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A Survey of Water Conditions in the Grand Manan  
Channel in September - 1950.

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Introduction

Grand Manan Channel (Figure 1) is the name given to the passage between the Island of Grand Manan, near the mouth of the Bay of Fundy, and the Coast of Maine. Johnson (1925) designates both the Grand Manan and the Maine Coast as fault scarps, though the bottom contours suggest subsequent glaciation and the Maine Coast has been somewhat eroded by land drainage.

The Grand Manan Coast consists of sandstone cliffs which rise abruptly from sea-level to 200 feet (60 metres) or more. There are no significant bays or harbours. The Maine Coast too is quite abrupt but is cut up with many indentations. The Channel itself has a fairly level floor, the greater part being between 40 and 50 fathoms (73 and 91 metres). A small cut runs into the northern end with depths as great as 60 fathoms (109 metres). The sediments are mixed: sand, mud, gravel, shell, and stone being reported with no obvious pattern.

The Grand Manan Coast runs roughly NNE - SSW and the Maine Coast NE - SW giving the channel its minimum width at the north end,  $5\frac{1}{2}$  nautical miles (10.2 kilometres) between Liberty Head and Indian Beach. In the south, the width is approximately 11 nautical miles (20.4 km.) between Long Point and Southern Cross. The length from Southwest Head to Liberty Head is about 14 miles (25.9 km.).

Across some 60 percent of the southern end there is a series of shoals, rocks and ledges, some forming islands as Machias Seal

Island, others breaking in heavy weather. To the southwest, the land drainage from a considerable area debouches into Machias Bay. In the northwest, through Quoddy Roads there is a significant tidal flow to and from Cobscook Bay. North of the channel the New Brunswick Coast forms a sort of shallow bay with depths, except immediately north of the channel, less than 40 fathoms (73 metres). Here, between East Quoddy Head and Bliss Island, the greater part of the tidal flow to and from Passamaquoddy Bay takes place. The flow of water through the approaches is broken up by a group of islands known as the Wolves. The tidal range is fairly great in the channel, being up to 19 feet (5.8 metres) during springs at Machias Seal Island and up to 25 feet (7.6 metres) at Eastport. Tidal currents up to 3 knots are charted in the channel.

#### September 1950 Survey

The Grand Manan Channel has long been known as a region of extremely well mixed water and one where vigorous local mixing adds to the homogeneity (Mavor 1923, Hachey, 1931, Watson, 1936). It was the object of this survey to examine in some detail the water structure in the area, to determine the major factors contributing to the mixed character, and to ascertain the degree to which tidal motion modifies the water mass. The observations were made between 18 September, 1950, and 26 September, 1950, from the research vessel C.N.A.V. "WHITETHROAT". At intervals of approximately 1.4 to 2 miles (2.6 to 3.7 km.), along fixed lines, lowerings were made with a sea-sampler (Spilhaus and Miller 1948) providing temperature-depth traces and water samples at depth intervals of ten metres.

Five lines were laid down for observation, three in the channel

proper and two in the northern approaches. These are shown in Figure I, and pertinent data tabulated in Table I. Each line of observations was run as quickly as possible so that the result might be taken as representative of a distinct phase of the tide. On the three lines in the channel sections were taken at high water, low water and at half tide (either ebb or flood). High water and low water sections were made in the Northern Approaches.

