gradient of about 3°F. existed. These measurements were made about 3 hours after low water and as mentioned above are undoubtedly due to the outflow of superficial harbor water past Point Allerton where it has been pinched off by the incoming flood.

It is of interest to note the large change in the temperature structure since the previous cruise in late August . At that time the water was highly stratified, with a decrease in temperature of more than 20°F. from the surface to 200 feet, maximum temperature greater than 68°F. and minimum temperature less than 45°F. Three months later the water was virtually isothermal at about 50°F.

Distribution of Temperature, Salinity, Density, and Sound Velocity in Boston Harbor and Approaches

In the section Minots Light to Manchester, Figure 5, the water above 100 feet was virtually isothermal, with temperature between 48° and 49°F. Below that depth the temperature increased slightly, but less than 1°F. At either end of the section the shallow water was about 1°F. colder than that in the center of the section.

The salinity distribution was very similar to the temperature distribution with the water very nearly isohaline at between 32.0 and 32.1 °/oo in the upper 100 feet, increasing about 0.5 °/oo between 100 and 150 feet. At either end of the section the shallow water was slightly less saline, albeit vertically isohaline at 31.9 °/oo at the northern end and 31.5 °/oo at the southern end.

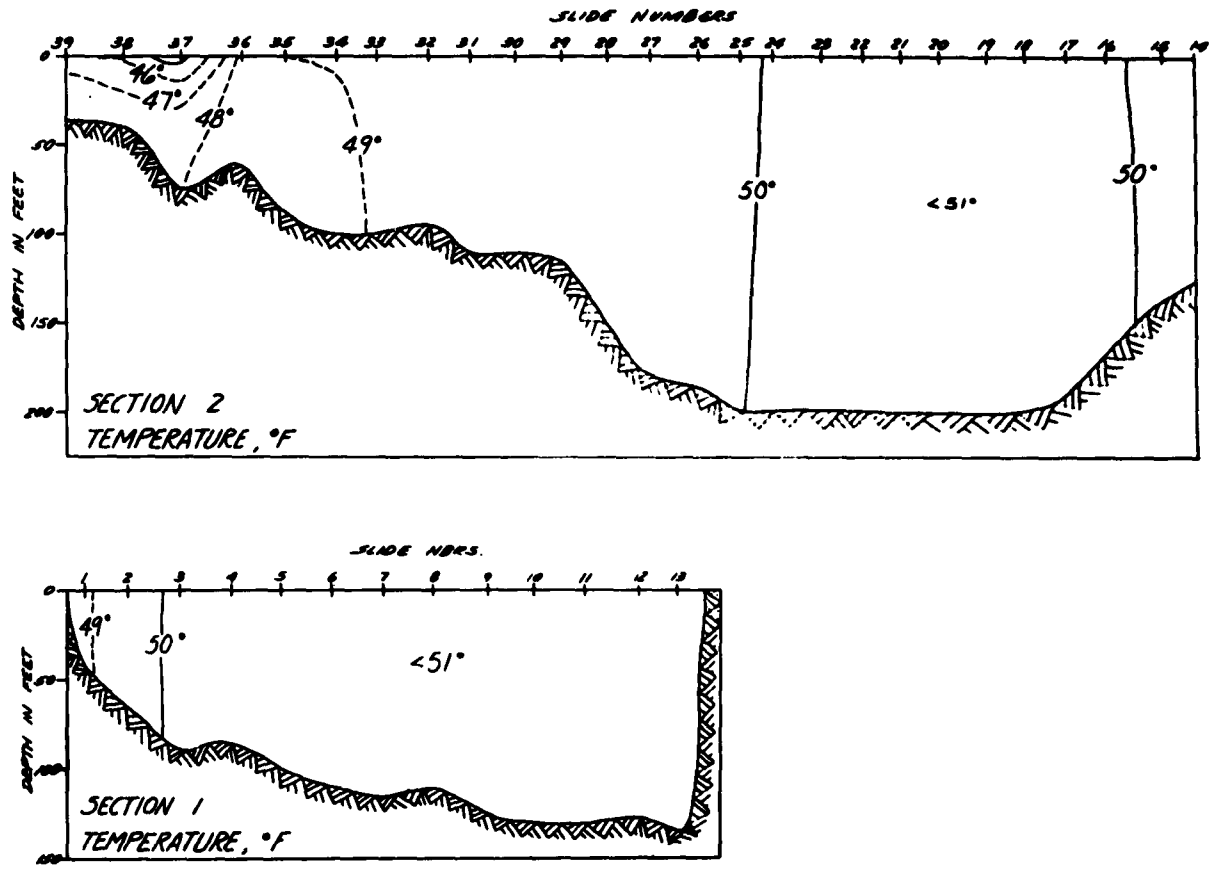

Fig. 4 Distribution of temperature (°F.) along sections in Cape Cod and Massachusetts Bays, HAZEL III - Cruise 8, November 1951.

