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WATER MOVEMENTS IN PASSAMAQUODDY BAY

By E. E. Watson

Atlantic Biological Station

Summer 1930

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During the summer of 1930 investigations were carried out in three regions (1) The main portion of the bay lying between St. Andrews and Deer Island (2) Chamcook Harbour (3) Bocabec Bay.

It was thought that a study of conditions in the two passages connecting Passamaquoddy Bay with the Fundy waters would give information concerning the circulation through the bay as a whole, but owing to the length and complex nature of the western Passage it was found impossible to interpret the small number of observations that could be obtained. A series of simultaneous temperature observations taken at stations 855 and 9 are shown on the accompanying graph.

A hydrographic section taken from Tongue Shoal (known also as sand reef) to Upper Green Point, at half flood and at half ebb, shows some interesting temperature effects. Below 20 metres the temperature changes very little with tide or depth. At 10 metres, however, the temperature is much lower for flood tide than for ebb. The water coming in to the bay through Letite finds its density level between 5 and 15 metres and its temperature is approximately that of the water below 20 metres, so that now all the water below 10 metres has the same temperature, while above 10 metres the temperature change is very rapid. On the ebb tide however enough mixing has taken place to affect the temperature of the water down to 20 metres depth and the temperature rise commences at 20 metres instead of at 10 metres. On the other hand at station 855 (in the deep channel off Upper Green Point) the temperature curves at half flood and half ebb are almost identical, the temperature between 10 and 20 metres being very slightly lower on flood than on ebb. It appears that this station is so near Letite Passage that the effect of mixing in

the remote portions of the bay are not observable, at any rate not until a later stage of the ebb tide.

Chamcook Harbour

On August 5 simultaneous hydrographic observations were taken at three stations in this region; from the Prince at Sta. 1019 in the deep water between Kilmarnock Head and Minister Island, from a row boat at Sta. 1020 in the entrance channel of the harbour, and from the Delphine at Sta. 1021 in the middle of the outer basin of the harbour. The Delphine also took observations at Sta. 1022 in the inner basin as soon after those at Sta. 1021 as possible.

It was thought quite probable that Chamcook Harbour, with its shallow entrances at both ends, would be a likely trap for cold water. The results of the observations show on the contrary that the bottom water is much warmer than that at a corresponding level at Sta. 1019, and the water in the inner basin is altogether warmer than any water in the outer basin!

The effect of the sloping bottom between Sta. 1019 (30 metres) and Sta. 1020 (5 metres) is very marked. As may be seen from the density sections the surfaces of equal density conform to the bottom when the tide is flooding. Momentum and friction carry the heavy bottom water at Sta. 1019 up over the sill at Sta. 1020 and on the other side of the sill it falls immediately to the deepest portion of the basin. Within the harbour, however, we have fresh water streams and favourable conditions for warming and mixing, so that there are powerful Archimidean forces tending to produce a surface outflow. By the time high water is reached these forces have already asserted themselves and the equal density surfaces are sloping upward from Sta. 1020 to Sta. 1019, and remain like this during ebb tide and low water. Within the outer basin the cyclonic circulation of the surface water, due to the earth's rotation, causes

the heavier water to rise in the centre, as is clearly the case at Sta. 1021. As the shore line and the shape of the basin change with the height of the tide it is to be expected that there will be variation in the position as well as in the height of this 'bump' of heavier water. The water of the inner basin as observed at Sta. 1022 is lighter and warmer than that of the outer basin. Indeed at low water and half flood the bottom water of the inner basin is lighter than the surface water of the outer basin. Further observations were taken at various points in the two basins on August 7. As before, the bump of heavy water was present at Sta. 1021 at high water, but not at low. At low water the density of the surface water in the Chamcook River estuary is about the same as that of the shallow water off James Brook, on the west side of the inner basin. Yet this latter water had a higher salinity than any other water in the whole harbour'. Also the surface water at Sta. 1021 was lighter and fresher than that in the estuary. In general the water of the inner basin is fresher and warmer than that of the outer basin. It may be that the cyclonic circulation in the outer basin allows the river water to hug the shore very closely until it enters the inner basin, but in this case its path would take it over the very point off James Brook where the highest salinity was found. An alternative explanation is that there is a fresh water spring in the middle of the inner basin. A great many more observations would be necessary to give a true picture of conditions in the inner basin, especially as it is further complicated by the flow of water over the Bar Road. However, the motion of the water in the outer basin of Chamcook Harbour, which is the larger and more important, seems relatively clear.

#### Bocabec Bay

In this region an attempt was made to measure the currents directly.

