SURVEY

OF

TIDES AND CURRENTS

IN

CANADIAN WATERS

REPORT OF PROGRESS

BY

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OTTAWA
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OTTAWA, 31st October, 1895.

WM. P. ANDERSON, ESQ., C.E.,
Chief Engineer,
Department of Marine and Fisheries.

SIR,—I have the honour to submit the following report on the progress of the Survey of Tides and Currents in Canadian waters. In it I will endeavour to state fully the progress made in the extension of the system of tidal stations, and in the preparation and publication of Tide Tables; and also to describe the character of the current in the Strait of Belle Isle, and its relation to the Gulf of St. Lawrence in general, as some additional light has been thrown indirectly upon this, by the work of the present season. With regard to new results obtained this year in the survey of the currents, it will only be possible at this early date, immediately at the conclusion of the season, to give an outline of the work as undertaken. To this some notes of unusual directions of the current between the Gaspé coast and Anticosti are added, which may be of practical service in the meantime, until the results obtained can be fully worked out and made clear by suitable illustration.

TIDAL STATIONS AND OBSERVATIONS.

At the present date there are seven tidal stations in operation; and these are now supplied with a complete outfit of the necessary instruments. The recording instrument in use at all of these stations is the self-registering tide-gauge of Lord Kelvin's design, to which some improvements have been added in the endeavour to meet our special requirements. These instruments give a continuous record of the tide, day and night throughout the year. (For description of these instruments see Annual Report, Department of Marine and Fisheries, for 1893; Appendix No. 4, page 33.) For the adjustment of these instruments it is necessary to have correct time, and also to obtain direct measurements from a plane of reference or datum.

At isolated stations, where the time cannot be otherwise obtained, dipleidoscopes or meridian instruments have been erected, which give the exact time of the sun's meridian passage; or apparent noon. In this way the driving clock of the recording instrument can be correctly regulated; and the necessity for telegraphic time signals has been dispensed with. The other requirement is supplied by means of a sight gauge; which consists either of a graduated staff standing on a float, or of a metal tape attached to a float and passing over a pulley-wheel. The choice between these forms of sight gauge depends upon the range of the tide at each station; and they serve to give the direct measurement required from a datum plane of reference. Where the range of the tide is so great as to require a metal tape for the sight gauge, Chesterman's steel tapes have been used. These answer admirably in themselves,

as they are so thin and light; but unfortunately, in sea water they rust through in a few months time, which has necessitated the frequent re-determination of the datum plane of reference. The divisions and figures on these tapes are marked by a process of etching, as the metal is too thin to engrave; and if any non-corrosive metal were substituted for steel, such as aluminium or nickel, the figures could not well be etched upon it. The attempt to protect the steel by lacquer or copper-plating has been only partially successful. A trial is now being made with a ribband of German silver, with a small punched hole at each foot, which is marked by a stamped number. The divisions of the foot are read on a fixed vernier.

All of the stations are especially arranged for heating in winter, to prevent the tide pipes from freezing. The heating is supplied by coal oil lamps or small oil stoves; and during the past year improvements have been made in the forms of lamps and burners used, with a view to greater efficiency and safety, as the lamps have to be kept burning throughout the night.

At stations where it is necessary to have a continuous barometric record, a barograph is provided. In some cases the records at present taken by the Meteorological Service, are sufficient for tidal purposes.

In the recording instrument now in use, the driving clock forms a part of the whole, and cannot be detached. Hence if anything goes wrong with the clock, the whole instrument has to be removed and forwarded to some city for repair. This has been the chief source of interruption to the record at the more isolated stations; especially at those with which there is no communication throughout the winter months. From extensive inquiry it appears that all the various patterns of instruments for recording the tide are made on this principle; and to avoid the inconvenience referred to, it will be necessary to design a new form of instrument in which the clock can be readily detached. When the clock has to be sent away for cleaning or repairs, it can then be replaced by another in a few minutes, without interruption to the record. At present, all the recording instruments are working satisfactorily, and they should continue to do so until this change in design can be made for the stations where it is required.

At some of the more exposed stations, much trouble has been given by the movement of the waves in rough weather, which is often so considerable as to record itself on the tidal diagram; and the tidal curve itself is thus complicated with wave motion. The inlet pipes which admit the water to the vertical tide pipes, were originally provided with finely perforated roses or strainers with a view to preventing this; but they have not served this purpose successfully. The further method was therefore tried, at St. Paul Island, of laying a long intake-pipe out along the bottom into deeper water, where the wave motion would naturally be less felt. This intake consists of a two-inch iron pipe with joints of rubber hose for flexibility in laying, and a special fitting by which to connect it under water with the lower end of the tide pipe. It is laid entirely below low water, and ends in a depth of 18 feet; and yet it appears to have comparatively little effect in reducing the amount of the wave motion on the tidal diagram. Possibly in the severe storms of winter, it may be relatively of greater advantage. Even at Father Point, where the intake-pipe consists of 260 feet of three-inch pipe, continued by 140 feet of two-inch pipe, ending at a depth of 12 feet at low water, the wave motion is still perceptible on the tidal diagram in very rough weather. If such a pipe could be carried out into water of sufficient depth, it would no doubt secure the desired result; but there is usually a limit to the depth which it is practicable to reach. At Forteau Bay, where the tide gauge for the Strait of Belle Isle is situated, the bay itself freezes over, which keeps the water surface quiet during the winter gales, and thus obviates the greater part of the difficulty. The effect of the wave motion which still remains on the tidal diagram itself, it is necessary to eliminate by tracing a mean line to represent the actual tide curve.

The tide gauge at Father Point, which was incomplete at the date of last year's report, was not finished until late in the season, on account of the delays met with; but on the 17th of last December it was finally in working order. The difficulties were increased by the unusual severity of the gales in the fall, which destroyed

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repeatedly the temporary dams required in excavating the tide trench across the rocky foreshore. The intake-pipe in the tide trench was laid with much difficulty, as the winter was setting in. It was most important to finish the gauge then; because much of the work would have had to be done over again, if it had been allowed to remain incomplete until the spring.

The intake-pipe serves to lead the water for 260 feet across the foreshore to the tide well, which is situated at high water mark. It is laid at the level of ordinary low water; and between this level and extreme low water it acts by siphoning. This method was adopted to save excavating the tide trench to a greater depth below water, which would have been very expensive in the circumstances. The method has proved entirely satisfactory, as special precautions were taken. The pipe in the tide trench consists of sound spruce and fir logs with a bore of three inches, and these were laid green to prevent shrinkage or cracking, and the lengths were carefully jointed with sail cloth saturated with white lead. Special air pipes were also connected with the main pipe, and furnished with taps to allow the air to escape, in order to keep the pipe constantly filled with water, and thus to insure the action of the siphon. As the sea surges heavily into the outer end of the tide trench in rough weather, and the water then is much mixed up with air, a further precaution was taken to prevent the air from entering the pipe. A two-inch iron pipe was laid out along the bottom for 140 feet from the end of the wooden pipe, extending into 12 feet depth at low water. Any air which still finds its way into the intake-pipe is allowed to escape by opening the air taps at high water.

This spring, an ice shove of 20 feet in height formed along the outer edge of the rocky foreshore. This carried away the iron pipe; but it is so arranged as to be easily relaid; and the end of the wooden pipe itself is protected by a permanent cement dam across the outer end of the tide trench in the rock.

