SURVEY

OF

TIDES AND CURRENTS

IN

CANADIAN WATERS

REPORT OF PROGRESS

BY

W. BELL DAWSON, C.E.
Engineer in charge of Tidal Survey.

OTTAWA
GOVERNMENT PRINTING BUREAU
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ANNUAL REPORT

OF THE

Engineer in charge of the Survey of Tides and Currents in Canadian Waters

FOR THE YEAR 1899.

OTTAWA, December 20, 1899.

W. 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 this Survey. All the tide tables have been prepared and issued as usual, with the improvements referred to in my last report; and considerable progress has been made in working out practical results from the tidal observations which have been secured. In this work, I have had the assistance of Mr. R. Angus and Mr. S. C. Hayden; who also attended to the office work while I was away; as leave of absence for three months was granted to me on account of my health. Because of this also, it was not possible to undertake much in the way of new work this season. The principal tidal stations have continued in operation under the charge of the observers; and nearly all of them have been visited this season by myself or Captain Douglas. One secondary tidal station has also been established this season at the outer end of Belle Isle Strait.

The last report, containing information as to the tides of the Bay of Fundy with observations on the tidal bore in the Petitcodiac River, has met with much appreciation. As the survey becomes more widely known, the requests for information and the correspondence resulting, continue to increase. Many examples could be given of the accessory ways in which this survey often proves of value, in addition to its direct service to the shipping interest. The tide-levels especially, which require to be carefully worked out for the reduction of the tidal observations themselves, have been of important service in connection with harbour works, in several instances during the past year.

The total expenditure on this Survey during the fiscal year from June, 1898 to June, 1899, was $5,186.35. This includes, in addition to the ordinary fixed charges, the sum of $973.22 for the tidal observations in the Bay of Fundy in the summer of 1898; and $834.15 for repairs to the crib-work of the gauges at Forteau Bay and St. Paul Island.

THE PRINCIPAL TIDAL STATIONS.

These stations have been in continuous operation throughout the past year, with the exception of Yarmouth; although some interruptions of a minor character occurred also at other stations.

The gauge at Yarmouth, N.S., was fitted up originally in 1898, as a summer station; without any provision for heating in winter, which requires a much more elaborate construction. As it is milder there in winter than at any of the other principal stations, the gauge was continued in operation to obtain as much tidal record as possible. At Yarmouth the mean temperature for January and February is 26½° Fahr., which is 3½° higher than at Halifax. The tide-column is of wood which is non-conducting; and some thick oil on the surface of the water in the tide-column, protects the water from the cold air; and thus, as it rises and falls with the tide, the oil keeps the ice from adhering to the inside of the column as much as it otherwise would. Notwithstanding such precautions, more than a month of record was lost during the first winter, in 1899 on account of frost; namely, from February 2 to March 10.

At Father Point the outer end of the inlet pipe was again carried away by ice on December 16, 1898; and when this occurs, the lowest of the low waters are not recorded on the gauge. This pipe could not be replaced until the early spring; and some of the low waters were accordingly lost during the winter. In relaying it, it was made more secure than before; so that the ice grounding upon it, might not shift it. There was also an interruption of six days at the end of January; for repair to the gauge clock. The balance-wheel escapement had to be removed and sent to Quebec for this repair.

At St. Paul Island, some trouble again occurred because of the partial chokage of the inlet to the gauge, by the accumulation of gravel in the autumn storms. This accumulation is due to the shallow water in the bay where the tide gauge is situated, and the severe exposure on the eastern side of the island. On the western side the water is deep, close to the rocks; but if the gauge were placed there, it would be necessary to have a special observer, and to build a house for him and provision it; as there is no habitation on that side of the island. It is more economical therefore, to persevere under the existing difficulties.

There was also an interruption here of three days in August, owing to the difficulties of communication. Supplies shipped on April 20 were not delivered on the island till August 10. Meanwhile, on July 13, the observer cabled for additional tide sheets for the recording instrument; but with the best arrangements that could be made, the last tide sheets on hand were used before new ones were received.

At South-west Point, Anticosti, the crib-work and tide-well of the gauge were damaged in a severe storm in December, 1897. The observer succeeded in getting it to work again in February. As the expense of repairs could not be afforded in the ensuing season of 1898, it was decided to let the gauge go on as it was, as long as it would work. It so continued until January, 1899; when the sand and gravel accumulating within the damaged crib-work, caused partial chokage of the inlet to the tide-pipes; and the record became in consequence unreliable.

After careful consideration, it was decided to discontinue the tide gauge at this station; the reasons being as follows:—It was found from the extensive series of tidal observations of 1896, that no large area in the Gulf of St. Lawrence can be referred with advantage to South-west Point as a port of reference. It must therefore be considered chiefly as a station commanding the entrance to the Lower St. Lawrence; and its record chiefly for use as a basis for tidal differences and ratios. The record already obtained, comprising more than three complete years, is sufficient for these purposes; for which it is extremely valuable in being simultaneous with the observations at Father Point and Quebec. The tidal relations between these three stations, are examined and discussed further on in this report.

When the observations were discontinued at this station, an exchange of time with Quebec Observatory was made by cable, in order to check the dipleidoscope on which the accuracy of the time used throughout the period of the observations, has depended. It was found correct.

The station was not completely dismantled; but was left in condition to fit up as a summer station at any time, for reference when the tidal currents on the Lower St. Lawrence come to be more fully investigated.