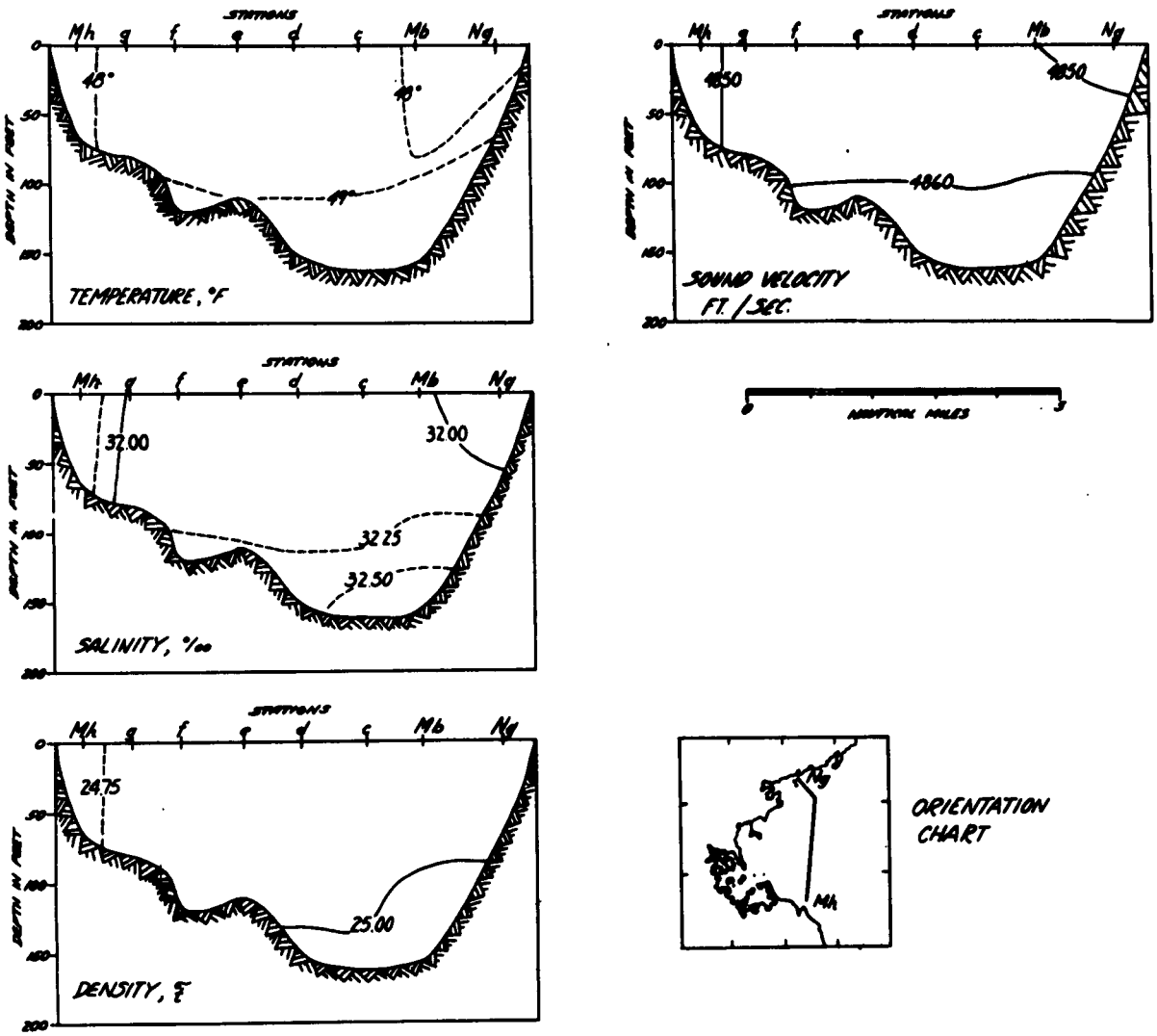

Fig. 5 Distribution of temperature, salinity, density, and sound velocity in the section Minots Light to off-ing of Manchester, HAZEL III - Cruise 8, November 1951.

In this section the sigma-t of the water above 100 feet was approximately 24.8 with the exception of the column at station Mh where the decrease in salinity reduced it to about 24.55 σ_t. Below 100 feet the density increased to a maximum of 25.1 σ_t at 150 feet.

Essentially iso-sound-velocity conditions prevailed above 100 feet with the exception of the ends of the section where the sound velocity was slightly reduced. Between 100 feet and 150 feet the velocity increased about 10 feet per second.

These virtually homogeneous conditions are in considerable contrast to the conditions of maximum stratification which occurred three months before. During the months of May through September, sound rays will be refracted strongly downward, but during the late autumn and winter months the refraction will not be a limiting factor in the operation of sonar equipment.

In the section from Boston Inner Harbor out through North Channel to the longitude of Boston Light Vessel, Figure 6, the temperature diminished from a maximum at the surface at the farthest upstream station, in the Mystic River, to a minimum at Deer Island and along the bottom of the Inner Harbor. Out through North Channel and seaward from there the temperature increased slightly with depth and distance offshore.

The salinity increased from a minimum, $< 23{,}0$ $^{o}/_{oo}$ at the surface, in the Inner Harbor south of the Charles River to > 30.5 $^{o}/_{oo}$ at the bottom. The strong salinity gradient was confined to the upper 20 feet and to the Inner Harbor. A moderate horizontal salinity gradient occurred in North Channel 30.25 - 31.5, offshore of which salinity increased only slightly seaward and with depth, approaching 32.0 $^{o}/_{oo}$ at the surface at the seaward end of the section and reaching nearly 32.5 $^{o}/_{oo}$ at 170 feet.

The density distribution closely reflected the salinity distribution, owing to the fact that the temperature range was so small. The density ranged from less than 18.0 σ_t at the surface in the Inner Harbor to 25.0 σ_t at 170 feet at the outermost station.

The distribution of sound velocity likewise reflected the relatively large salinity changes rather than the small temperature change. Sound velocity increased with depth and seaward from a minimum of less than 4800 feet per second in the Inner Harbor, south of the Charles River, to