An additional tide gauge has been erected this season at Halifax. It has been placed at the north wharf, on the property of the Department of Marine and Fisheries. This site has the advantage of being in close proximity to Her Majesty's Dock Yard, where the old tidal records of 1860 and 1861 were obtained, from which the tide tables for Halifax are at present calculated. This will bring the new observations into direct relation with the old ones; which is important until it can be ascertained whether the accumulation of the tide in Bedford Basin has any influence on the tide in Halifax Harbour itself, as compared with the tide on the open Atlantic coast in the vicinity. As the range of the tide is only about 6 feet, it is probable that any such local influence will prove to be inappreciable.

During the past year the only serious interruption to the tidal records occurred at St. Paul Island, where the tide gauge was partially destroyed by the unprecedented gale of the 11th of February. This gale amounted to a hurricane in violence, and along the adjoining coast of Cape Breton buildings were carried away which were thought to be well beyond the reach of the sea. The tide gauge at St. Paul Island was built in a sheltered recess in the cliffs, and was held in place by crib-work, set between the cliffs, and braced above by beams mortised into the rock at both ends. The crib-work and the lower parts of the bracing withstood the storm, but the tide-house, which was set at 12 feet above high water, was carried away and the recording instrument lost. A spare recording instrument was at once sent to the makers in Glasgow for alteration, to adapt it to that station. In making the repairs this season the new tide-house was set at a higher level, and it now stands at 23 feet above high water; and the bracing was also extended and strengthened, which should make the tide gauge secure against further injury.

The tide gauge at Grindstone, Magdalen Island, was removed this season, and the materials used in the erection of the new guage at Halifax. The tide at the Magdalen Islands proved to have a very small range; so much so that it was often difficult for days together to make out the time of high and low water with any certainty, especially at the neap tides. This may possibly be due in part to the disturbing effect of the wind, which is relatively large when the tide itself has so small a range, but it also illustrates the remarkable fact that the tide-wave, which enters the Gulf of St. Lawrence from the Atlantic through Cabot Strait, between

Cape Breton and Newfoundland, spreads out in the interior of the gulf so as to become almost inappreciable, till at the opposite side, between Gaspé and Anticosti, it regains its original range and proceeds up the St. Lawrence to Quebec, with ever increasing height. In these circumstances the persevering efforts which have been made to maintain a tide gauge on St. Paul Island, in Cabot Strait itself, are fully justified; as this gauge gives the desired results to better advantage than it is possible to obtain them at the Magdalen Islands, where the only compensating advantage is the hope of better shelter.

At Anticosti the only improvement required in the tide gauge was the new form of inlet by which the water is admitted to the tide pipes. The present inlet has worked satisfactorily during the summer months, but the change was necessary before the winter heating was commenced.

In the erection of the new tide gauge at Halifax, and the repairs at St. Paul Island and Anticosti, the superintendence of the work was intrusted to Captain Douglas, R.N.R., who gave his personal attention to it.

The seven tide gauges now in operation are as follows:—

I. *St. John, N.B.*—Gauge situated at Reed's Wharf in St. John Harbour. To furnish a basis for tide tables for this harbour, and also to serve as a reference station for the Bay of Fundy. Range of tide: springs, 26 feet, neaps, 20 feet. Observer, D. L. Hutchinson, director of the St. John Observatory.

II. *Halifax, N.S.*—Gauge situated at the wharf of the Department of Marine and Fisheries. To furnish a basis for tide tables, and also to serve as a reference station for the Atlantic Coast. Range of tide: springs, 7 feet, neaps, 4 feet. Observer, C. Bryant, foreman shipwright, H. M. Dock Yard.

III. *St. Paul Island, C.B.*—Gauge situated at Atlantic Cove, on the east side of the island. To command Cabot Strait, the main passage by which the tides enter the Gulf of St. Lawrence from the Atlantic. Range of tide: springs, 4 feet, neaps, 2 feet. Observer, J. McLeod, superintendent St. Paul Island.

IV. *Strait of Belle Isle.*—Gauge situated at Forteau Bay, at the inner end of the strait. To command this entrance to the Gulf of St. Lawrence, and also to bring the currents in the Strait into relation with the tides. Range of tide: springs, 5 feet, neaps, 3 feet. Observer, A. Hart, Forteau Bay.

V. *Anticosti.*—Gauge situated at South-west Point. To command the entrance to the St. Lawrence. Range of tide: springs, 7 feet, neaps, 4 feet. Observer, H. Pope, light-keeper and meteorological observer.

VI. *Father Point.*—This gauge is at the pilot station, and at the head of the deep channel of 150 fathoms which extends up the Lower St. Lawrence from the gulf. It serves also as an intermediate station between Anticosti and Quebec. Range of tide: springs, 13 feet, neaps, 7 feet. Observer, J. McWilliams, meteorological obse ver and signal officer.

VII. *Quebec.*—Gauge situated at the dry dock, Lévis. To furnish a basis for tide tables for Quebec Harbour, and with reference to depth of water in the St. Lawrence Ship Channel. Range of tide: springs, 17 feet, neaps, 12 feet. Observer, U. Valiquet, resident engineer, Lévis Dry Dock.

These tidal stations also serve to furnish the tidal data required in making the survey of the currents. The tide gauges at Father Point and Anticosti have also proved of service to the Department of Public Works in connection with the determination of mean sea level, which Mr. R. Steckel of that department is now making for the purposes of the general goedetic survey.

This season, tidal observations were also taken for three months at Pictou, N.S., Neguac, N.B., and Bonne Bay, Nfld., as a tentative measure, to ascertain in what way tidal differences throughout the Gulf of St. Lawrence can best be obtained in relation to the above principal stations.

TIDE TABLES, RECORDS, AND PUBLICATION.

The record obtained from the self-registering tide gauge at Quebec was found to be sufficiently extended to serve for the calculation of tide tables for that harbour. The record from November, 1893, to January, 1895, or a little over a full year, was carefully tabulated and reduced to datum; and any exceptionally high or low tides due to storms were eliminated. The digest thus prepared from the record was transmitted to the Nautical Almanac Office, London, where the best possible advantages exist for the analysis and computation of the tides. Tide tables for both Quebec and Halifax for 1896 have there been prepared by Mr. E. Roberts, by the aid of the tide-predicting machine designed primarily for the prediction of the tides in India.

The Halifax tables are based at present upon old records taken at Her Majesty's Dock Yard during the years 1860 and 1861. There exist also still older records, obtained at the same site in 1851 and 1852, which it is very desirable to incorporate with those from which the tide tables are now calculated, in order to extend the basis on which they rest, and thus to make the tables more accurate. It has not been possible to do this, however, for lack of funds; and another year must therefore pass before this advantage can be obtained.

Since 1891 tide tables for Halifax have been issued by this department, in the form of a small booklet; but it has not been possible to obtain adequate circulation for them in this form. It has therefore been decided to supply the tide tables direct to the leading almanacs, without charge; in the endeavour to make them widely available to masters of vessels and to the pilot service. The tide tables for both Halifax and Quebec for 1896 have accordingly been supplied to the Canadian Almanac, published in Toronto; to the Star Almanac, published in Montreal; and also to Greenwood's Nautical Almanac, an English publication in which tidal information for all parts of the world is given. The tide tables for Quebec will also be issued by the Harbour Commissioners of Montreal, especially for the Pilot service; and the Halifax tables have also been supplied to Cogswell's Almanac, in which the information is principally for the province of Nova Scotia itself. With these tables, tidal differences are given which extend their application to the Atlantic coast of Nova Scotia, and to the Lower St. Lawrence respectively.