T A B L E I

Data on Survey Sections

1. Northern End: From West Quoddy Head to beyond Long Eddy Point  
Lat.  $44^{\circ}49'N$ , Long.  $66^{\circ}56'W$  to Lat.  $44^{\circ}49'N$ , Long.  $66^{\circ}44'W$ .  
Average length of section 8.5 miles (15.7 km.). Number of observations per section 6. Average time per section 1 hr. 25 min.
2. Southern End: From Little River to Southwest Head: Lat.  $44^{\circ}39'N$ ,  
Long.  $67^{\circ}11'W$  to Lat.  $44^{\circ}36'N$ , Long.  $66^{\circ}55'W$ . Average length of section 11.5 miles (21.3 km.). Number of observations per section 1 hr. 40 min.
3. Longitudinal: From West Quoddy Head to Southwest Head: Lat.  $44^{\circ}49'N$ ,  
Long.  $66^{\circ}55'W$  to Lat.  $44^{\circ}37'N$ , Long.  $66^{\circ}58'W$ . Average length of section 12.2 miles (22.6 km.). Number of observations per section 7. Average time per section 2 hrs. 5 min.
4. North Eastern Approaches: From Long Eddy Point to the Wolves:  
Lat.  $44^{\circ}49'N$ , Long.  $66^{\circ}46'W$  to Lat.  $44^{\circ}58'N$ , Long.  $66^{\circ}40'W$ .  
Average length of section 10 miles (18.5 km.). Number of observations per section 6. Average time per section 1 hr. 30 min.

5. Northern Approaches: From Head Harbour to the Wolves:

Lat.  $44^{\circ} 58' N$ , Long.  $66^{\circ} 53' W$  to Lat.  $44^{\circ} 54\frac{1}{2}' N$ , Long.  $66^{\circ} 40' W$ .

Average length of section 9.2 miles (17 km.). Number of observations per section 7. Average time per section 1 hr. 40 min.

The sea sampler must be lowered below the greatest depth of sampling, for which reason data do not go very close to bottom. Each observation was supplemented by a surface sample and surface temperature. The average time required to work a complete section was 1 hr. 44 min. and work was planned so that the designated tidal phase occurred in this interval.

Observations

The temperature-depth and salinity-depth relationships observed on each lowering of the sea-sampler are plotted in figures 2 to 6 inclusive. In figures 7, 8 and 9 temperature and salinity are plotted in profile for the three sections in the channel proper.

Salinities ranged from  $32.4^{\circ}/\text{oo}$  to  $33.0^{\circ}/\text{oo}$  and temperatures from  $10.0^{\circ} C$  to  $12.1^{\circ} C$ . with moderate scatter about a straight line on a T - S presentation. The variations, however, were mainly geographical or temporal variations. Very few vertical gradients of any magnitude were observed.

1. Northern End:

The section from West Quoddy Head to a point beyond Long Eddy Point was worked on three different days at high water, low water and half flood. (Figures 2 and 7). At all stages of the tide the station beyond Long Eddy Point (outside the channel proper) showed comparatively large vertical variations ( $1.8^{\circ} C$ . in temperature and

0.56 ‰ in salinity at half flood). In comparison to the remainder of the section this stratification seemed to involve a decrease in surface salinity and bottom temperature and an increase in surface temperature and bottom salinity. Apart from these outer observations the greatest variability was observed in the half flood section near the West Quoddy end (1.3 °C. and 0.35 ‰). The station under West Quoddy Head showed little vertical variation at any stage of the tide and the eastern half of the channel was similarly unstratified. At high water the whole section showed a definite lack of stratification.

During the half-flood section on September 18th, a body of water with salinity as low as 32.5 ‰ was present on the western side of the section. There is no evidence of water of as low salinity at other stages of the tide but the long interval between the various crossings of this section make it not surprising that the continuity should appear strained. It is possible that the appearance of this low salinity water off West Quoddy Head indicated the passage into the channel of the low salinity water found later in the longitudinal section.

## 2. Southern End:

The section from Little River to Southwest Head was worked three times within twenty-four hours, at half-flood, high water and low water (Figures 3 and 8).

In this section the only significant vertical gradients were observed at half-flood, when there was an apparent invasion of the area by a warm surface layer less than 10 metres thick, and a cold saline bottom water. The progress to high water brought waters of

higher salinity and lower temperature into the centre of the section with the production of fairly large horizontal gradient. At any station, however, mixing from top to bottom was very nearly complete.

### 3. Longitudinal Section:

The section from Southwest Head to West Quoddy Head was worked three times during the 20th and 21st September, at half ebb, high water and low water (Figures 4 and 9). The section ran almost north and south cutting the channel diagonally.