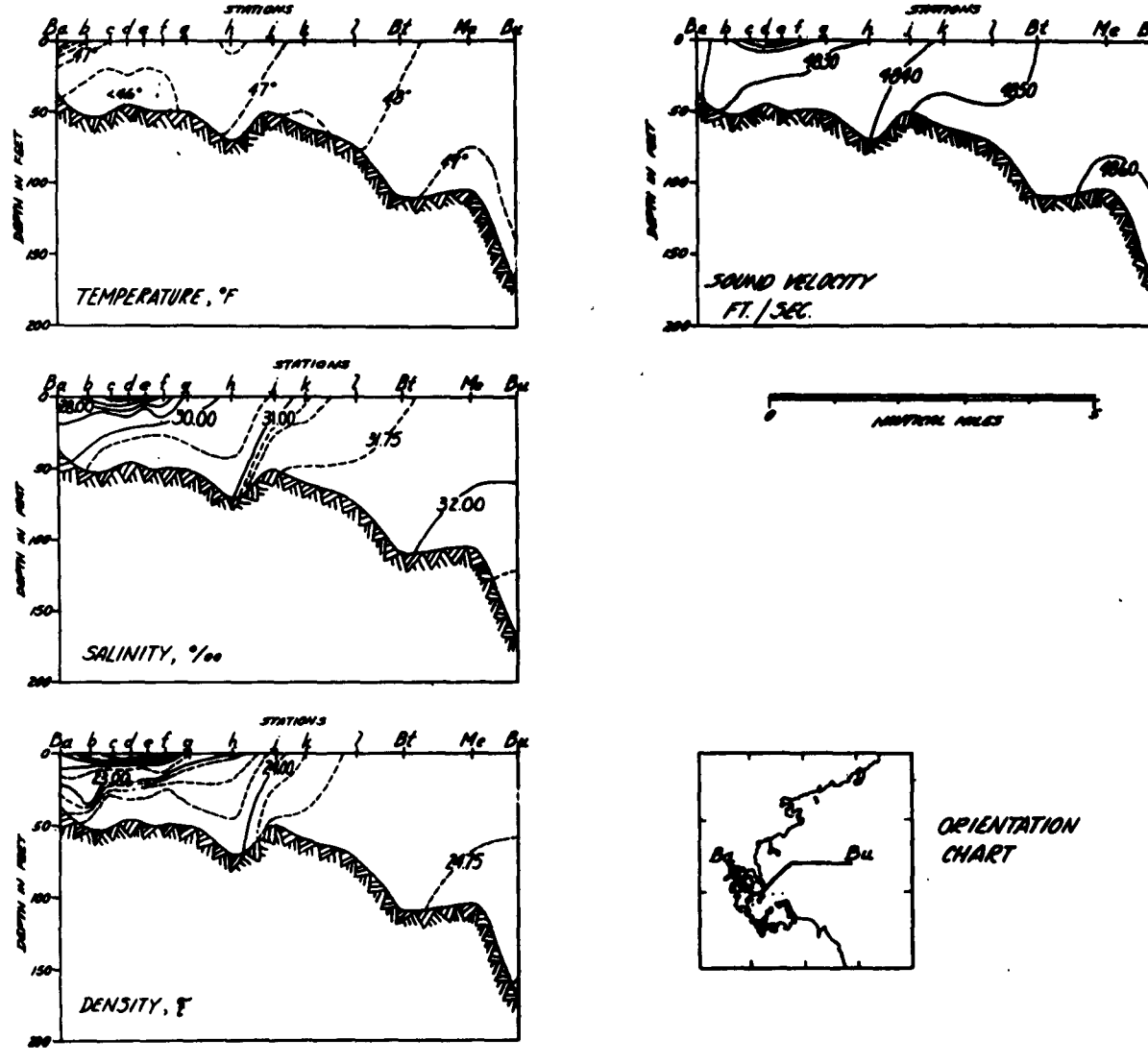

Fig. 6 Distribution of temperature, salinity, density, and sound velocity in the section Chelsea River to longitude of Boston Light Vessel, HAZEL III - Cruise 8, November 1951.

greater than 4860 feet per second at depths greater than 100 feet. Maximum vertical sound velocity gradients lay at shallow depths in the Inner Harbor and minimum ones in the upper 100 feet offshore. This is in direct contrast to the condition reported for the last cruise, in August, when the minimum vertical gradient lay in the Inner Harbor and maximum ones occurred at mid-depths offshore. Further, the sound velocity decreased with depth during the previous cruises where, as in November, sound velocity increased with depth. The November stratification was due probably to the large amount of runoff of fresh water from the land, described below.

Attendant Precipitation and Stream Flow Data

Precipitation and stream flow data for New England are available from the Geological Survey Water Bulletin for November 1951. Precipitation was far above normal over the entire district during November, being 6.55 inches or 179% of normal in Massachusetts. Stream flow was likewise far above normal, the runoff of representative rivers averaging 280% of normal. Ground water levels also rose to well above seasonal averages and were at their highest stage of record in eastern and central Massachusetts.

The precipitation and stream flow in Massachusetts in November were the greatest recorded for the year, as indicated in Table I. This large runoff, presumably chiefly from the Charles River, was reflected in the low surface salinities and strong salinity gradients in Boston Inner Harbor. The greater than normal rainfall in October and November and greater than normal runoff beginning in July must certainly have provided for the passage of an abnormally great amount of fresh water through Boston Harbor during the last four or five months of the year.