It is to be noted that such tide tables as have been published in the past, have been based upon a fixed difference from some distant port, usually on the other side of the Atlantic; and consequently they have been very much in error, especially at certain parts of the lunar month. This will therefore be the first time that tide tables are published for any Canadian port which are based upon direct observation; the only exception being the booklet above mentioned, issued since 1891. These tables also give the height of the tide as well as the time of high and low water. This is very important with reference to the depth of water in the St. Lawrence Ship Channel; and also to show the depth of water available at any tide for vessels entering the dry docks at Lévis and Halifax.

In reducing the tidal observations to a definite plane of reference, great difficulty has been experienced from the want of satisfactory datum levels in our cities. In St. John, N. B., there are no reference marks extant, or any other means of determining correctly at the present time the original low water level on which the Admiralty chart of the harbour is based; nor the low water level adopted for the more recent survey of the harbour by the Department of Public Works. A satisfactory low water datum must therefore be determined afresh, by means of the tidal observations now in progress. At Quebec the bench mark still exists, which was cut on the building of the Department of Marine and Fisheries at the time that the Admiralty surveys were made. The height of the tide in the present tide tables is therefore referred to the original low water datum of the Admiralty chart. This is of direct practical importance to shipping; as the tide tables thus show at once the depth of water which may be counted upon in addition to the soundings given on the chart. In obtaining this result, advantage was taken of the

geodetic levelling done by Mr. Steckel, by which the levels have been carried across the river from the old Admiralty bench mark to the dry dock at Lévis, on which the tide gauge stands. At Halifax, three datum planes exist; as the city datum and the Royal Engineers' datum are both of them distinct from the Admiralty datum. The tides will be brought into closer relation with the Admiralty datum as the new observations proceed.

A sufficient record at St. John, N. B., has now been obtained to warrant its use for the calculation of tide tables for that harbour. If it had been possible to afford the necessary outlay for the reduction of this record, tide tables might also have been prepared for St. John for 1896.

Facsimile copies of the records from two tide gauges erected on the Pacific Coast by the Department of Public Works, are regularly transmitted to this office through the kindness of Mr. L. Coste, chief engineer of that department. These records are obtained at Victoria, B.C., and in the Strait of Georgia, at the mouth of the Fraser River. They are being kept on file until the records themselves are sufficiently extended, and funds are made available, to enable them to be used for the preparation of tide tables.

It is very important that tidal differences should be determined at once for other points, with reference to the principal stations at present in operation; but unless more money is made available for the purposes of this survey, it will only be possible to extend the work and to improve the accuracy of the tide tables by very slow degrees.

SURVEY OF THE CURRENTS.

In commencing the survey of the currents last season in the Gulf of St. Lawrence, one of the most important objects at the outset was to ascertain whether any general current existed across the width of the gulf; or what general circulation there was in the gulf area as a whole. With this knowledge as a basis, the nature of the currents in any special region could then be investigated with intelligence, and with greater hope of success. The main lines across the gulf on which it appeared most probable that some such general current might be found, also coincided with some of the more important steamship routes, which gave additional importance to their examination. Accordingly, during last season (1894) the currents were examined in the two main entrances to the gulf, at Belle Isle and off Cape Breton, to ascertain whether any continuous current passed through the gulf to the west of Newfoundland. No evidence of a general current in this direction could be found; while the indications off Cape Breton pointed to the greater probability of a general current across the gulf in the other direction, namely, on a line from the mouth of the the St. Lawrence at Gaspé past Cape Breton into the Atlantic. This was investigated during the present season (1895) and much information was also obtained regarding the currents between the Gaspé coast and the island of Anticosti.

As the work of these two seasons has thus had the same general object for one of its purposes, it will come within the scope of the present report to include an outline of last season's results. Also by repeating the substance of the information with regard to the Strait of Belle Isle, a more extensive circulation can be given to it; as it appears necessary to place more reliance upon the direct circulation of these reports. The results of last season's work were communicated to the Hydrographer of the Admiralty, and to the United States Hydrographic Office; but it requires time before the information can be introduced into new editions of the Sailing Directions, and so reach the commanders of vessels interested. Copies of the report were also sent to the managers of the leading steamship companies; but such wrecks as the ss. "Mexico," ss. "Dracona," and ss. "Mariposa," which have occurred this season, so far as they may be attributable to the currents, show the need of making still more widely known if possible whatever information regarding the currents is obtained by means of this survey.

CURRENT IN THE STRAIT OF BELLE ISLE.

This strait has a width of 10 to 12 miles for 35 miles of its length; and is entirely free from any rock or shoal throughout. It lies east and west (magnetic). The north shore is bold and the water off it is deep; the south shore is low, but dips off rapidly into about 30 fathoms.

There has been a wide-spread impression that the current in the Strait of Belle Isle runs constantly inwards. A branch from the Arctic current which runs southward along the outer coast of Labrador, has been supposed to run into the Gulf of St. Lawrence through the Strait of Belle Isle, and to find its way out again through Cabot Strait, between Cape Breton and Newfoundland into the Atlantic. On some physical maps, and also on the weather charts issued by the Meteorological Service, this is definitely represented. The description given in the latest edition of the Sailing Directions (1894) although less positive than formerly, still favours this view. It is there stated:—"Under ordinary conditions of wind and weather a current enters the Strait of Belle Isle and flows westward.....but with south-west gales the current may be reversed." The remark on the Admiralty chart is, however, as follows:—"The movements of the water in Belle Isle Strait are made up of a general westerly set affected by tidal streams and winds. The resulting set may be in either direction." This remark gives little countenance to the theory of a constant inward flow; and is in itself sufficiently non-committal to cover almost any conditions. There is no attempt made, however, to describe the conditions under which the flow in either direction may take place.

On the other hand the fishermen along the coast seem to believe that the current is usually in the same direction as the prevailing wind at the time. From the report on the wreck of the ss. "Mexico" this season on Belle Isle, its loss appears to have been due to the over-running of its reckoning in proceeding eastward through the Strait of Belle Isle, which shows that the current sometimes runs in that direction. It was already explained in the report of this survey for last year, that the current runs through the Strait of Belle Isle in both directions, and that there are times when it may be nearly as strong in the outward direction from the west, as inward from the east.

The idea of a constant inward flow appears to be based on the drift of icebergs, and as they are most usually seen drifting inwards, it has been inferred that this is the constant direction of the current. The converse of this is, however, much nearer the truth; and it may be stated in general, that when icebergs are numerous at the outer end of the Strait of Belle Isle, and are also found within the strait, this indicates that the direction of the current has been predominantly inwards from the east during the few days previous, while the absence of icebergs indicates a current predominantly outwards from the west. This of course refers to the presence or absence, in the strait, of floating bergs, and not to bergs which may be aground near either shore. It may also be noted that only a very small percentage of the bergs off the outer end of the strait ever enter it. Captain Vaughan, who resided four years on Belle Isle, states in a pamphlet on the subject that for ten icebergs which enter the strait, there are fifty that pass the mouth and go southward. In doing so they follow the general drift of the Arctic current which passes Belle Isle; and the larger bergs also ground at the entrance to the strait.