At all stages of the tide the waters immediately off West Quoddy Head were completely mixed. This state of complete mixture held for the entire section at high water. On the falling tide a condition of mild stratification (maximum variation  $0.30^{\circ}$  / $\infty$  in S. and  $0.9^{\circ}$  C.) spread over the northern part of the section covering half of the section at low water.

There was a body of water slightly warmer and less saline than that found at the end of the channel which was centrally located in this section at high water and moved down to the southern end on the falling tide.

At all stages of the tide the water at the southern end of the section was completely mixed.

### 4. Northeastern Approaches:

The section from Long Eddy Point to a point northeast of the Wolves was worked at low water on September 22nd and at high water on September 26th. (Figure 5). The northern part of the section, especially just south of the Wolves was quite stratified, more so at high water than at low (maximum variation  $0.6^{\circ}$  C. and  $0.40^{\circ}$  / $\infty$ ). In general, salinities were lower at low water than at high water,

probably due to efflux from Passamoquoddy Bay where mixture with river outflow takes place. At low water there was evidence of slight instability in the vertical columns with a temperature maximum and a salinity minimum both occurring at between 10 and 20 metres.

#### 5. Northern Approaches:

The section from off Head Harbour to the Wolves was worked at low water and high water on September 25th (Figure 6). The amount of stratification increased from West to East and from high water to low water. There was again a slight tendency towards instability, more perhaps at low water than at high water. This is probably due to incomplete mixture of the waters coming from the Passamoquoddy Bay efflux and from the northeast.

#### Discussion

During the time of this survey the central portion of the Grand Manan Channel contained water of temperature slightly above  $11.0^{\circ}\text{C}$ . and salinity slightly under  $32.65^{\circ}/\text{oo}$ . This water was almost completely mixed from top to bottom.

With rising tides the area was invaded from the south by waters of lower temperature and higher salinity with marked vertical uniformity. These are waters which have been mixed when carried back and forth, by the tides, over the area of shoals to the south of the channel.

On the falling tides a body of more stratified water invaded from the north and spread more than half way down the channel at low water.

It would appear that the greater part of the mixing which contributes to the homogeneity of the waters takes place as they

are swept back and forth over the southern shoals. These central mixed waters are replaced slowly while fresher water is added from land drainage along the Maine Coast, and, under proper condition, from the Quoddy Roads efflux. The result is a central water which is warmed, and has its salinity reduced, in situ. This light water must be subjected to a dynamic tendency to flow out on the surface over the waters to the south and to the north. A certain volume must be regularly removed in this manner at either end of the channel.

There does not seem to be any clear cut picture of residual motion shown by these data. They neither refute nor amplify the statement made by Watson (1936) "therefore the residual current is directed northward but is small". Whatever the residual motion of the waters in the channel at the time of survey, it must be expected that meteorological conditions will have a large effect. Periods of steady winds with a northerly component will flood a greater part of the channel with the more stratified waters found to the north, although even in such instances it is to be expected that high water will find well mixed waters in the southern portion. On the other hand steady winds with a southerly component may extend the area of homogeneity well into the northern approaches. This, considering the prevailing south west winds of summer, may account for the northerly resultant current shown by Dawson's (1908) data (Mavor, 1922). A recent survey (MacGregor and McLellan, 1951) using a GEK observed residual currents to the southward under variable winds in early October.

Summary

1. Five lines of observations in the region of the Grand Manan Channel were run at different stages of the tide using a sea-sampler (Spilhaus and Miller, 1948).
2. The area is one of very low stratification where the waters of the Bay of Fundy, not in themselves highly stratified, are subject to vigorous local mixing.
3. The greater part of the mixing seems to take place where the rising tide carries water over the shoals at the southern extremity of the channel. A significant amount of mixing also takes place in the vicinity of points such as West Quoddy Head and Long Eddy Point.
4. The slight stratification which is found in the Bay of Fundy proper and is most pronounced in late Summer, probably a few weeks earlier than the date of this survey, has its influence upon the channel waters during the falling tide. At this time waters which are not completely mixed move down from the north and may extend half way along the channel.
5. At all times of the tide, vertical gradients of temperature and salinity were small. In particular, the southeast quadrant of the channel was entirely free from stratification.
6. No evidence of a definite pattern of residual flow was observed. It is suggested that winds may have an important effect, and that the residual flow may be either northward or southward.