It was found quite impossible to use a current meter of the ordinary fresh water type. Two drags were constructed from sheet metal, one for measuring surface currents and the other for measuring currents at any desired depth. By anchoring the boat with at least two anchors, with their lines at right angles, the point where the lines meet can be maintained relatively stationary. A light sail twine line attached to the float of the drag is allowed to run freely from this point and the time taken to travel a certain distance measured with a stop watch. The velocity of the drag is therefore measured directly, the only important source of error being the movement of the boat. Observations were taken in the Eastern channel, between Dick Island and Hardwood Island, on September 2; and in the Southern channel, between Hospital Island and Kilmarnock Head, on September 4. Temperature readings were also taken from the Prince at Sta. 846 on September 4.

In the accompanying velocity diagrams showing the results obtained the velocities have been split into two components, one in the direction of the channel and the other at right angles to this. Thus the diagrams shown on the left represent the distribution with depth of the velocity components along the channel, while the smaller components across the channel are shown by the diagrams on the right. The direction of the channel is of course chosen somewhat arbitrarily, and while a slight change would not affect the left hand diagrams it might change the right hand ones quite appreciably.

The most striking feature of these results is the behaviour of the water at 5 metres depth which in the Eastern channel is still flowing outward even at half flood. In the Eastern channel flood water runs most rapidly at 0 - 3 metres depth, while in the Southern channel it flows in at all depths below 3 metres. At half flood the surface water in the latter was flowing outward. The direction of the currents below 15 metres

is definitely due to the configuration of the bottom. This is well illustrated by the diagram for the eastern channel at half ebb. Here the apparent set of the 20 metre current towards the ENE, as shown in the right hand diagram, simply means that the current is following the channel which runs to the SE. On the other hand there is a decided set of surface water (0 - 2 metres) towards Dick Island, starting at low water and reaching a maximum at 2 1/2 hours flood. This may be due to coastal mixing.

Where the coast is rough, with many islands and shoals, as around Hog Island, Dick Island and the Eastern shore of Big Bay, turbulence and mixing of the water is caused by the tidal streams. The surface water near the shore becomes heavier than the surface water further out and Archimidean forces are set up which tend to produce a shoreward surface current and an off shore under current at a depth of perhaps 5 metres.

The temperature records taken at Sta. 846 from the Prince on September 4 show that from half flood to half ebb, temperatures at the surface and below 10 metres remain quite steady, but the greatest variations are at 5 metres. Half an hour before high water the temperature at 5 metres went up 2°, with subsequent oscillations. It seems that the 5 metre depth is by far the most important in any study of this region.

#### Conclusion

The drag method of measuring velocities was tried late in the summer, on September 2 and September 4. The first of these days was ideal, with calm water and no wind. On September 4, however, working in the southern channel of Bocabec Bay, conditions were bad. The wind was so strong that the boat dragged both her anchors, and the gusts which came from either side of Kilmarnock Head made accurate measurements difficult. In spite of this, the writer feels that the method can be made reliable even under the worst conditions, and that it is the only satisfactory method for

discovering the movements of the waters in the Passamaquoddy region. The problem of constructing the complicated movements of the water from laborious salinity determinations is so difficult as to be almost futile, except in conjunction with direct current measurements. The hydrographical methods applied to the oceans do not seem suitable for a region in which tidal changes are of paramount importance.

It is hoped that the writer will have the opportunity to carry on this new method of attacking the problems of Passamaquoddy Bay.

Department of Physics,  
Queen's University.

*October 31st 1930*

Sept 2nd 1930

EC

NNW ← → SSE

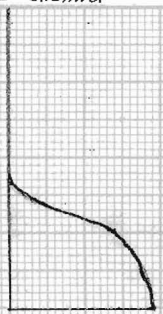
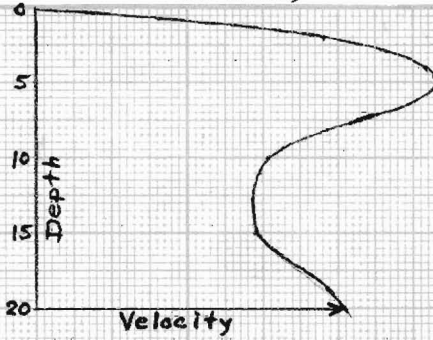
WSW ← → ENE

into Bay

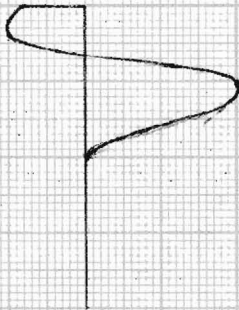
out of Bay

across channel

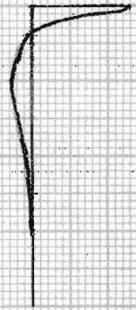
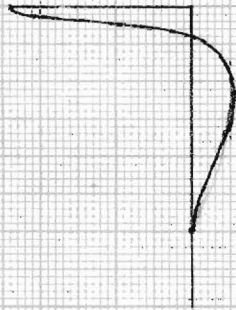
Half Ebb