The causes of interruption above cited will serve as examples of the nature of the difficulties to be met, against which foresight is required. The difficulty of obtaining a uniform datum level for the height of the tide, when open tide-scales cannot be used in winter, and the special appliances and office methods which have been devised for this purpose, need not be detailed here.

INSPECTION OF TIDAL STATIONS.

The tide gauges at Quebec and Father Point were inspected by myself in August, on the expiry of my leave of absence. At Father Point, an extensive series of levels was taken instrumentally, to compare the actual rise and fall of the tide on the beach with the record on the gauge; as this gauge works by siphoning through an inlet pipe

nearly 400 feet long. The results need not here be detailed. They will afford a table of correction to be applied to the readings of the height of the tide, to allow for the siphoning action; which is essential in the reduction of the observations.

The gauges at St John and Halifax were also visited in October; and careful instrumental levels were taken to check the elevation of the datum used. This is the more needful as both gauges are supported by timberwork; and check levels had not been taken for two years. At St. John the wharf against which the gauge is placed, floats up three inches at the higher tides. The column of the gauge itself, stands free of the wharf however, and rests directly on the bottom. It had not altered quarter of an inch in level since 1896. At Halifax the column of the gauge it set in a pile wharf; and it was found that no vertical movement had occurred of as much as quarter of an inch in two years, although the gauge sways with the piling when vessels moor to the wharf. The determination of these levels for datum is essential to the reduction of the observations.

The gauges at Forteau Bay and St. Paul Island were visited by Captain Douglas in the course of the season. Some important improvements were made; the levels were taken, and the dipleidoscopes, on which time for the observations depends, were adjusted by astronomical observations. The data for time and height are the two necessities at the tidal stations.

At the outer end of Belle Isle Strait a summer tidal station was established in July. The site chosen was in Henley Harbour, at the mouth of Chateau Bay. The record began on July 24, and is to continue as late as possible in the autumn. The reasons for the establishment of this station need not be discussed at length, although the best location for the purposes in view was carefully considered. By recording the tide of the open Atlantic at the outer end of the strait, it will afford a valuable comparison with Forteau Bay at the inner end, and possibly also with other Atlantic tidal stations.

OTHER TIDAL OBSERVATIONS RECEIVED.

We have to acknowledge during the year the receipt of the following information:—

Shubenacadie River.—Observations of the speed and the time of turning of the tidal current in the Shubenacadie River, Nova Scotia, were received from Mr. J. F. Armstrong, Assistant Engineer on the Midland Railway, now under construction.

Moncton.—The level reached by an exceptional tide at Moncton was noted by Mr. E. P. Cook, the Harbour master. It occurred on August 21, 1899, and reached a level only 4½ inches below the exceptional tide of October 12, 1887, which is the highest tide there recorded, next to the Saxby tide of October, 1869. These levels are important with reference to the dyked lands around the head of the Bay of Fundy. Mr. Cook kindly sent also several observations of the time of arrival of the tidal bore.

Chicoutimi.—Tidal observations at Chicoutimi for a period of two months in 1897 have been received from Mr. F. W. Cowie, C.E., of the Public Works Department. These were obtained by means of a self-registering gauge loaned by this Survey. As Chicoutimi is at the head of tide-water on the Saguenay River, this record will be valuable in furnishing a basis for the Saguenay tides, which will be of advantage for the growing trade of that river. Chicoutimi is 75 miles inland from Tadousac, at the mouth of the Saguenay.

Annapolis.—The level of the highest known tide at Annapolis, Nova Scotia, was determined and referred to a permanent bench-mark by Mr. J. S. Hodgson, C.E., of Wellington, Massachusetts, while engaged in a survey for the sewerage of that town. This information he kindly took the trouble to communicate. Unfortunately it does not at present afford a comparison with the tidal observations obtained at Digby, at the other end of Annapolis Basin, as continuous levels are wanting; but meanwhile it is locally important.

Seymour Narrows, B.C.—The original observations obtained here in 1897 by the United States Coast Survey have been kindly communicated to this department. These observations show the time of the turn of the current for a period extending from April to October in that year. Similar observations were also taken in Sergius

Narrows, Alaska. The turn of the current has thus been brought into relation with the tide, and the results are now published in the Tide Tables issued by the United States Coast Survey.

TIDE TABLES FOR 1899; PUBLICATION, ETC.

Quebec, Halifax, and St. John, N.B.—The tide tables for these principal harbours were again furnished to the leading British and Canadian Almanacs, as far as they were willing to publish them. These tables give the time and height of the tide, the depth of water on dock sills, &c.; and they are accompanied as before by tidal differences by which the time of the tide at a large number of other ports, becomes known. The manner of publication was the same as described in last report; and it will therefore be sufficient to give a list of the almanacs in which they appear, in whole or in part:—

Canadian Almanac.—All the above, in full.—The Copp, Clark Co., Toronto.
Greenwood's Almanac.— " " —Capt. W. N. Greenwood, Lancaster, Eng.
Brown's Almanac.—Halifax tide tables.—Messrs. J. Brown & Son, Glasgow.
Belcher's Almanac.—Halifax tide tables.—The McAlpine Co., Halifax.
Cogswell's Almanac.—Halifax; time only.—Mr. R. H. Cogswell, Halifax.
McMillan's Almanac.—St. John; time only.—Messrs. J. & A. McMillan, St. John.
Moore's Tide Tables.—Quebec; time only.—Messrs. T. J. Moore & Co., Quebec.
The Quebec *Chronicle*.—Quebec tide tables in full; one month at a time.
The St. John *Telegraph*.—St. John tide tables in full; one month at a time.