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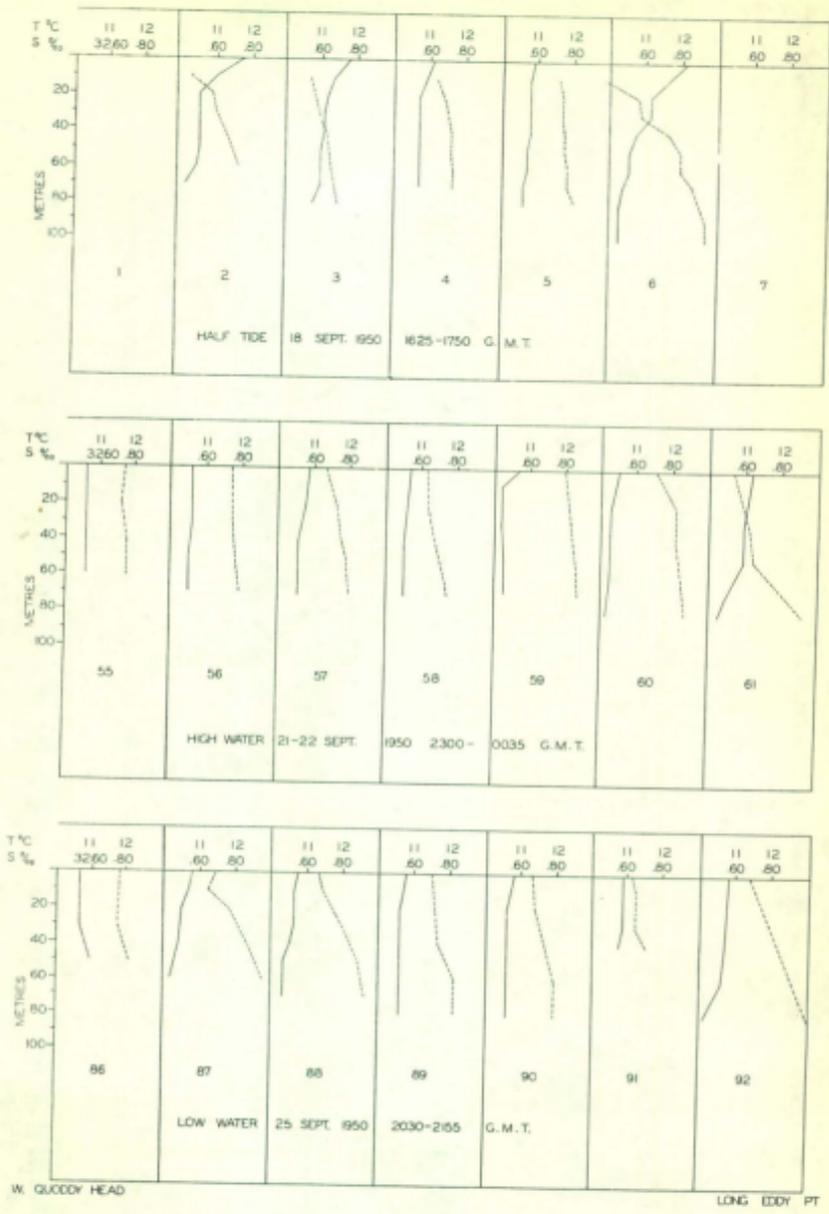


Figure 2.

Northern End: West Quoddy Head to Long Eddy Point, Temperature and Salinity observations.