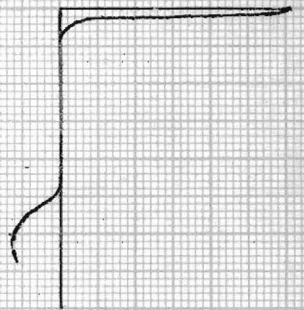
Low Water



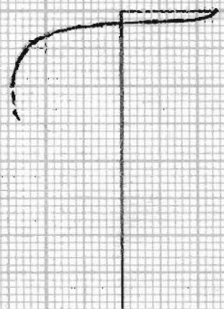
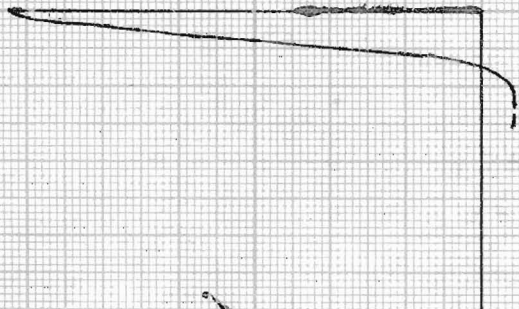
1 hour Flood



2 1/2 hours Flood



Half Flood



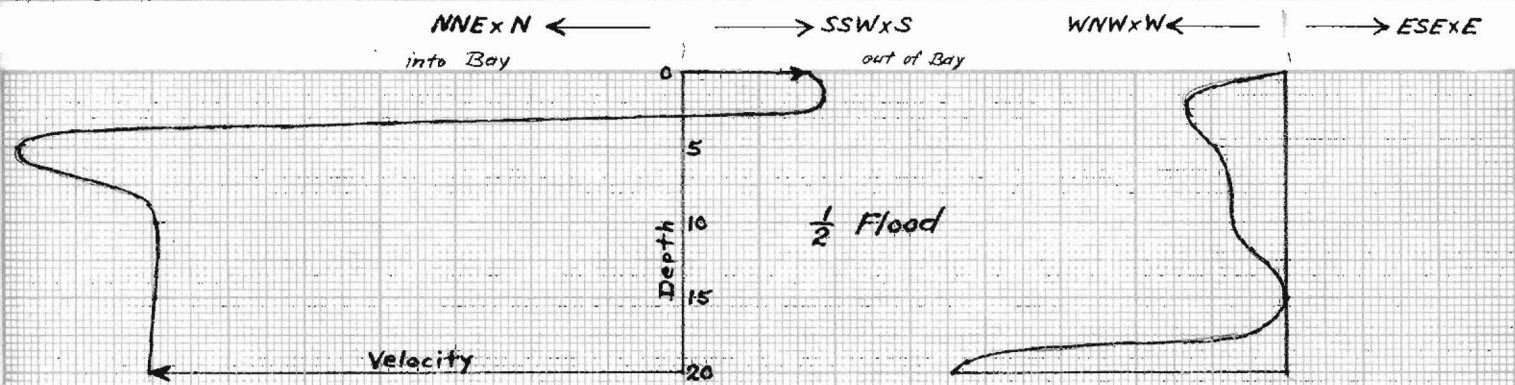
Scale : 1cm = 1 metre per minute

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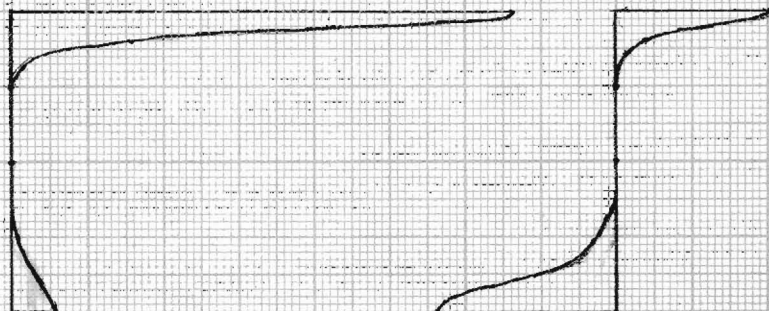
bat