Flushing Time of Boston Inner Harbor

An estimate of the flushing time for Boston Inner Harbor reported in WHOI Reference No. 51-84 was twelve days. This estimate was based on the mean river flow of the Charles and Mystic Rivers amounting to 23.4×10^6 cu. ft./day. For purposes of comparison with this mean figure, an attempt has been made to compute the flushing time for the Inner Harbor on the basis of selected runoff data for the New England District, Table I, and the salinity data for the cruises in May, June, August, and November. For lack of a better figure the drainage area tributary to

TABLE I

Precipitation, Runoff and Ground Water Levels, 1951

	J	F	M	A	M	J	J	A	S	O	N	D
Precipitation for Massachusetts												
Inches	3.35	4.65	4.76	3.13	4.00	2.67	3.34	3.83	2.47	4.18	6.55	4.77
% of Normal	91	139	123	88	117	76	95	106	67	124	179	134
Runoff from N. E. District												
Inches	1.84	3.06	3.10	6.90	2.57	1.16	1.07	0.92	0.67	1.04	3.50	2.94
% of Normal	103	236	106	131	82	91	129	185	118	133	268	194
Ground Water Level (Middlesex County)												
Net change in month (feet)	+0.86	+0.92	+0.41	-0.81	-0.18	-0.65	-0.89	-0.79	-0.66	+0.68	+2.48	+0.74
Departure from monthly average (feet)	+0.87	+1.17	+0.85	+0.60	+0.70	+0.96	+1.26	+1.12	+0.93	+1.76	+2.69	+2.58
Estimated Mean daily runoff for 300 square miles, tributary to Boston Inner Harbor x 10^6 cu.ft.	35.2	58.5	59.2	134.0	48.2	22.2	20.4	17.6	12.8	19.9	67.0	56.3

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Boston Inner Harbor was taken as 300 square miles (Charles River 232, Mystic River 72, Chelsea River ?). This yielded monthly mean runoff volumes as given in the last line of Table I, averaging 55 x 10^6 cu.ft./day for the year 1951, a figure slightly more than twice as much as that given above for the mean river flow. Precipitation and runoff were on the whole above normal in 1951, total runoff for the year amounted to about 57% of total annual rainfall. The volume of river water in the Inner Harbor was determined by the usual method (Ketchum, 1950) assuming a sea water salinity of 32.0 $^o/_{oo}$. When this amount of river water was divided by the mean daily runoff as computed for the appropriate months, flushing times of 1 to 8.7 days were obtained as given in Table II. It is not felt that these figures are too reliable because the runoff may vary in any month considerably from the monthly mean. However, with the absence of any other better data, these are presented. They certainly express a reliable order of magnitude.

One conjecture may arise from these results. With average flushing time of about 5 days and with a tendency for high precipitation and runoff to be isolated to short times during the month, large variations in the fresh water content and, hence in stratification within the Inner Harbor, may occur during months of minimum thermal gradients.

Transparency

Transparency measurements were made in Boston Harbor and approaches with black and white secchi discs. The range of visibility of the white disc was from 5 feet in the Mystic River to 9 feet in President Roads, Quincy, and Hingham Bays, 15 feet at the outer end of North Channel, and greater than 25 feet in all stations east of the longitude of the Graves. The black disc could be seen to approximately one-half the above listed depths. It is apparent from these figures that the transparency of the water during this cruise was on the whole about 25% greater than that observed on previous cruises.

TABLE II

Summary of Flushing Data, Boston Inner Harbor, 1951.
(Mean Volume of Boston Inner Harbor 2370 x 10^6 cu.ft.)

Date	River Water in Harbor x 10^6 cu.ft.	%	Runoff/day x 10^6 cu.ft.	Flushing Time Days
5 May	133.7	05.6	134. (April) 48.2 (May)	1 2.8
26 June	159.6	06.7	22.2 (June)	7.25
23 Aug.	153.1	06.5	17.6 (Aug.)	8.7
24 Nov.	232.8	09.8	67.0 (Nov.)	3.5

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