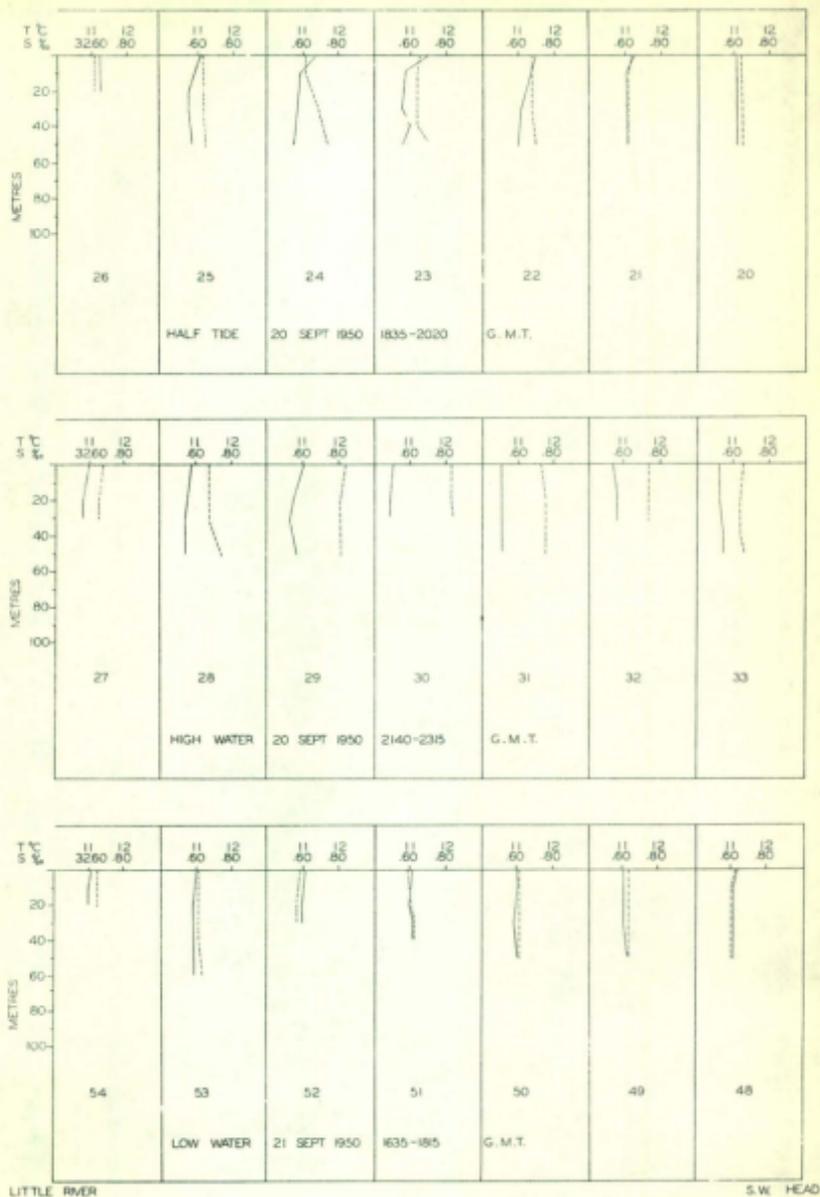


Figure 3.

Southern End: Little River to South West Head, Temperature and Salinity observations.