BOCABEC BAY - Southern Channel

Sept 4th 1930



$1\frac{1}{2}$  hours Ebb



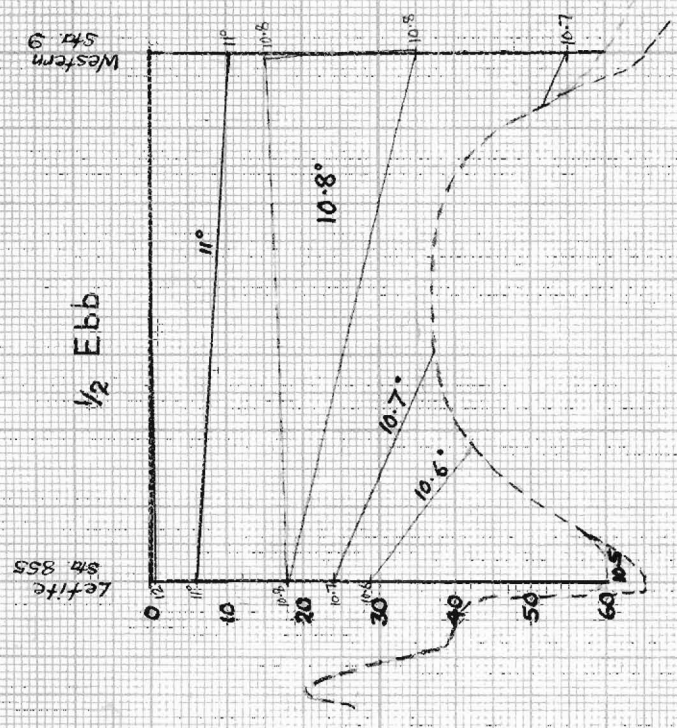
$3\frac{3}{4}$  hours Ebb



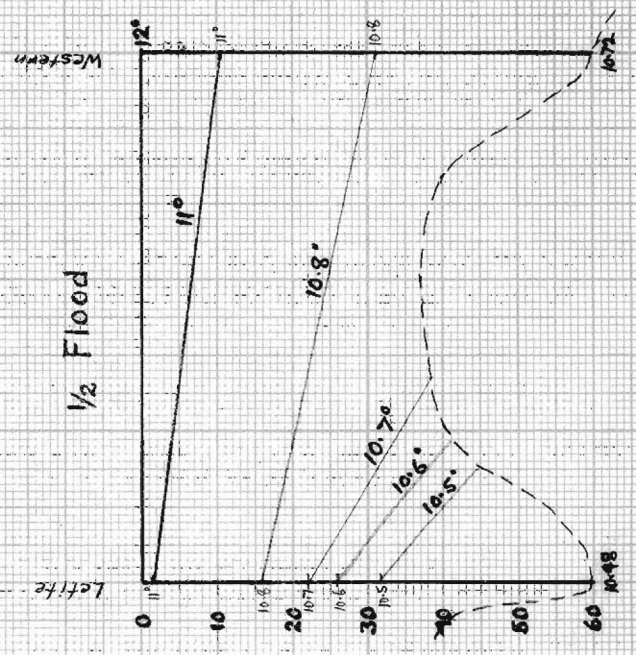
Scale: 1cm = 1 metre per minute

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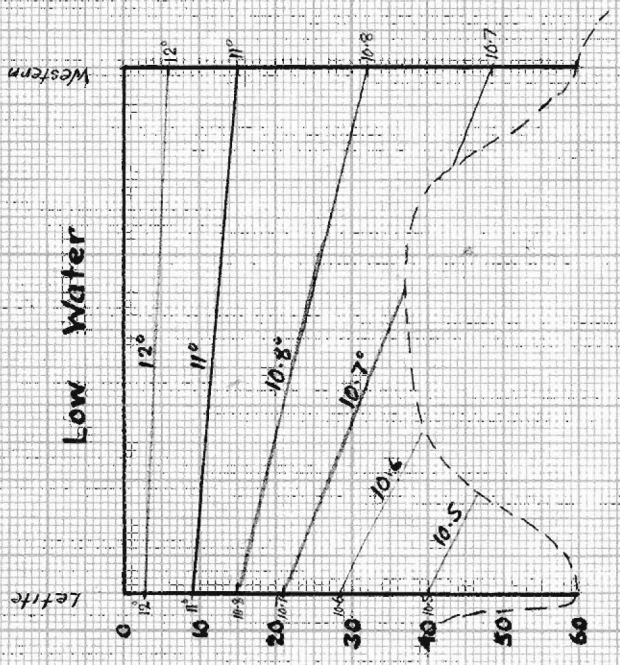
Simultaneous Temperature Sta 855 and Sta 9, Aug 1st / 30