It may be stated in general terms that the current in the Strait of Belle Isle was found to be fundamentally a tidal one. The best comparisons of the current with the tide showed a complete correspondence between the two, especially in moderate weather and during the prevalence of moderate westerly winds. On such occasions there were several days during which the current ran east and west for an equal length of time in each direction and turned regularly in correspondence with the rise and fall of the tide. This may therefore be considered as the normal condition of the current. With a heavy and long continued wind the current would first run for a longer time with it and a shorter time against it; and eventually would run continuously in the same direction as the wind, with a fluctuation in

velocity corresponding to the tide. This continuous current might be in either direction according to the direction of the wind.

In this strait also, where the range of the tide is only about four feet, and the current seldom exceeds two knots per hour, the effect of the wind upon the current is all the more marked in proportion. It must not be too hastily assumed however that the wind alone is the cause of the movement of the water in the same direction, as it appears probable that the tendency of the current to flow in the same direction as the wind, is due to the combined influence of the wind itself, and to difference in barometric pressure over wide areas.

CURRENTS IN THE STRAIT AS OBSERVED IN 1894.

The current in the Strait of Belle Isle was examined in both July and September, at the narrowest part of the strait near Amour Point. To avoid the tide rips which occur off this point, a section line was chosen a little to the eastward, on a line from Green Island, at the south side, to the red cliffs on the north shore, which lie immediately east of Loup Bay. The width of the strait is there 11½ miles; and three stations were chosen on this section. The usual depth is 30 to 40 fathoms; but the water is much deeper near the north shore. The bottom appears to be bare rock running in ridges parallel with the direction of the strait. The surveying steamer was anchored at these stations for one or two days at a time; and was moved from one to another to ascertain any difference in the current at the two sides of the strait, while the same conditions of wind and weather prevailed. The tides were observed simultaneously at Forteau Bay within 12 miles of these stations, in order to ascertain the relation between the rise and fall of the tide and the direction of the current in the strait.

Comparisons of the current on the north and south sides of the strait were made by the best means available, to detect any difference between them. The best simultaneous observation of the currents on the two sides was obtained on September 15th, while the steamer was anchored three miles off Green Island, and an iceberg was drifting up and down with the tide, four miles from the north shore. At that time the current was running east and west in fair harmony with the tides; and complete data were obtained from the iceberg, as its height was measured immediately afterwards. This observation showed that the current on the north side of the strait ran inwards from the east for a longer time than on the south side, and outwards from the west for a shorter time. Also, on the north side, the current from the east, as shown by the path of the iceberg, was stronger than the current from the west, while on the south side the currents were practically equal in the two directions. On another occasion, during a period of persistent current from the east (September 8th), observations made while the steamer was at anchor near the north side, compared with the speed of icebergs near the south shore, showed that the current was practically equal at the two sides of the strait.

From these observations, and also from a comparison of the current as measured successively at the different stations, it appears that there is on the whole a tendency on the south side to greater tidal regularity, and on the north side to greater persistency of flow in one direction or the other. This is probably due to the greater depth on the north side, and consequently, the greater momentum of the water there, as compared with the frictional resistance.

With this explanation regarding the amount of difference in the current on the two sides of the strait, we may proceed to a closer comparison of the relation between the tides and currents, based upon observations during such times as the current ran in harmony with the tides, and turned in regular correspondence with them. Also, the best instances that were observed of a persistent or predominant current for several days, from the east or west respectively, and the conditions under which this took place.

The tide itself, as recorded at Forteau Bay, had a range which did not exceed five feet. The difference between the spring and neap tides was not very marked;

while on the other hand, when the moon's declination was great, the diurnal inequality in the tides was quite distinct. The currents in the strait showed the same characteristics; there was little appreciable difference in the velocity at spring and neap tides, as the currents were much more disturbed by the winds than any such difference would amount to. But the diurnal inequality in the current was well marked when this inequality occurred in the tide itself. The greatest velocity of the current in either direction under ordinary conditions of tidal regularity did not exceed two knots per hour.

The dates during which the currents followed the tides with the greatest regularity and the conditions of weather then prevailing, are given below. The directions of the wind are magnetic, as these correspond best with the direction of the strait itself. The magnetic variation is 35° W.

Monday, July 9th, to Friday, July 13th—Wind moderate; from the west or variable in direction. During the four days there were 60 hours westerly wind, averaging 9 miles per hour.

Thursday, July 26th to Saturday, July 28th—During two previous days (July 24th to 26th) there were 36 hours of westerly winds averaging 15 miles an hour; and 12 hours of easterly and variable winds averaging 14 miles per hour. From July 26th to 29th, winds from N.W. to S.W. for 54 hours, averaging 15 miles per hour.

Monday, September 17th to Friday, September 21st—Including the two days previous, or in all from September 15th to 21st there were 72 hours of westerly winds, averaging 15 miles per hour; and 72 hours of easterly winds, averaging 8 miles per hour.

The following summary shows the velocity of the current in the two directions, which in these periods is nearly equal; and a comparison is also given to show the relation between the times of high and low water at Forteau Bay, and the turn of the current in the strait, as observed at three points on the section line above mentioned.

Velocity of the Current.—The velocities given below were obtained by means of the most improved forms of current meters; and were all measured at the standard depth of 18 feet, which was well below the keel of the steamer.

July 9th to 11th; as observed one mile off Green Island, and

July 12th and 13th; as observed at the centre of the st ait:—

Current from the east, maximum: 1·16 to 1·98 knots per hour.
Current from the west, maximum: 1·30 knots per hour.

July 26th to 28th; as observed at the centre of the strait:—

Current from the east, maximum: 1·80 to 1·98 knots per hour.
Current from the west, maximum: 1·08 to 1·26 knots per hour.

September 17th to 21st; as observed three miles off the north shore:—

Current from the east, maximum: 1·02 to 2·04 knots per hour.
Current from the west, maximum: 0·92 to 1·81 knots per hour.

The inequalities of the current in the last instance correspond with the diurnal inequality in the tides themselves.

Comparison of the Current with the Tide.—This comparison was made to obtain a relation between the direction of the current in the strait and the time of high and low water as observed at Forteau Bay.

During the periods of greatest regularity, as given above, the current ran inward from the east during the rise of the tide, and would either stop at high water, or still continue to run inwards for some time afterwards. The greatest length of time after high water during which it was observed to run inwards was two hours and fifteen minutes. The current then turned and ran outward from the west during the fall of the tide, and would continue in that direction for a length of time after low water, which varied from forty minutes to two hours and fifty-five minutes.

These differences in the relation between the turn of the current and the time of high and low water are partly due to the irregularity in the tides themselves. On the average the current ran inward from the east for one hour and forty minutes after high water, and outwater from the west for an equal period of time after low water. A similar result was also obtained from a direct comparison between the turn of the current and the time of the moon's transit.

A relation of this character is very important to obtain; as it shows most clearly the true tidal character of the current in the strait. When the tidal record itself, which is now being obtained from the tide guage at Forteau Bay, becomes sufficient for the calculation of tide tables, such a relation will enable the direction of the current under normal conditions when undisturbed by the wind, to be given in advance as definitely as the times of high and low water themselves.