It was arranged to have these tide tables reprinted from *Greenwood's Almanac*, as a neat pamphlet; and 450 copies of this, were widely distributed. This is a step in advance of last year's publication. It served to make these tide tables more widely known, and it also enabled all applications for copies of the tables to be met.

The other tide tables issued were as follows:—

Charlottetown, Pictou, and St. Paul Island.—Accompanied by tidal differences for Northumberland Strait, and the south-western side of the Gulf of St. Lawrence. These tide tables were computed by the Tidal Survey and printed by the Department; and 350 copies were distributed as widely as possible.

Father Point.—Prepared in manuscript only; and posted at the Lighthouse at Father Point. As this is the Pilot Station for the Lower St. Lawrence, they are there accessible to the pilots.

Ste. Croix Bar.—Tide tables were again computed for this locality, as it is still the shallowest point in the tidal portion of the St. Lawrence above Quebec, pending the completion of the dredging operations. These tables were published in company with the tide tables for Quebec, by the Montreal Harbour Commissioners; in the publication they prepare annually for the information of the St. Lawrence pilots.

TIDE TABLES FOR 1900 AND 1901.

As the principal tide tables for Quebec, Halifax, St. John, N.B., and St. Paul Island, for the year 1900, are still based upon the same length of tidal record as before, there is no further improvement in their accuracy. It is also improbable that there will be any in the tide tables for 1901, which are already in hand for calculation.

It may be well here to review the amount of tidal record secured up to date; and also to consider the question of the degree of accuracy of the tide tables as they stand at present.

TIDAL RECORD OBTAINED TO DATE.

The tidal record obtained at the principal stations, up to the end of 1898, is given in a summary form in Table D. appended. The reasons of the more important interruptions are also indicated. The table further shows how far the record has yet been

worked up, as a basis for tide tables, and for the purposes of tidal comparison. The dotted lines in the table indicate that the work to which they refer, has not yet been done.

A considerable amount of tidal record, as indicated, has now been reduced and tabulated, and thus made ready for harmonic analysis. This analysis is only partially made as yet, for want of means to meet the necessary cost. It is only when this is done, that further improvement in the accuracy of the tide tables themselves will be secured. The additional record thus prepared, comprises two years at Quebec; two years at St. John, N.B.; and one year at St. Paul Island.

Besides the stations indicated on the Atlantic coast, two good series of tidal observations are being secured on the Pacific coast, from the tidal stations established by the Department of Public Works. These are at Victoria, B.C.; and at Sand Heads at the mouth of the Fraser River in the Gulf of Georgia. One full year of tidal record from each of these stations has now been tabulated, ready for harmonic analysis. Tide tables might thus be prepared at once for these Pacific ports, if means were available to meet the cost of the calculations required.

The shorter tidal records obtained in the summer seasons, are not shown in the table. These now comprise nine secondary stations in the Gulf of St. Lawrence, eight secondary stations in the Bay of Fundy, and one at the outer end of Belle Isle Strait. The tidal record obtained at these, has already been detailed in the annual reports of progress, referring to the work of the seasons during which they were in operation.

Besides the use of this record as a basis for tide tables, the tides at the principal stations have been largely used also for comparison with those at the secondary stations, in working out tidal differences, by which the time of the tide at a number of other ports becomes known.

In addition to the tidal record itself, full meteorological data are being secured for comparison, throughout the period of these observations. A continuous barograph record has been obtained from the three tidal stations which command the Atlantic seaboard; namely, Forteau Bay in Belle Isle Strait; St. Paul Island; and St. John, N. B. The daily weather charts issued by the Meteorological Service since 1896, are also received regularly and fyled. This service has also supplied since 1893, when the tidal observations themselves were commenced, a daily abstract of wind and barometer from ten meteorological stations throughout the area in question; namely, from Quebec, Father Point, South-west Point of Anticosti, Belle Isle, Chatham in Miramichi Bay, Magdalen Islands, Sydney in Cape Breton, Halifax, St. John, N.B., and Yarmouth, N.S. Also since 1893, a complete set has been kept of the monthly Pilot Charts of the North Atlantic, issued by the U.S. Hydrographic Office. These charts show the tracks of all the important storms, and are very convenient for reference. The monthly weather charts for Canada have also been kept on fyle since their first issue in 1896.

TIDE TABLES.—IMPROVEMENT IN ACCURACY ALREADY SECURED.

The following condensed summaries show the improvement in the accuracy of tide tables for our principal harbours, as already obtained by this Survey, when compared with other sources of information. This by no means represents all the progress made, however. Such tide tables as were available in the past, gave only the time of high water and low water; but in the tidal predictions now issued by this Survey as annual tide tables for Halifax, Quebec, and St. John, N.B., the height of the tide is given as well as the time. This is important, as at two of these harbours the range of the tide is about thirty feet.

For our present purpose, in testing the accuracy of the tide tables as now calculated, a sufficient basis is afforded by a comparison between the time of high water as predicted in the tables, and the time as actually observed.

HALIFAX.—The earliest tide tables issued by the Tidal Survey were for this port. They were based upon constants derived from the harmonic analysis of two years of old record, obtained in 1860 and 1861. These tide tables were issued as a booklet as early as 1891, before the plan was taken of supplying the information direct to the

almanacs, adopted on account of the very limited circulation which this booklet secured. It was not until the year 1897 however, that the local almanacs adopted the tables of this Survey, and republished them.