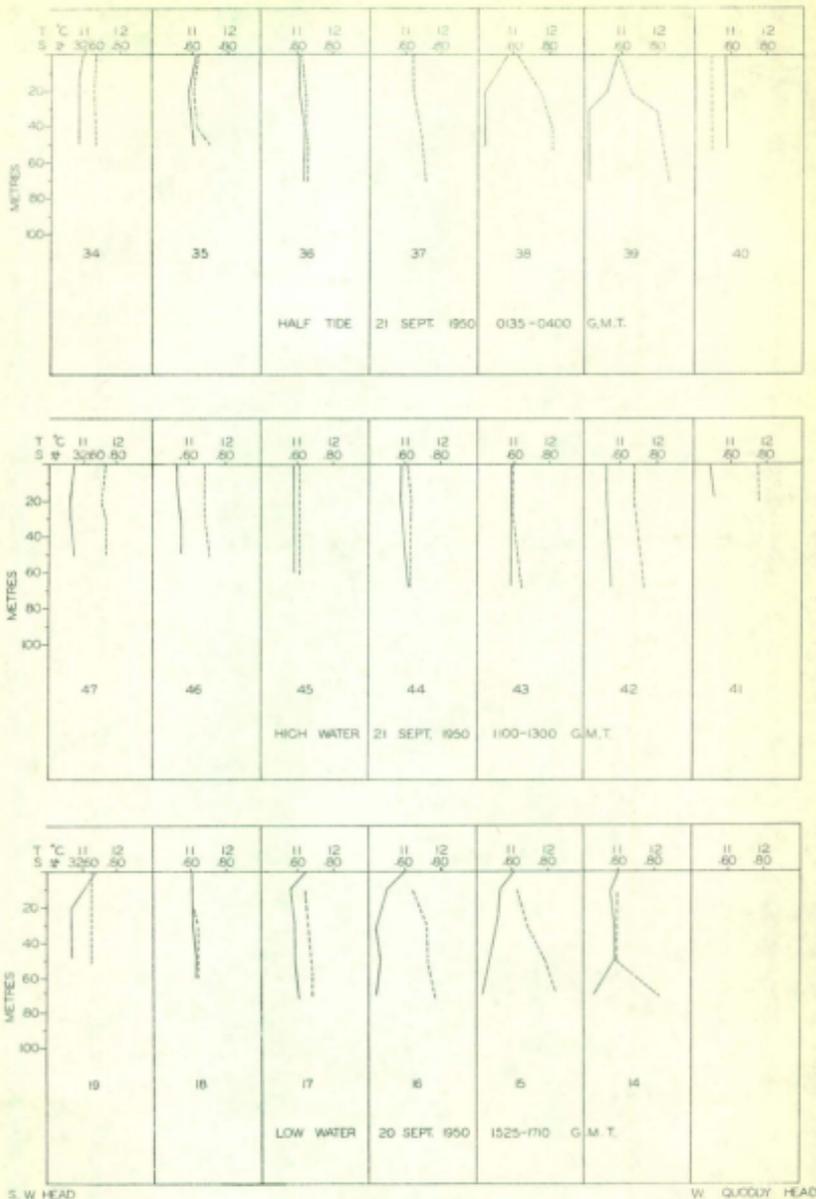


Figure 4.

Longitudinal Section: South West Head to West Quoddy Head,  
Temperature and Salinity observations.