The actual direction of the current in much complicated by the disturbing influences of the wind and barometer, as will be seen from the following instances in which the current ran persistently from one direction or the other.

Persistent Current in one direction or the other.—The most marked example of a persistent current running out of the strait from the west occurred from Monday, July 16th, to Thursday, July 19th. During these three days the current (as observed three miles off the north shore) ran in from the east for only five hours, and out from the west for 19 hours each day. The maximum velocity of the current from the east was 1·38 knots per hour; and from the west 2·44 knots per hour. The long run from the west was stronger at the beginning and end of the time, with an interval of weaker flow between the two. The times of high water corresponded with this minimum in the current from the west, and with the maximum current from the east. This condition of the current may therefore be considered as consisting of two components; a steady flow from the west, together with the usual tidal current in the two directions. As the moon's declination was at its maximum at the time, the diurnal inequality would largely account for the difference between the actual current from the east at the one tide, and the minimum of the current from the west at the other.

The best example of a persistent current running in through the strait from the east occurred from Wednesday, September 5th, to Saturday, September 8th. All the indications concurred in showing that the current ran continuously in the one direction during these days; although the observations were much interrupted by bad weather. There were also about a dozen icebergs seen in the strait during this time; and their motion agreed with the regular observations in showing that the current ran continuously inward from the east. The current then varied from a minimum of 0·54 knots per hour to a maximum of 3·15 knots, in the one direction. The tides themselves were anomalous; as the low water for five successive tides scarcely fell below mean sea level, and the whole rise was less than two feet, or about half of the usual amount.

In stating the conditions of wind and barometer during these periods of predominant flow, it may be well to recall that a difference of barometric pressure should tend to produce flow from the higher towards the lower pressure, just as in the case of the wind

At the time of the predominant flow from the westward (July 16th to 19th), the wind ranged from N. W. to S.W. For three days previously, from July 13th to 16th, the average for 72 hours was 16 miles per hour; and from July 16th to 18th., the average for 60 hours was 14 miles per hour from the same direction. This was succeeded by easterly winds and broken weather. Also, from the morning of the 14th the difference of barometric pressure gave a barometric gradient which was inwards at Cabot Strait and outwards at the Strait of Belle Isle. This continued till the evening of the 17th when the pressure equalized itself; and by the morning of 19th a low pressure area developed over the Gulf which gave inward gradients at both straits and thus reversed the conditions for Belle Isle. The effects of both wind and barometer are thus in general accord with the direction of the current from the westward. It will also be noted that the total mileage of westerly wind in the case

of this predominant current, is nearly double of its greatest amount during the periods when the current ran in harmony with the tides.

During the continuous flow from the east (Sept. 5th to 8th) the conditions of wind and barometer were disturbed and complicated, as a storm centre was passing over the northern part of Newfoundland at the time. The low pressure area of this storm centre was over the gulf during the 5th and was nearest to the strait on the morning of the 6th, on its way eastward to the Atlantic. From the morning of the 5th till the evening of the 8th there were 60 hours of N. N. W. wind averaging 25 miles per hour, and rising at times to 45 miles. During the remainder of the time the winds were light and variable. The relation of wind and barometer to the current at this time is not clear; beyond the general fact of the occurrence of a severe disturbance at the time of this continuous current.

Under-currents.—The under-currents in the Strait of Belle Isle were carefully observed at a depth of 25 to 30 fathoms by instrumental methods, and also by obtaining the speed of icebergs which served as "deep floats" for comparison with the surface velocity. The under-current would have had much greater importance if the current through the strait had proved to be a continuous one, for which an actual gauging of volume was required.

During the times that the current ran in fair correspondence with the tides, when the conditions may be considered as normal, the under-current was usually stronger than the surface current when the flow was from the east, and it was always weaker than the surface current when the flow was from the west. From the best ratios obtained when the current ran steadily, and omitting observations near the turn of the tide, the following percentages have been obtained:—

Current from the east. Under-current 5 per cent stronger than the surface current.

Current from the west. Under-current 70 per cent of the velocity of the surface current.

During the period of predominant current from the westward (July 16th to 19th) the under-current ran with much greater regularity in the two directions than the surface current. This indicates that the surface current itself was of the nature of a "wind-drift," and that the time was not sufficiently prolonged for the wind to influence the current to the bottom.

During the period of persistent flow from the eastward (Sept. 5th. to 8th) the under-current was decidedly stronger than the surface current, amounting on the average to nearly 20 per cent more. This result was obtained chiefly from the motion of icebergs.

Temperatures.—The temperature of the water was taken to ascertain its relation to the direction of the current through the strait; as the water at the Atlantic end is colder than the water at the western end towards the Gulf of St. Lawrence. It was therefore to be expected that the current running in from the east would be the colder of the two; and the temperature of the water might thus furnish an indication to vessels of the probable direction of the current.

The numerous observations taken are summarized and tabulated in the Annual Report of the Department of Marine and Fisheries for 1894, Appendix No. 3; page 100-102. They show that there is little appreciable difference in the temperature of the currents in the two directions so long as the current maintains its tidal character; but the difference is naturally more marked during the periods of predominant flow in one direction, already mentioned. It might perhaps be possible to ascertain from extended observations the amount of the difference to be expected under such conditions, above or below the normal temperature for the season. But at best, the temperature could only be taken to indicate the predominant direction of the current during the few days previous, and could not be relied upon to show its actual direction at the time.

The temperature of the water has a more important relation to the presence of ice in the strait. When the predominant direction of the current is inward from the east for a few successive tides, it will undoubtedly carry icebergs into the strait if there are any at its outer end at the time. The current from the east is thus not

only cold in itself, but also brings in ice with it which further chills the water in the strait. The cold water, the current from the east, and the presence of icebergs within the strait, are thus concomitants of each other.

It is not to be inferred, however, that warm water in the strait is an indication that ice will not be met with; because the water in the strait itself may be relatively warm, notwithstanding that icebergs are numerous at its mouth around Belle Isle, and possibly as far in as the vicinity of Cape Norman. It is possible for this ice to be moving southward with the general Arctic current on both sides of Belle Isle, past the mouth of the strait, without affecting either the direction of the current or the temperature of the strait to any great distance inwards.

The following statement with regard to the current in the strait of Belle Isle at other seasons of the year, is based on information furnished by Mr. T. M. Wyatt, who has been lightkeeper at Amour Point for 15 years, and by Mr. Charles Davis, a resident of Forteau Bay. In the spring of the year, the prevailing winds are easterly, and the current also runs in continuously from the east, and only slacks with the tide without turning. The duration of this easterly current varies from year to year, but usually continues for one or two months in the interval between the beginning of April and the end of June. A strong west or north-west wind however, will make the current run out from the west. In the summer, the currents are less strong and not so persistent, and are more under the influence of the tides. In the autumn the winds are often easterly in the latter part of September and October; but perhaps more often westerly; and in either case the current is influenced by their direction. Later in the autumn north-west winds occur with colder weather. These winds continue to be prevalent during the winter months, and give the current an outward direction from the west.

This statement must be qualified by the usual uncertainties attributable to the weather; and it is also to be noted that any continuous currents are more persistent on the north shore where these observations were made. The residents on the south shore would convey the impression that the currents are much more regular in their tidal character; but their statements appear to be based upon the currents in the shallow water inshore, which may be different from those in the open strait.