Up to 1896 therefore, the tide tables in common use for Halifax, were those published by *Belcher's Almanac;* based upon a contant difference of time with Brest, France. When the recording gauge had been established at Halifax, a comparison was made between the time of the tide as shown in these tables and the actual tide as recorded on the gauge, during the month of January, 1896. The result was as follows, for the time of high water:—

Extreme variation between the time of H. W. as given in these tide tables, and the actual time as observed: 0 h. 46 m. early to 0 h. 31 m. late.

Average error during this month, 20 minutes.

Tide Tables of U. S. Coast Survey.—The tide tables for Halifax since 1896, given in this publication, have been calculated from tidal constants furnished by this Survey, which were derived from the two years of the old record, first submitted to analysis.

Tidal Survey tables.— The tide tables for Halifax issued by this Survey, are now based upon the harmonic analysis of five years of tidal record; comprising four years of old record, and one year from the present tide gauge. To test the accuracy of these tables, a comparison was made between the time of the tide as there given, and the observed tides as recorded on the gauge. This comparison was made for a period of one month in the summer season; from July 18 to August 18 in 1898; it is given in Table A. herewith. The condensed result is as follows:—

Extreme variation between the predicted time of H. W. in the tide tables, and the actual time as observed: 14 m. early to 14 m. late.

Average variation during this month, 6 minutes.

Although the Halifax tables show the least irregularity of any of our ports when computed from the tides on the other side of the Atlantic, the improvement already obtained by basing them upon observations taken in the port itself, is marked. The average error in the time of the tide has thus been reduced to less than one-third, as compared with the old method of computation; or in other words, 70 per cent of improvement in the accuracy of the tide tables has been secured.

The harmonic constants for Halifax as they now stand, were published in the last report; from which it will be seen that the monthly and fortnightly components among the long-period tides, are not yet satisfactorily determined. An improvement in this respect will be secured, as further tidal record is obtained and submitted to analysis, in the future.

St. John, N.B.—The only tide tables formerly available were those given in *McMillan's Almanac,* published at St. John, and computed by means of a constant difference in time from Brest, France. These tables gave only the time of high water, without any reference to the height of the tide; although the range at St. John is greater than at any other harbour of the same importance in North America.

The tide curves at St. John were found to be so uniformly regular, that several series of comparisons were made in the early days of this Survey, in the hope of obtaining some constant difference in time, which would serve to compute reliable tide tables. Brest had already been used in the computations; and as it is one of the best established tidal harbours in the world, its tide tables are unusually accurate. A comparison was therefore made between these tables and the observed tides at St. John, which extended over a continuous period of eleven months in 1893. The difference in the time of high water, which had been assumed to be a constant one, was found by this comparison to vary through a range of more than an hour and a half. The use of a constant difference would thus leave a margin of error which is too wide to be desirable. It is not therefore necessary to give the comparison in a tabular form.

A comparison was next made between the observed tides at St. John, and the tide tables for Eastport; the nearest port in the United States for which tide tables are published. This comparison extended over eight months in 1893; and after omitting a few exceptional values, the difference in time of high water was found to range from 29 minutes earlier to 37 minutes later; which is also too wide a variation to be considered

satisfactory as a basis of computation. It is also unnecessary to give this comparison in a tabular form.

It was accordingly thought better to wait until the tidal record at St. John itself could be submitted to analysis; rather than to issue tables which would embody errors corresponding with these variations. Hence although the early record began in 1893, the first tide tables issued for St. John were for the year 1898. The advantage of this course is now apparent; as the tide tables now issued by this Survey, prove to be much more correct than could be obtained by either of the above methods; although they are as yet based upon two years only of tidal record. This also attests the value of St. John as a port of reference, owing to the unusual regularity of its tides.

Tide Tables of U.S. Coast Survey.—Up to 1896, the method given in these tables was to compute the St John tide from Eastport, by a small constant difference in time. The difference first given was 2 minutes, which was afterwards altered by 5 minutes. Subsequently, since 1897, the tide at St. John has been referred to Liverpool, England; the difference in time for high water being 22 minutes to be added.

To test the result of the present method of referring these tides to Liverpool, a comparison was made for the month of September, 1897. The time of high water computed by the difference given, was compared with the time of the tide at St. John as observed, the result being as follows:—

Extreme variation between the time of H. W. as found by this method, and the actual time as observed, 1 h. 02 m. early to 0 h. 16 m. late.

Average error during this month, 17 minutes.

It would thus appear that little if any improvement is secured by this method, over the old plan of computing by a constant difference from Brest. Also, to ascertain whether this reference to Liverpool gave any advantage over the former method in the United States tide tables, of referring the St. John tide to Eastport, a further comparison was made for this month of September, 1897. The time of high water at St. John, computed from Eastport by the difference formerly given, as above, was compared with the tide as there observed. The average error during this month was thus found to be only 9 minutes; from which it would at least appear that no advantage has been secured by referring the St. John tide to the more distant port of Liverpool, instead of to Eastport. The reason for the preference appears to be that the Liverpool tide tables are based upon a record extending over seven years, whereas the tides for Eastport are calculated from a tidal record of a single year.

In order to show for comparison the actual variation which may be expected between two neighbouring places, such as St. John and Eastport, distant 60 miles, the result of the simultaneous observations of 1898 may be cited. These extend over two and a half months, from the middle of August to the end of October. After omitting three days in October on which there was disturbance from a heavy storm, the tides as observed simultaneously at St. John, and at Welchpool on Campobello Island opposite Eastport, are found actually to vary as follows:—

Extreme variation of the difference in the time of high water as observed at the two places: from 10 minutes early to 10 minutes late, as compared with the average difference in time as found from the whole series of observations.