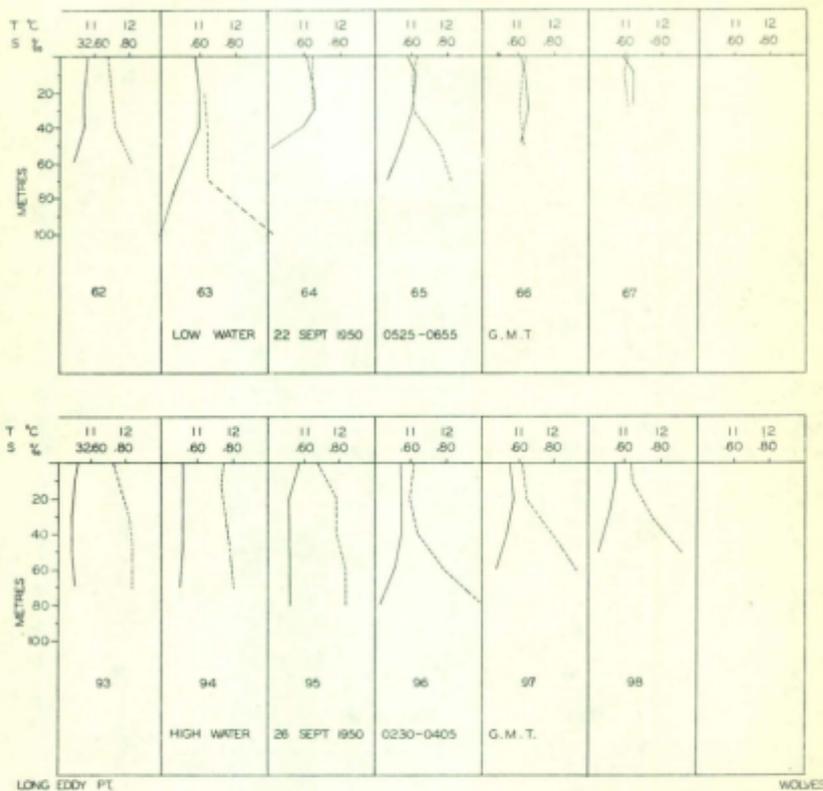
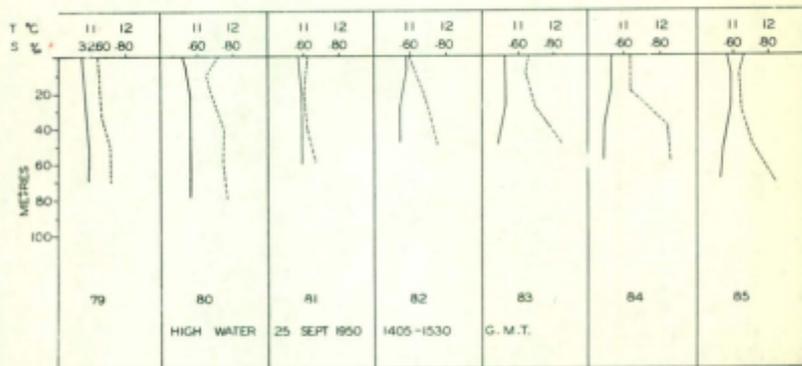
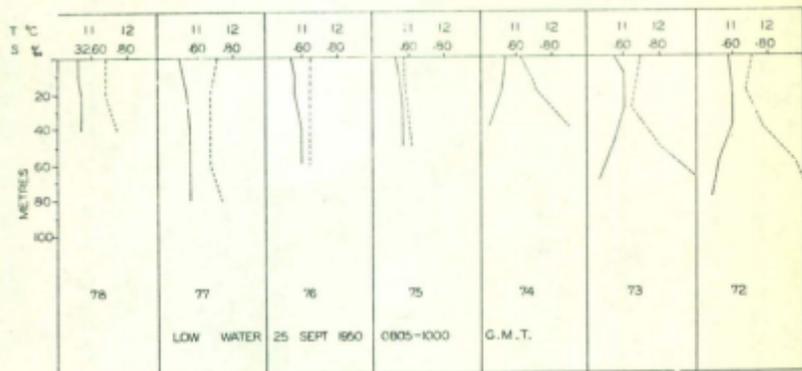


Figure 5.

Northeastern Approaches: Long Eddy Point to the Wolves,  
Temperature and Salinity observations.



HEAD HARBOUR

WOLVES

Figure 6.

Northern Approaches: Head Harbour to the Wolves, Temperature and Salinity Observations.