Summary for the Strait of Belle Isle.

In the following summary, the general characteristics of the current in the Strait of Belle Isle are given as correctly as they can be deduced from its behaviour during the time the observations were made. The velocities given, were measured at the standard depth of 18 feet.

1. The current is fundamentally tidal in its nature; and under normal conditions, it runs east and west with velocities which are nearly equal. It attains at times a velocity of two knots per hour in each direction.

2. The conditions are normal in moderate weather, and during the prevalence of moderate westerly winds.

3. During heavy winds, especially when easterly or westerly in direction, the current which runs with the wind becomes stronger than the current against it; and eventually, the current may come to be continuous in the same direction as the wind.

4. The greatest velocities of the current which were observed during heavy winds (in the months of July and September) were as follows:—From the east, 3·15 knots, and from the west 2·50 knots per hour.

5. The presence of ice in the strait, and the temperature of the water, have also a relation to the predominant direction of the current; but they do not afford a reliable indication of its actual direction at the time.

6. Under normal conditions, and when both surface current and under-current are taken into account, the difference on the average is in favour of a greater inward flow from the east.

7. The actual flow throughout the year, when the influence of the wind is included, appears also on the whole to be greater in the inward direction from the east, than outward from the west.

Current in the eastern end of the Gulf, immediately west of the Strait of Belle Isle, between Rich Point and the Esquimaux Islands.

From observations at three stations in this region, occupied between July 31st and August 3rd immediately after prolonged westerly winds, the current was found to be from the west (magnetic) at the centre and on both sides. The velocity amounted to 0·79 knots per hour at the centre, and 1·19 to 1·37 knots at the sides.

This in the circumstances is likely to be as great a velocity from the west as ever occurs, owing to the wind conditions for the week preceding this direction of the current. From July 24th to 31st there were in all 124 hours of westerly wind, averaging 20 miles per hour, and only 48 hours of easterly wind, averaging 19 miles per hour; or in all 2,530 miles of westerly wind, and 890 miles of easterly wind. The westerly winds also continued during August 1st and 2nd. The layer of water in motion from the west had a thickness of only 5 to 10 fathoms; which tends also to show that its movement was due to the previous direction of the wind.

From the above characteristics of the current in the Strait of Belle Isle, it is clearly possible for a vessel to over-run its reckoning in either direction through the strait. Also, vessels entering through the strait should not assume that the current is necessarily in their favour in making the run westward to round the eastern end of Anticosti; as it is possible that the set in the strait itself and also in the eastern end of the gulf, may be against them.

The Belle Isle Current in Relation to the Gulf in General.

On account of the tidal character of the current in the Strait of Belle Isle, it is clear that no great volume of water can enter the Gulf of St. Lawrence from that quarter. During the summer season, the current flows through the strait in both directions with velocities which are nearly equal; and there is only a difference in favour of inward flow from the east, which on the whole does not probably amount to more than a moderate percentage. There is reason to believe that in the early spring the preponderance of inward flow from the east may be proportionally greater than at other seasons. There is some evidence to show that the incoming water may then penetrate the gulf as far as Bonne Bay on the west coast of Newfoundland. But no reasons have been found for supposing that this water passes completely round the west coast of Newfoundland and finds its way out into the Atlantic through Cabot Strait, between Cape North and Cape Ray, in accordance with the theory which has been more or less accepted up to the present time. All the indications are against this theory; and the results of last season's work were already sufficiently conclusive to enable the theory to be considered as disproved. This conclusion is further corroborated by the investigations of the present season; which show that if there is any general current across the extent of the gulf, it must lie in an entirely different direction.

It may be allowable therefore to sum up briefly the reasons for this conclusion, from all the evidence yet obtained, during the two seasons.

The water in the Strait of Belle Isle is exceedingly clear. It is also very cold, and when flowing in the inward direction, its temperature as late as September is below 45° for the average of its depth from surface to bottom. Its density is as high as that of any water found within the gulf being on an average 1·0244 at the surface.

The water in Cabot Strait is quite different from this in its character. The greater part of the width of that strait is occupied by water which has the usual milky-green colour of ordinary seawater. The out-flowing current in Cabot Strait, is on the side next to Cape North, or the further side from Belle Isle. This out-flowing water has also a distinctly brown tinge; its surface temperature ranges from 55° to 65°; and its average density to a depth of ten fathoms from the surface

is 1·0230; and as far down as a depth of nearly twenty fathoms it is still both warmer and fresher than the Belle Isle water. If therefore the Belle Isle water has any influence on this current it can only be of a very indirect character. The greater speed which it is reported to have in the spring of the year, may be due in some measure to the incoming water at Belle Isle, if at that season its volume is considerable; for even if the water itself does not reach Cabot Strait, it may still act by displacement, as the total volume of the Gulf must remain nearly the same. Even this measure of influence cannot, however, be definitely asserted.

There is not only this difference in the character of the water in these two straits, but also a want of connection between them. The few observations obtained along the west coast of Newfoundland show that there is a slight current from the S.W., or in the contrary direction to that which the theory supposes. It is also stated by Lieut. Betty, navigating lieutenant of H.M.S. "Pelican" who has spent more than one season cruising along the west coast of Newfoundland, that the current there, between Cape Gregory and Rich Point, runs almost constantly from the S.W., and is only intercepted by the ebb and flood tides running in and out of the larger bays on the coast.

It might still be supposed however, that any water entering through the Strait of Belle Isle would be most likely to pass out at Cabot Strait as a cold under-current along the bottom. The total depth of Cabot Strait is 250 fathoms; the coldest water forms a layer between the depths of 30 and 50 fathoms, and below this the water is again warmer but with a higher density, which ranges from 1·0254 to 1·0260. As this cold layer occurs in other parts of the gulf area also, it cannot be taken as an indication of any special direction; and the characteristics of the deep water from 100 fathoms downwards, show how different it is from the Belle Isle water. The indications so far as obtained, also show that the deep water from 100 fathoms downwards is entirely quiescent.

There is therefore no confirmation to be found for the theory that a constant current enters the Gulf by the Strait of Belle Isle and leaves again by Cabot Strait; but on the contrary, all the evidence so far met with, is directly against it.

General Examination of the South-western Side of the Gulf.

For the survey of the currents this season, the ss. "Lansdowne" was again made available for three months, from June 26th until September 27th. During this time it was necessary to call twice for coal, and also to spend several days in obtaining fresh water. In the month of August the weather was unusually broken and stormy, which also occasioned some loss of time. The surveying party consisted of myself and Mr. H. M. MacKay as assistant; the night observations were taken by Mr. G. E. Hardie during July and August, and Mr. R. E. Tyrwhitt in September. Meteorological observations were also taken by Mr. MacKay throughout the season. Captain G. J. W. Bissett commanding the ss. "Lansdowne," and the other officers, also gave their co-operation in facilitating the work.

There was considerable inconvenience for want of suitable anchorage appliances as provision had to be made for anchoring in all depths up to 250 fathoms, and on account of the low state of the funds available, it was towards the end of the season before appliances of a satisfactory character could be obtained.