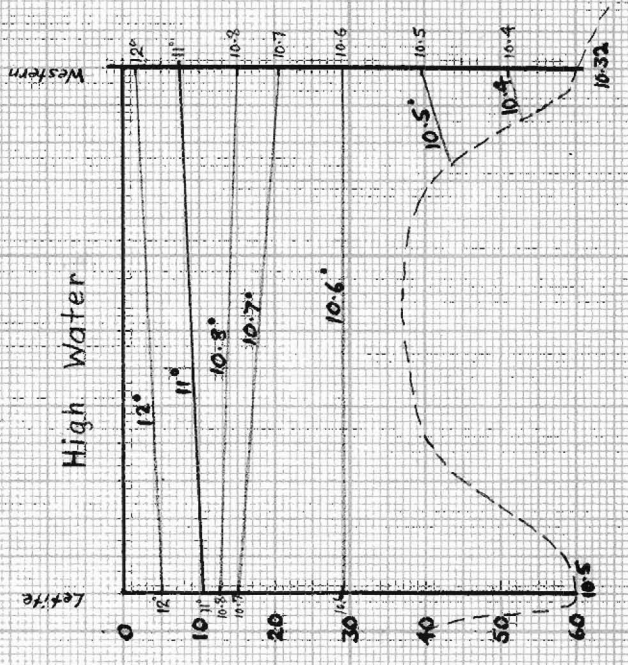
803 AM



2 18 PM



1109 AM



5 26 PM