Mean variation from the average difference, $3\frac{1}{2}$ minutes; during one lunar month from August 17 to September 16. This is given for one month only, to correspond with all the other comparisons, which are also for one month.

Tidal Survey tables.—These are based upon the harmonic analysis of two years of the tidal record at St. John itself. To test their accuracy, the time of high water in the tables was compared with the tide as observed during one month, from July 18 to August 18, 1898. This comparison is given as Table B. herewith; the result when summarized being as follows:—

Extreme variation between the predicted time of H. W. in the tide tables, and the actual time as observed: 16 m. early to 5 m. late.

Average variation during this month, 6 minutes.

This shows an improvement in accuracy of 65 per cent as compared with the method at present given in the United States tide tables; as well as a distinct improvement over the method of computing from Eastport.

QUEBEC.—The Montreal Harbour Commissioners have issued tide tables for Quebec for a number of years back; and in the absence of better data, these were computed by adding a constant difference of 4 h. 36 m. to the time of the tide as given in the tide tables for London Bridge. A comparison of these tables with the observed tides at Quebec, during the month of August, 1894, shows the following error in the time of high water:—

Extreme variation between the time of H. W. as given in these tables, and the actual time as observed: 1 h. 06 m. early to 0 h. 28 m. late.

Average error in the tables during the month, 17 minutes.

Tide Tables of U. S. Coast Survey.—In the comprehensive tide tables issued by the United States Survey since 1896, the method of obtaining the time of high water at Quebec is to subtract the constant difference 10 h. 05 m. from the time of the tide at Rangoon, Burma. A comparison of the time of high water as computed in this way, with the observed tide at Quebec, for the month of June, 1897, gives the following result:—

Extreme variation between the time of H. W. as found by this method, and the actual time as observed: 14 m. early to 54 m. late.

Average error during this month, 22 minutes.

It would appear from this average error, that no improvement is secured by this method, as compared with the old plan of adding a constant difference to the time of high water at London Bridge.

Tidal Survey tables.—These are based upon two years of tidal record at Quebec. The time of high water in the tables was compared with the tide as observed during one month, from July 18 to August 18, 1898; the comparison being given as Table C. herewith. The result when summarized is as follows:—

Extreme variation between the predicted time of H. W. in the tide tables, and the actual time as observed: 26 m. early to 3 m. late.

Average error during this month, 12½ minutes.

This indicates the improvement already secured by basing tide tables upon observations at Quebec itself, as compared with the old method of computing from London Bridge, which was in use up to 1896, when tide tables for Quebec were first issued by the Tidal Survey, and were adopted by the Montreal Harbour Commissioners. This improvement is equivalent to a decrease in error of 26 per cent. The improvement in accuracy is even greater than this, when compared with the method in the United States tide tables, which is still given in the tables for 1900. Although the comparisons are made for different months, they nevertheless show that the Tidal Survey tables are distinctly superior in accuracy to tide tables computed in either of the other ways indicated.

It may seem unsatisfactory that tide tables based upon two years of direct observation still present so appreciable an error as the above average shows; an error twice as great as at St. John or Halifax. This must be attributed to the irregularities in a tide at the head of a long estuary, which are probably due in some measure to wind disturbance. In such circumstances, more than two years of tidal record are required to eliminate the irregularities. Several additional years of tidal record have been obtained at Quebec, since the original analysis was made which forms the basis of the tide tables at present; but the comparatively small sum required for the analysis of further record, could not be afforded out of the appropriation for this Survey, during the last few years, for the improvement of the basis of the tide tables.

CHARLOTTETOWN AND PICTOU.—The region of Northumberland Strait in which these ports are situated, is now referred to the principal tidal station at St Paul Island, as explained fully in a previous report. The method used is first to deduce the time of the tide at Pictou from St. Paul Island, by means of a series of variable differences; and the tides at other harbours in the strait are then computed from Pictou. We may thus take Pictou itself as the test port for this region, in examining the accuracy of tide tables.

In the only other publications and almanacs in which tide tables for this region appear, the method employed is to refer the tides at Pictou to some Atlantic harbour,

by means of a constant difference in time. This leads to serious error, chiefly because of the large diurnal inequality in the tides in this strait.

In *Belcher's Almanac*, which is extensively used throughout the provinces bordering on this strait, a tide table for Pictou is given. A comparison was made for the month of July, 1896, between the time of high water in this table, and the tide at Pictou as recorded on a self-registering gauge. The result shows the following wide range of error in this tide table :—

Extreme variation between the time of H. W. as given, and the actual time as observed : 1 h. 13 m. early to 1 h. 35 m. late.

Average error in the tables during this month, 45 minutes.

Tide Tables of U.S. Coast Survey.—In these tables, the tide at Pictou is referred to Sandy Hook at the entrance to New York harbour. The difference for the time of high water at Pictou, as revised in 1896, is given as 2 h. 34 m. to be added to the time at Sandy Hook. A comparison was made for a period of one month, July 16 to August 16, 1897, between the time of high water at Pictou computed in this way, and the time as there observed, with the following result :—

Extreme variation between the time of H. W. as found by this method, and the actual time as observed : 1 h. 45 m. early to 1 h. 11 m. late.

Average error during this month, 38 minutes.