In the investigations of last season to ascertain whether any general current could be traced across the gulf from the Strait of Belle Isle, the examination of Cabot Strait furnished an indication which pointed in an entirely different direction. The out-flowing water around Cape North was found to be appreciably fresher or lower in density than the water at the central part of that strait and towards the Newfoundland side. The value of this indication was remarked in last year's report; as it pointed to a possible connection with the constant current which was shown on the charts as flowing eastward along the Gaspé coast at the entrance to the St. Lawrence, and which might also be presumed to have a low density. These currents although 200 miles apart both flow towards the south-east, or in an outward

direction in relation to the River and Gulf of St. Lawrence; and there was good reason to believe that they were both of a constant character.

It was accordingly proposed this season to examine into the nature of the current in the Gaspé region; and also to ascertain whether any general set or drift could be traced across the width of the gulf to connect this with the out-flowing water at Cape North.

The entrance to the St. Lawrence between the Gaspé coast and Anticosti Island lies on the line of a deep channel which connects them with the ocean. This channel runs in from the Atlantic between the Grand Banks on the east and Banquereau and Misaine Bank on the west, with a width of some 40 miles, and a continuous depth of nearly 250 fathoms. After passing through Cabot Strait, it maintains its width and depth entirely across the gulf; passing north of the Magdalen Islands and between the Gaspé coast and Anticosti. It then penetrates the Lower St. Lawrence nearly to the mouth of the Saguenay, where the depth has only diminished to 150 fathoms at a distance of 420 miles from Cabot Strait. A branch of this deep channel also extends from the Magdalen Islands for a certain distance towards the Strait of Belle Isle.

At the beginning of this season, the region at the mouth of the St. Lawrence between the Gaspé coast and Labrador and around the west end of Anticosti, was examined to ascertain what characteristics of the water could be relied upon for the purpose of tracing its movements with the best hope of success. Although the colour of the water had been found to be appreciably different in different parts of the gulf, this is not an indication of a very definite character, though it may sometimes be helpful. The two characteristics chiefly relied upon in tracing currents are the temperature and the density of the water.

In examining the temperatures in this region and comparing them with the numerous observations which had now been obtained in other parts of the gulf area, it soon became evident that for the purpose in view this could not be relied upon as any definite indication of the direction of the movement of the water. The surface temperature in the summer season usually ranges from about 50° to 65°, and in proceeding downwards this temperature gradually falls, until at a depth of 40 or 50 fathoms it is only 30° to 34°, or practically at the freezing point. Where the greater depths are met with, the water below this again is found to be appreciably warmer. There are considerable areas, however, in which the depth is less than 50 fathoms, and where the conditions are accordingly restricted.

It appears, therefore, that in general, the temperature of the surface water merely rises with the progress of the season; and it is also natural that the water should become warmer to a greater depth as the season advances. Even this has its limitations, however; as at a depth of 50 fathoms no greater rise in temperature has yet been found than from 32° to 34°, between the month of June and the end of September.

In the Gaspé region, as well as in Cabot Strait, the coldest water forms a layer between the depths of 30 and 50 fathoms. Also in the vicinity of the Strait of Belle Isle the same low temperatures are found at these depths; although there the temperature towards the surface is relatively lower, as a rule, than in the other regions. As these conditions, therefore, occur at all three angles of the gulf, and have also been found at a few intermediate points where observations have been obtained, it appears not at all impossible that this cold layer may extend very generally over the gulf area; and it cannot, therefore, be taken as an indication of direction of movement of the water.

Below this cold layer, in the deeper water of the channel above referred to, the temperature from 100 to 200 fathoms is found to range very constantly from 38° to 41°. This result was obtained last season in Cabot Strait; and the constancy of the actual temperatures obtained at different dates at these depths, as well as the precautions taken to insure accuracy in the observations are given in detail in last year's report. During the present season, the same temperatures have also been found at these depths between the Gaspé coast and Anticosti, which is 220 miles further in than Cabot Strait, along the deep channel leading from the Atlantic,

This deep water, from such indications as have been obtained, appears also to be entirely quiescent, and to have therefore little direct relation to the currents in the gulf, in so far at least as they affect navigation.

From a limited number of determinations made in the eastern portion of Cabot Strait, and also along the west coast of Newfoundland and in the Strait of Belle Isle, the density of the surface water in that region appears usually to range from 1·0233 to 1·0245. This is much the same as in the open Atlantic; as the density of the surface water off the coast of Nova Scotia was found to range from 1·0235 to 1·0245. The deep water however, as found from samples taken at depths of 100 and 150 fathoms, both in the vicinity of Gaspé and in Cabot Strait, ranges in density from 1·0254 to 1·0261. Again, on the western side of Cabot Strait, the outflowing water which occupies a width of about 10 miles on the side next Cape North, has a density at the surface of 1·0220 to 1·0227; and in the western portion of the gulf, off the New Brunswick coast, areas were found in which the density was even lower than 1·0220. These densities are in all cases the true specific gravity of the water, reduced to 60° Fahrenheit, and determined by hydrometers specially designed for the purpose.

The density of the deep water, from 100 fathoms downwards, is very interesting in affording an explanation for the otherwise anomalous fact that the colder water at 50 fathoms is found to float upon it. It also corresponds with the density at similar depths, off the coast of Nova Scotia, as reported by the "Challenger" expedition. It would, no doubt, be very interesting to trace the connection of this deep water with the ocean, as the channel in which it lies runs out into the Atlantic basin with uninterrupted depth. But this investigation does not promise any result of immediate practical importance.

On the other hand, the density of the water towards the surface, which is a measure of the degree of saltness of the water, or the amount of fresh water with which it is mixed, is of special value in the regions under consideration. The distinct difference in density as above described, affords an indication which is much more definite than difference of temperature, for the purpose of tracing any general set or current across this portion of the gulf.

The temperature and density of the water may also serve indirectly to throw light upon the distribution of fish; as it has been found on other coasts that their movements depend largely upon these elements. The depth at which the cold layer occurs may have a bearing in this connection, as the fish have usually a preference for cold water. It may also be noted that at the greater depths of 150 to 250 fathoms the bottom as shown by samples brought up by the anchor, is soft mud from brownish-blue to slate colour; and the marine life there, judging by such specimens as came up, consists chiefly of sea-pens and other stalked creatures, which root themselves in the muddy bottom. There does not therefore appear to be at these depths much food of an inviting character for fish. An examination of such conditions might well prove useful, in view of the large annual value of the Canadian fisheries.

As the indications above mentioned were sufficient as a preliminary, a careful examination was made of the Gaspé current itself. This occupied the month of July; and the region selected for the purpose was that lying between the Gaspé coast and the Island of Anticosti. This region is limited by the shore lines extending from Fame Point to Cape Rosier on the Gaspé side, and from West Point to South-west Point on the Anticosti side. These shore lines are parallel to each other at a distance of 40 miles apart; and the currents were therefore likely to be more regular and less disturbed than in either of the more open areas lying immediately to the north-west and south-east. The currents in the Mingan channel north of Anticosti were also examined, and information was thus obtained regarding both passages by which the St. Lawrence River communicates with the gulf.

As had been anticipated, the water flowing south-eastward along the Gaspé coast proved to be distinctly lower in density or fresher than ordinary sea water, especially towards the surface. The movements of the current and its other characteristics were first ascertained; and the endeavour was then made to trace

the water by its lower density across the width of the gulf in the direction of Cape North. The density of the water was taken along a series of sections, and at various depths between the surface and 50 fathoms; or as far down as the depth at which the coldest water had been found. The density of the water at 10 and 20 fathoms was chiefly relied upon for comparison; because if a greater depth were selected, there are considerable areas where interruption would occur from the shallower banks; and on the other hand the disturbing influence of variable winds should be less marked at these depths than at the surface.