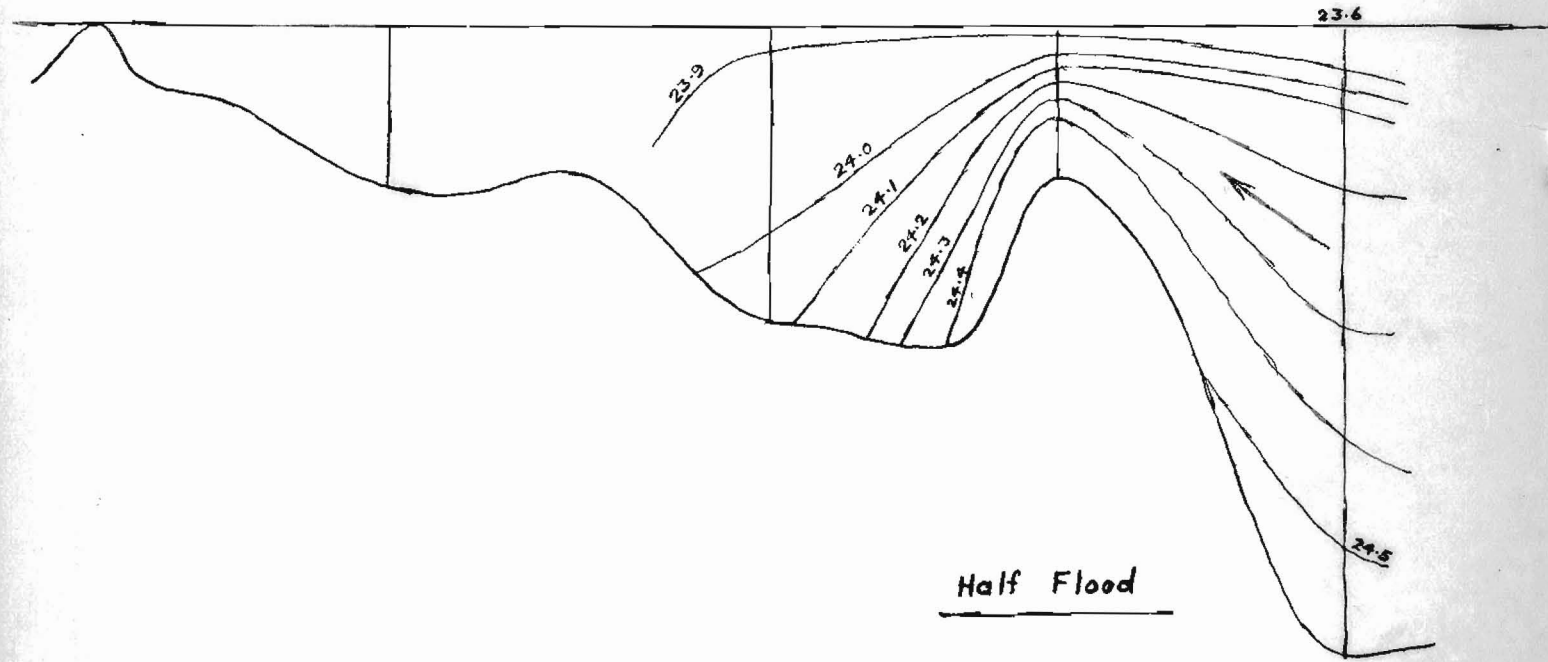
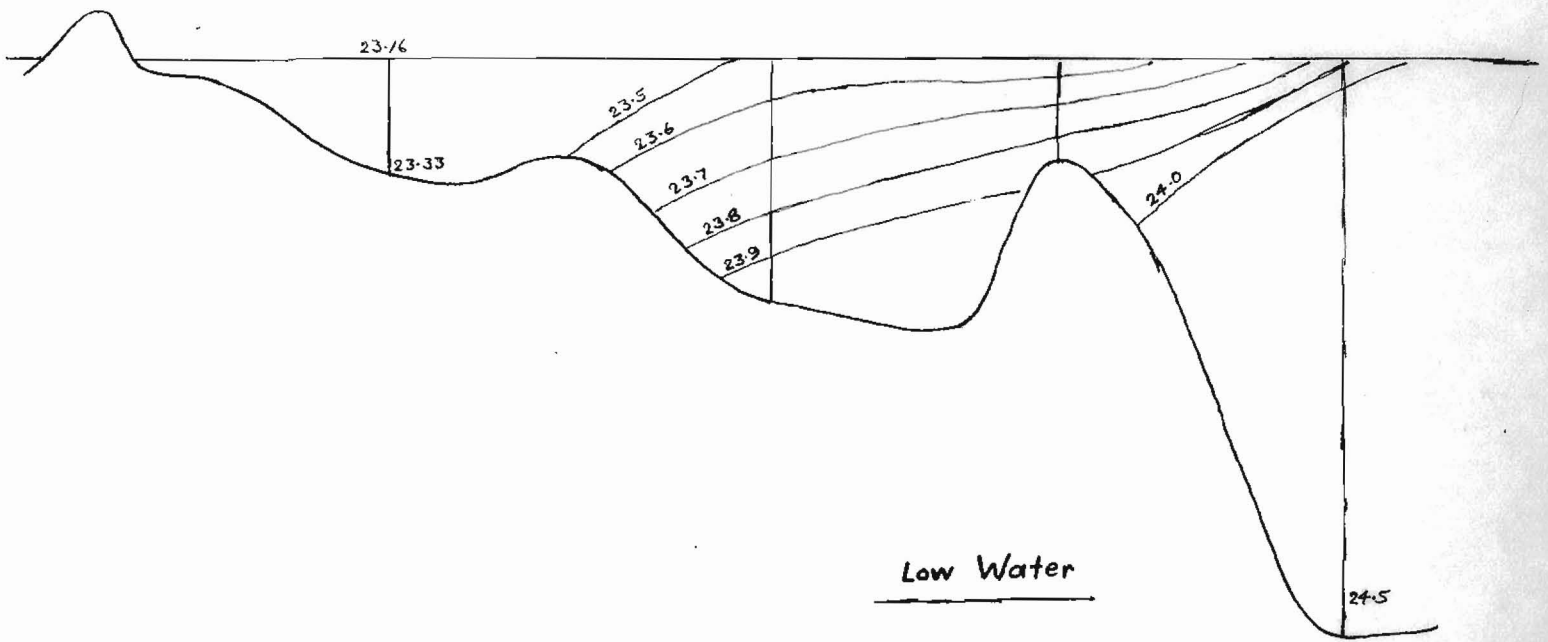
Bar  
Road