In both these instances, it is the method used that is at fault ; because it is not possible to refer the tides of Northumberland strait to an Atlantic port by a *constant* difference in time, without a large error resulting ; on account of the essential difference in the nature or type of the tide. This is clear from the following table, which gives the error in the time of individual tides, when computed by the method given in the United States tables. The alternation from early to late, is a feature of diurnal inequality, which is most conspicuous when the moon's declination is high.

Tides at Pictou, N.S. (Northumberland Strait.)	Error in the time of High Water.		Moon's declination.
	Early.	Late.	
	h. m.	h. m.	
1897. Sun., July 25 ; afternoon	1 34		Maximum north ; on 25th.
Mon. " 26 ; morning		1 11	
" " 26 ; afternoon	1 42		
Tues. " 27 ; morning		0 40	
" " 27 ; afternoon	1 22		
Wed. " 28 ; morning		0 43	
" " 28 ; afternoon	1 23		
Thurs. " 29 ; morning		0 14	
" " 29 ; afternoon	1 21		

Tidal Survey tables.—After observations of the tide were obtained in this region in the summer of 1896, a number of trial calculations were made, to arrive at the best method by which the above source of error could be avoided. The method above indicated was finally adopted. The improvement thus obtained appears from a comparison made for the month of August, 1897 ; in which the time of high water as now calculated for the Tidal Survey tables, is compared with the tide as observed at Pictou. In the following summary of the result, three tides which are disturbed by the wind are omitted.

Extreme variation between the predicted time of H. W. in the tide tables, and the actual time as observed : 35 m. early to 30 m. late.

Average variation during this month, 15 minutes.

This shows an improvement in accuracy of 61 per cent as compared with the United States tide tables, and an improvement of 67 per cent as compared with *Belcher's*

Almanac. The tide tables thus become of practical value; as is attested by Mr. H M. Mackay, a resident of Pictou, and formerly an assistant in this Survey, who superintended the tidal observations in this region in 1896. He thus writes in September last:—'You will be pleased to know that the tide tables for Pictou are regarded as very reliable. Those formerly in use, were, as might be expected, quite unsatisfactory.' It is also reported by residents of Charlottetown, that the same holds with regard to the tide tables for that port; these being computed from the Pictou tides.

Further improvement in the accuracy of these tables can only be obtained by the analysis of additional tidal record from St. Paul Island, on which they ultimately depend. This is the more needful, because the tides there have not a large range, and are consequently the more affected by wind disturbance; and a longer period of observation is therefore required as a basis of calculation. It has also been found best to refer to that station the tides in a large section of the south-western portion of the Gulf of St. Lawrence; and these tides would thus obtain the advantage of any improvement secured, as well as Northumberland Strait.

TIDES ON THE LOWER ST. LAWRENCE REFERRED TO QUEBEC.

The desirability of obtaining the best tidal data possible in this region need not be enlarged upon, not only because of the importance of the tides themselves to navigation, but also to obtain an adequate basis for the examination of the strong tidal currents on a route traversed by so large a volume of commerce.

On account of the discontinuance of the tidal station at South-west Point, Anticosti, a very thorough examination was made of the difference in the time of the tide based upon the simultaneous records obtained from the three principal stations at South-west Point, Father Point and Quebec, at the extreme ends and the middle of the estuary, a distance of 450 miles.

The time of the tide at South-west Point and Father Point can now be deduced from the Quebec tide tables by means of constant differences, which have been derived from a long series of simultaneous observations, as explained in previous reports. The tide tables for Father Point are computed from the Quebec tables in this way, one difference being used for high water and another for low water. With regard to the accuracy of the result as thus obtained, the point of importance is to know how far the differences in time for individual tides will vary from the average value, which is used as a constant difference. The range in the difference for high water between Father Point and Quebec is 56 minutes during the course of the year, and the range in the difference for low water is 1 hour 19 minutes. The extreme variation from the average value may be taken as half of this range in each case; and the limit of error in the present tide tables for Father Point, based upon the averages, is thus 28 minutes for high water and 40 minutes for low water. It is to be understood, however, that this is the limit; as usually the tides will be much nearer than this to their average value, especially in the summer season; and it is only occasionally that these more exceptional values will occur.

With a view to allow in the calculations for this variation in the difference, and thus to reduce the error, much labour has been expended, the object being to arrive at such relations between these three St. Lawrence stations as would enable the variation in the difference to be reduced to law. The investigations made need not be given here even in outline, as they may be considered technical. It may therefore be sufficient to say that no one law could be discovered under which a series of variable differences could be constructed, to allow for the greater part of the error resulting from this variation.

The outcome of the investigation was to show that improvement in the present method of the use of constant differences will only be secured when the means are available to make an analysis of the Father Point record itself, and to base tide tables directly upon this. It will probably be found that an improvement will then be obtained by making Father Point, instead of Quebec, the port of reference for other points in the open estuary for some distance above it. Also in the other direction, an improvement in accuracy as far as Anticosti Island and its vicinity will be obtained.

The differences show that the outstanding error in the time of the tide at South-west Point would thus be reduced by 20 per cent.

The analysis of the tidal record for Father Point itself, would be in accord with the modern view taken by the most eminent authorities on tidal questions. When the means available for this Survey are so limited, however, that the analysis of tidal record for the principal harbours of the country has to be deferred from year to year, the hope of doing similar work for Father Point would seem a long way off. It is because of this that the exhaustive examination into the tidal relations on the Lower St. Lawrence, above referred to, was undertaken, in the hope of securing improvement in the meantime.