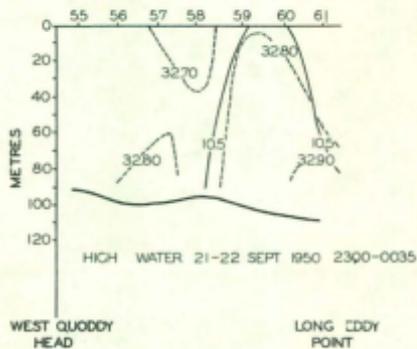
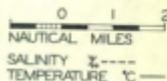
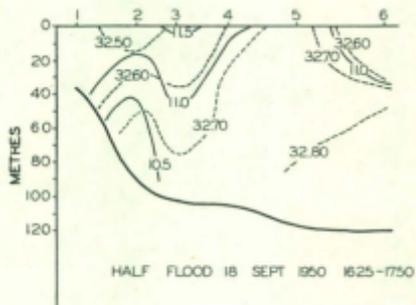
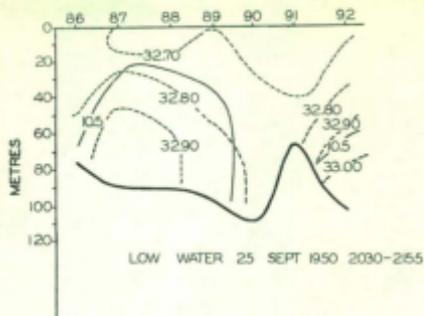
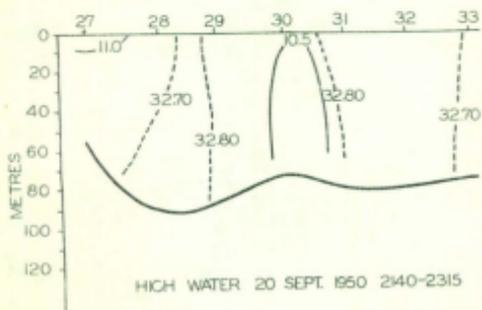
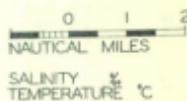
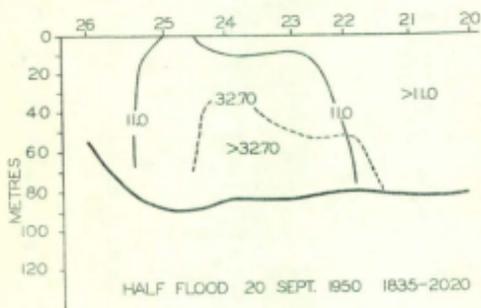
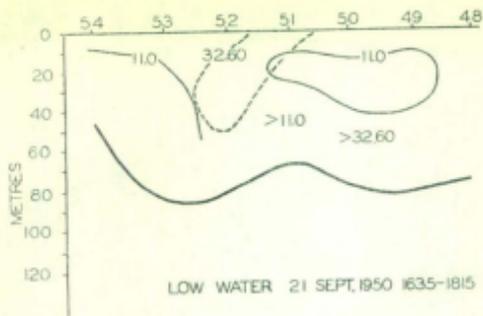


Figure 7.

Northern End: Temperature and Salinity in Profile.



LITTLE RIVER

SOUTH WEST  
HEAD

Figure 8.

Southern End: Temperature and Salinity in Profile.

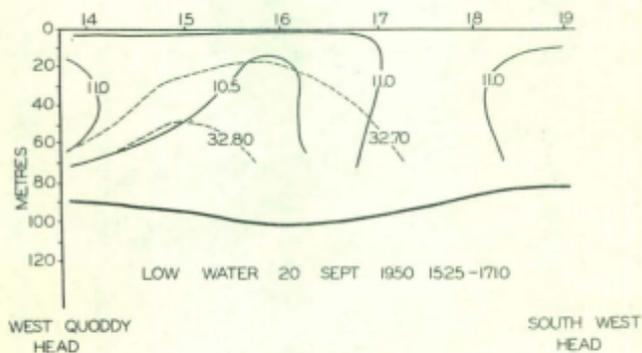
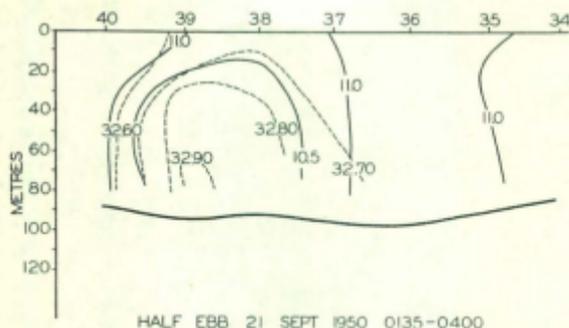
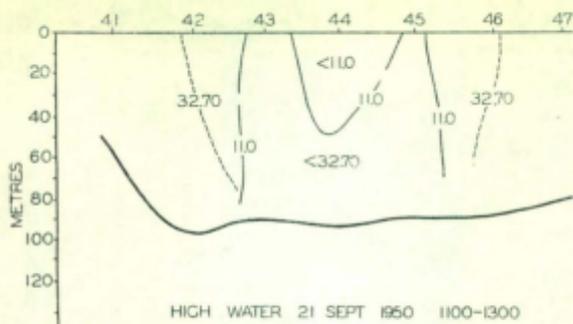


Figure 9.  
Longitudinal Section: Temperature and Salinity in Profile.