1022

1021

1020

1019



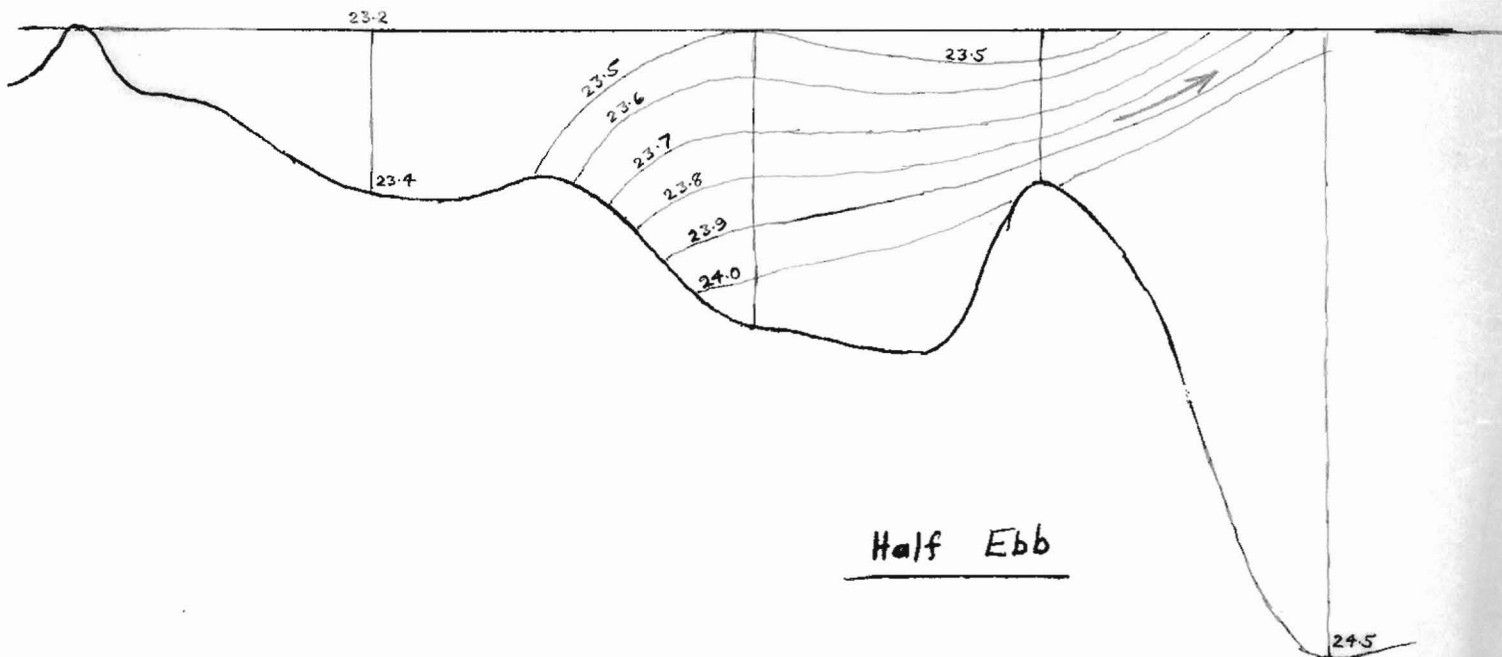
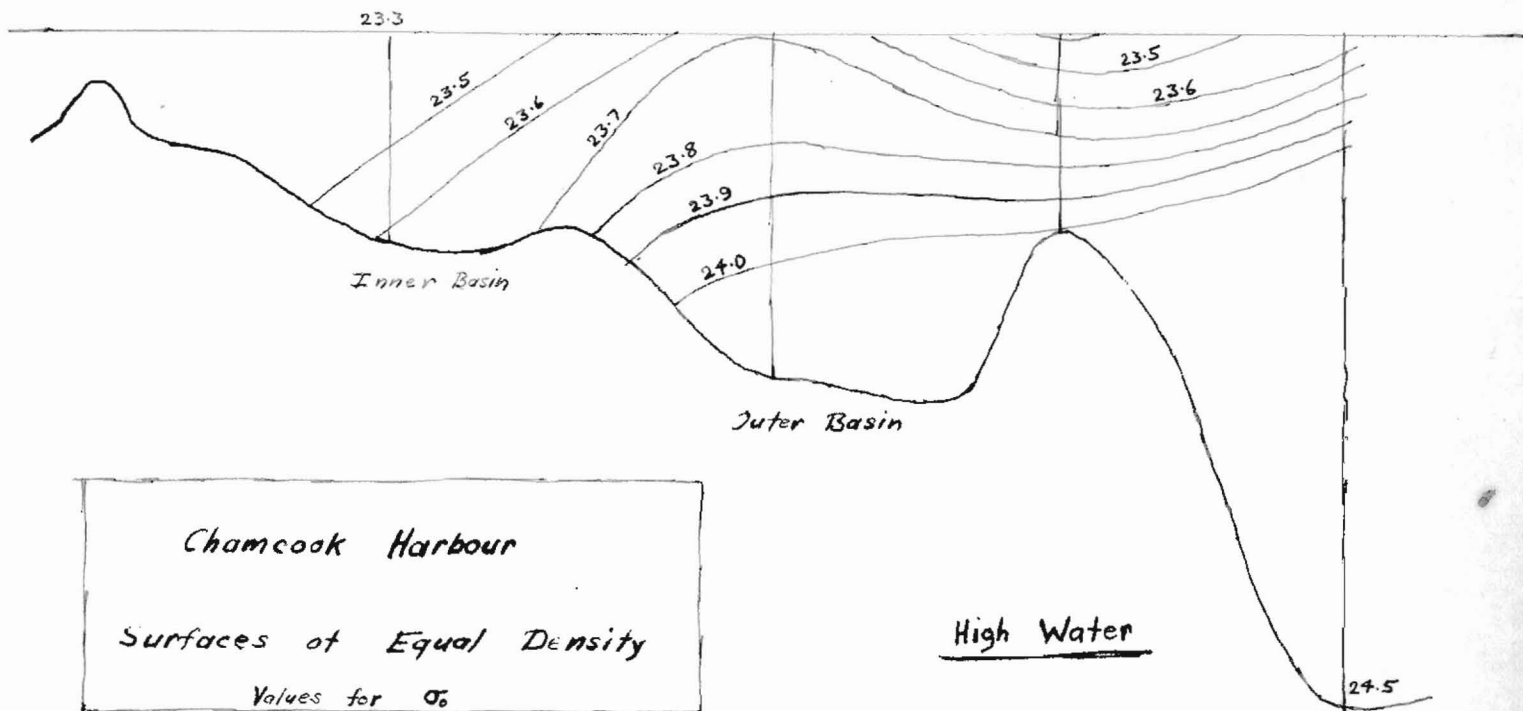
Bar  
Road