BAY OF FUNDY.—TIDAL DIFFERENCES.

In the summer of 1898, eight secondary stations were established around the Bay of Fundy, in order to extend the usefulness of the tables for St. John, N.B., to the whole of this region. The extent of the region is 210 miles, from Yarmouth to Moncton.

The reasons for the selection of the stations chosen, have been explained in the last report; as well as the levels of the tide as ascertained by the observations. The station at Welchpool on Campobello Island, opposite Eastport, Maine, affords a valuable connection between the work of this Survey, and the United States Coast Survey. At the four stations in the lower part of the bay, Yarmouth, Westport in Grand Passage, Digby, and Campobello, the whole range of the tide was obtained; from which results for both high and low water can be deduced. At the other four stations in the upper part of the bay, Windsor, Parrsboro', Hopewell Cape, and Moncton, only the upper part of the tide was obtained; as a record of the whole tide could not be secured where the range is so great, without very largely increasing the expenditure.

In deriving tidal differences from these observations, it was first necessary to ascertain whether any part of the region at the mouth of the Bay of Fundy, could better be referred to Halifax than to St. John as its port of reference. With this object, a trial comparison was made for a period of one month, between the time of high water at Yarmouth, at the mouth of the bay, and Halifax on the one hand and St. John on the other. The month selected was July 18 to August 18, 1898; and the condensed result of the comparison is as follows, when reduced to the same standard time:—

Yarmouth and Halifax. Difference in time of high water varies from 2 h. 26 m. to 3 h. 0 m. later; showing a range of 34 minutes.

Yarmouth and St. John. Difference in time of high water varies from 1 h. 01 m. to 1 h. 14 m. earlier; showing a range of only 13 minutes.

It thus appears that if the tide at Yarmouth is referred to St. John rather than to Halifax, much greater accuracy can be secured; as the error corresponding to the above variation, is only one-third as much.

The tide on the south-eastern coast of Nova Scotia as far as Cape Sable, can well be referred to Halifax; but from that cape to Yarmouth it changes rapidly in character, though the distance is only fifty miles. The greater variation in the difference of time with Halifax, in the above comparison, is due to modification in the diurnal inequality in the tide, as between Halifax and Yarmouth. It may therefore be concluded from this comparison, that the tides throughout the Bay of Fundy above Yarmouth, can best be referred to St. John.

In the earlier part of the record at some of the secondary stations of 1898, there is a little uncertainty in the accuracy of the time used. The resulting tidal differences are therefore based upon the parts of the record which are thoroughly trustworthy, as follows:—

Yarmouth, N.S.—From July 15 to December 31; affording a series of 319 simultaneous observations for the difference in time of high water with St. John; and 314 for low water.

Westport, in Grand Passage.—From August 8 to December 29, with an interruption of twenty days from November 24; affording 195 differences for H. W. and 212 for L. W.

Digby.—From August 3 to December 18; affording 238 differences for H. W. and 244 for L. W.

Campobello Island. (At Welchpool.)—From August 11 to November 14; affording 76 differences for H. W. and 162 for L. W.

Windsor, N.S.—From August 18 to October 12; affording 88 differences for the time of H. W.

Parrsboro'.—From July 24 to October 13; affording 148 differences for the time of H. W.

Hopewell Cape.—From July 30 to November 15; affording 203 differences for the time of H. W.

Moncton.—From August 11 to November 18; affording 180 differences for the time of H. W.

The Bore.—A number of observations of the time of arrival of the tidal bore at Moncton, were also secured, by the method of siphoning into a tide-well from the low-water channel of the river, as described in the last report. The arrival of the bore was thus recorded automatically on the tide gauge. The time as thus recorded was carefully compared and checked, by means of such direct observations as were obtained during the season; and any that were affected by irregularity in the working of the siphon, were thrown out. A set of 145 reliable observations was thus obtained; extending from August 24 to November 14.

It was discovered that the relation with the tide at St. John is more nearly constant, if the difference in time is taken between the arrival of the bore at Moncton and the *next following* high water at St. John. This is the more natural way, as the arrival of the bore corresponds in time with half tide at Moncton; and the following high water at St. John is caused by the summit of the same tidal undulation.

The differences given below are in standard time, and thus show the true differences in absolute time. They are derived from a tabulation of the observations in accordance with the moon's phases.

Time of arrival of the bore at Moncton, before the time of high water at St. John; from 145 observations:—

At Spring tides, 2 h. 09 m.

At Neap tides, 2 h. 33 m.

Average throughout the month, 2 h. 21 m.

It may be interesting to note that from twenty-three occasions during the season, on which the arrival of the bore was directly timed, the average value found was the same as above; namely, 2 h. 21 m. before high water at St. John.

This determination enables the time of the arrival of the bore to be found from the St. John tide tables. The difference between the values for spring and neap tides respectively, serves also to show the relation between the vulgar and the mean Establishment. This is a valuable indication with regard to the nature of the tide throughout the Bay of Fundy; being derived from observation at the extreme head of the bay.

Tidal differences.—The results obtained for the ports at which the tidal stations were placed, have been published as a slip accompanying the tide tables for 1900, already issued. In addition to the tidal differences which enable the time of the tide to be found, the available draught of water at spring and neap tides is given, for points in the upper part of the bay.

A more complete set of tidal differences for the whole Bay of Fundy will be prepared before the next tide tables are printed; based upon a comparison with the Establishments as already determined by the Admiralty for intermediate points. The observations now obtained, afford a valuable check upon these; and place the time of the tide throughout this bay upon a reliable basis.