These section lines were run between Gaspé, Anticosti and the Orphan Bank, in the vicinity of the Magdalen Islands, and on lines extending north-eastward from Cape Breton. It was necessary to make the determinations of the density at the time, as it was a question of tracing the water, and ascertaining the limits of areas of less density, without any previous clue as to where these limits would probably be found. Also in returning towards Gaspé, additional section lines were run from the west coast of Cape Breton to the Magdalen Islands and Prince Edward Island, to ascertain more definitely from what direction the water comes which flows past Cape North to the south-eastward. Several of the section lines in the vicinity of the Magdalen Islands and Anticosti, were also run a second time to ascertain to what extent the results already found might be liable to disturbance, or whether they might be considered as permanent.

This work was chiefly done in the month of August; and the remainder of the time available was spent in a further examination of the currents in the Gaspé region, for comparison with their characteristics as obtained in July.

The results of the work cannot be satisfactorily given at present, immediately at the close of the working season, until there is time to prepare charts and sections to show the distribution of water of the various densities met with, and the general circulation which may be inferred from it. The relation of the currents to the wind must also be worked out; as the disturbing influence of the wind occasions considerable complication in the movement of the currents.

In the meantime it may be stated in general terms that the density of the water on the south-western side of the gulf was found to be distinctly lower than further out towards the central region. This area of water of less density is approximately limited by a line from South-west Point, Anticosti, to St. Paul Island, C.B., and it is in the direction of this line that any slow movement or set of a general character across the gulf area must take place.

THE GASPÉ CURRENT.

It may also be of advantage to give at once some notes regarding the current along the Gaspé coast, and especially to mention some exceptional directions of the current, as to which, up to the present time, there has been no information available.

On the Admiralty chart entitled "Entrance to the River St. Lawrence," No. 1621, a current is shown to run constantly along the Gaspé coast from a north-westerly direction at about three miles off shore. In the Sailing Directions it is stated that this may be felt as far out as nine to twelve miles from land. Another line of constant current is also shown as lying along a line from the vicinity of Cape Magdalen, to South-west Point, which thus traverses the middle of the passage between the Gaspé coast and Anticosti. It is this central line of current which is alone represented on the general chart of the Gulf of St. Lawrence, No. 2516. It is explained, however, in the Sailing Directions that the current does not follow both these lines at the same time; and the change from the one direction to the other is attributed to the influence of south-west winds.

The first of these lines was found to represent fairly the usual direction of the current along the Gaspé coast. The other line is properly to be regarded as an alternate direction which the current may take; unless indeed there may be times at which the current becomes very wide-spread and weak. When the current is

found in the position shown by the line along the middle of the passage, it may even be accompanied by a reversal of the direction of the current along the Gaspé coast. The method of density sections above described was found a very effective one by which to ascertain the location of the current over a wide area at any given time, when compared with the regular observations of the speed and direction of the current as obtained from the steamer while anchored at different stations.

These changes in the position of the current may prove to be due to its displacement by the wind. There are also fluctuations in its velocity which are probably to be attributed to the influence of the tides. It is to be hoped that some light may be thrown upon these relative effects and the conditions under which they occur when the observations which have been obtained are worked out.

The following notes regarding the Gaspé current and its exceptional directions, may be given at present without explanation, to make known the possibility that such directions of the current may occur. The velocities were measured while the steamer was at anchor at the different stations, by means of current meters at the standard depth of 18 feet. The directions given are magnetic; the magnetic variation being 28° W.

The greatest velocity of the current on the Gaspé coast while it ran parallel to the shore from the usual north-westerly direction, was observed at a station 5 miles off Fame Point on July 5th. The velocity then was 2·81 knots per hour.

The most noteworthy instance of a reversal of this current occurred from July 27th to 31st. There is reason to believe that during these days the current in the offing of Fame Point ran continuously from the south-east, or contrary to its usual direction. From observations at a station 3½ miles off Fame Point, the greatest velocity from this south-easterly direction occurred on July 31st, when it amounted to 1·43 knots per hour.

It is possible, also, for the current to run directly on or off shore for a short time, as the following instances show:—

At a station 13 miles N.E. by E. from Cape Rosier, on July 11th, the current veered from N. to E.N.E. and back to N. It ran from the E.N.E. or directly towards the shore, for two hours, with a velocity of a little over one knot. During the following night it again veered in the same way, and ran from the E.N.E. for two hours, with a velocity of nearly one knot per hour.

At a station 4½ miles E.N.E. from Griffin Cove, on September 17th, the current ran for 4½ hours from directions between E.S.E. and E. by N., all of which set on shore. The velocity in these directions varied between one knot, and one and one-third knots per hour.

At two stations, 4 miles off Fame Point, and 5 miles off Griffin Cove respectively, the current on two occasions, while veering in direction, ran for about an hour directly off shore, with a velocity of over half a knot.

Also on the south coast of Anticosti, on July 22nd, at a station 5½ miles from the shore, and 4 miles east of Ellis Bay, the current ran for 5 hours from directions between W.S.W. and W. by N. or almost directly on shore, with a velocity which averaged over three-quarters of a knot.

At a station 6½ miles off the south shore of Anticosti, and 15 miles west of South-west Point, the current during the night of July 24th ran for three hours from directions between W. and S.W., or directly on shore, with a velocity of a little over half a knot. A few hours later the direction at this station was off shore during two hours, with a somewhat lower velocity.

The co-operation of the leading steamship companies was requested in the work of this season, in noting from the logs of their vessels the currents met with in the gulf, for comparison with the results obtained in the survey itself. Blanks were prepared in which the area of the gulf was divided into regions to accord with the various steamship routes, and on which it was desired that the direction of the current should be noted. These were supplied to the following companies:—

Messrs. H. & A. Allan, of the Allan Line; D. Torrance & Co. of the Dominion Line; D. W. Campbell, of the Beaver Line; Kingman, Brown & Co. of the Black Diamond Line; J. G. Br
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Diamond Line; J. G. Brock, of the Quebec SS. Co.; and also to the Gaspé and Baie des Chaleurs Line. The thanks of this department are due to these companies, and to the captains of their steamships for the trouble they have taken in the matter; and the notes made will undoubtedly prove of value.

The examination of the two entrances to the Gulf of St. Lawrence made last season to ascertain its relation to the Atlantic, and the more extensive investigations of the circulation in the interior of the gulf this year, have not only afforded important information with regard to the currents in the regions examined, but will also serve as a general basis from which to carry on with better advantage, the more thorough study of the nature of the currents in other regions of the gulf.

As the currents so far met with in the gulf area have usually had a strength of only one or two knots per hour, and have seldom attained three knots, they are very liable to disturbance from the wind. They seem also to be more or less influenced by the tides; which in their turn are affected by the barometer. To obtain complete information therefore, regarding these currents under all variety of conditions that can occur, will require much patient investigation. It is therefore, all the more necessary to direct special attention to the regions traversed by the leading steamship routes, in order that the results obtained may be of direct practical value.

I have, sir, the honour to remain,

Your obedient servant,

W. BELL DAWSON,

In charge of Tidal Survey.