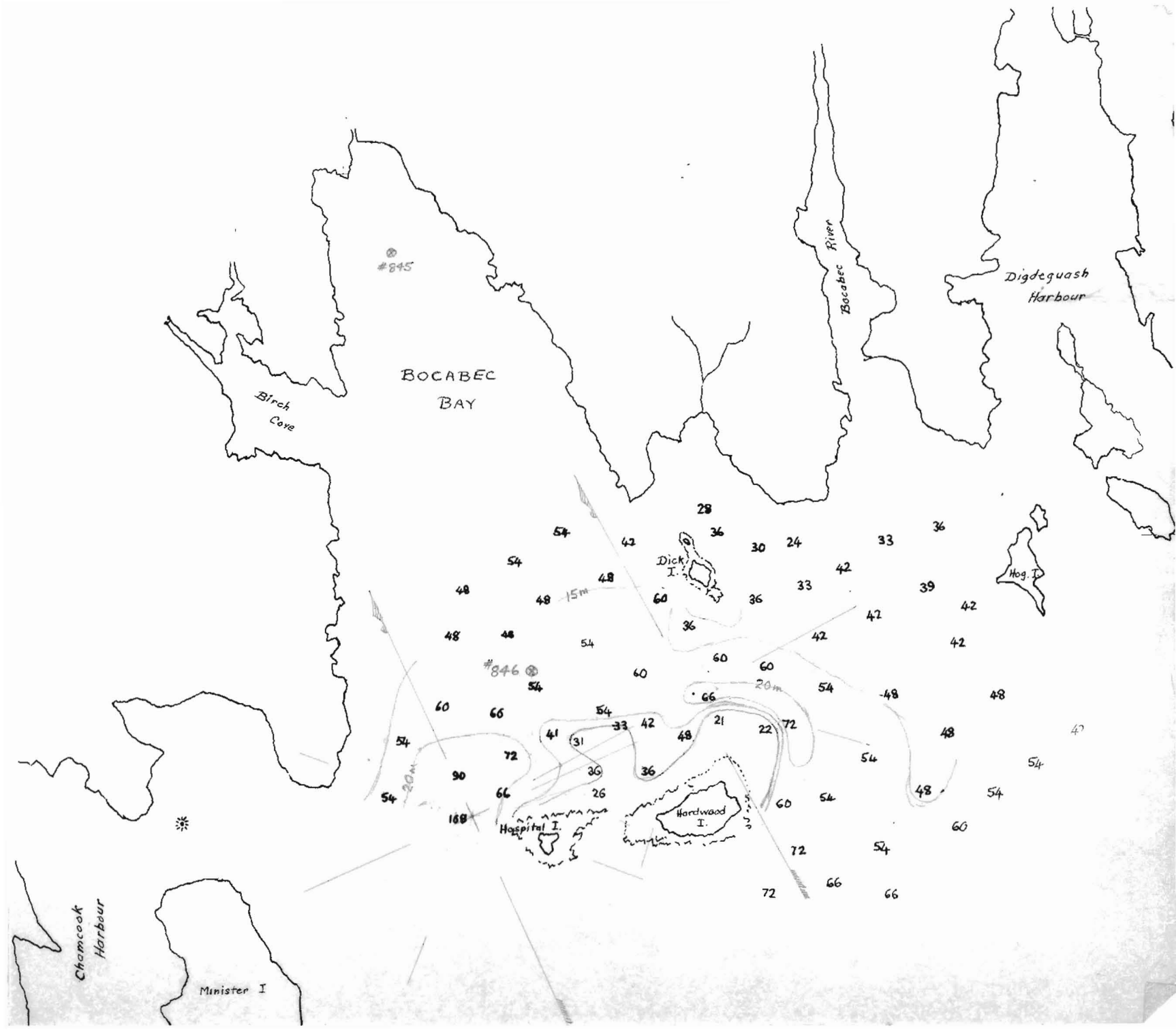
1022

1021

1020

1019







CHAMCOOK HARBOUR