The importance to navigation of a correct knowledge of the tide in this bay is evident, when the range of the tide is so great. In the upper part of the bay, navigation may be said to be entirely dependent on the tide, as the wharves do not extend beyond the half-tide mark, and vessels can therefore only reach their berths at high water.

I have the honour to be,

Your obedient servant,

W. BELL DAWSON,

In Charge of Tidal Survey.

TABLE A.

HALIFAX.—*Comparison of Tide Tables with Tides as observed.*

Tide Tables based upon five years of tidal record; 1851, 1852, 1860, 1861 and 1896; compared with tides as recorded by tide gauge.

Date. 1898.	Day of week.	High Water.		Low Water.		Moon.
		Time in Tables.	Variation from actual time.	Time in Tables.	Variation from actual time.	
		H. M.	Minutes.	H. M.	Minutes.	
July 18	M.	8 00	2 early.	2 04	14 late.	
" 19	Tu.	19 55	10 late.	14 08	10 "	New Moon.
		8 33	2 early.	2 39	11 "	
		20 31	6 "	14 43	8 "	
" 20	W.	9 07	3 "	3 10	8 "	
		21 08	3 late.	15 16	10 "	
" 21	Th.	9 42	3 early.	3 39	5 "	
		21 46	2 late.	15 51	4 "	
" 22	F.	10 18	1 "	4 09	1 "	
		22 25	2 "	16 30	3 early.	
" 23	Sa.	10 56	1 "	4 42	3 "	
		23 06	8 "	17 14	1 late.	
" 24	Sun.	11 37	9 "	5 21	6 early.	
		23 50	5 "	18 03	1 late.	
" 25	M.	.....	.....	6 06	8 "	
		12 21	11 late.	18 57	2 "	
" 26	Tu.	0 40	5 "	6 58	8 "	First Quarter.
		13 09	11 "	19 58	8 "	
" 27	W.	1 42	7 "	8 00	4 "	
		14 05	3 "	21 02	5 "	
" 28	Th.	2 48	3 "	9 04	6 "	
		15 08	8 "	22 03	0 "	
" 29	F.	3 58	2 early.	10 08	5 "	Maximum declination south.
		16 14	2 "	23 03	3 "	
" 30	Sa.	5 10	4 "	11 11	4 early.	
		17 19	2 late.	.....	.....	
" 31	Sun.	6 14	14 "	0 01	2 late.	
		18 20	3 "	12 12	4 early.	Perigee.
Aug. 1	M.	7 09	10 "	0 55	3 late.	
		19 15	0 "	13 09	3 early.	Full Moon.
" 2	Tu.	7 56	3 early.	1 46	3 late.	
		20 06	4 "	14 04	9 "	
" 3	W.	8 41	3 "	2 36	5 early.	
		20 54	3 "	14 57	16 "	
" 4	Th.	9 25	8 "	3 25	6 "	
		21 40	3 "	15 49	4 "	
" 5	F.	10 08	4 late.	4 13	7 "	
		22 25	6 early.	16 40	11 "	
" 6	Sa.	10 50	14 "	5 00	2 "	
		23 11	2 "	17 30	7 "	
" 7	Sun.	11 33	7 "	5 48	10 late.	
		23 59	11 "	18 22	10 early.	
" 8	M.	.....	.....	6 38	17 late.	
		12 19	4 early.	19 19	3 early.	
" 9	Tu.	0 49	7 "	7 32	2 late.	Last Quarter.
		13 09	13 "	20 22	3 early.	
" 10	W.	1 44	2 "	8 30	3 late.	
		14 05	10 "	21 27	2 "	
" 11	Th.	2 52	2 "	9 33	5 early.	Maximum declination north.
		15 08	6 "	22 30	14 late.	
" 12	F.	4 27	7 late.	10 34	3 "	
		16 16	9 "	23 26	24 "	
" 13	Sa	5 30	7 "	11 28	0 "	Apogee.
		17 18	10 "	.....	.....	
" 14	Sun.	6 18	5 "	0 13	15 late.	
		18 09	7 "	12 18	3 "	
" 15	M.	6 58	8 "	0 54	18 "	
		18 53	12 "	13 02	10 "	
" 16	Tu.	7 34	4 "	1 31	14 "	
		19 33	9 early.	13 41	6 "	
" 17	W.	8 08	1 late.	2 04	16 "	New Moon.
		20 12	2 "	14 17	12 "	
" 18	Th.	8 41	9 early.	2 35	2 "	
		20 50	10 late.	14 52	7 "	

TABLE B.

ST. JOHN, N.B.—*Comparison of Tide Tables with Tides as observed.*

Tide Tables based upon harmonic analysis of two years of tidal record, compared with observed tides as recorded by self-registering tide gauge.

Date. 1898.	Day of week.	High Water.		Low Water.		Moon.
		Time in Tables.	Variation from actual time.	Time in Tables.	Variation from actual time.	
		H. M.	Minutes.	H. M.	Minutes.	
July 18	M.	11 40	1 late.	5 26	8 early.	
		23 42	7 early.	17 40	8 "	New moon.
" 19	Tu.	.....	.....	6 00	12 "	
		12 14	0 early.	18 16	6 "	
" 20	W.	0 15	6 "	6 32	14 "	
		12 46	0 "	18 50	6 "	
" 21	Th.	0 49	5 "	7 04	15 "	
		13 17	3 "	19 23	8 "	
" 22	F.	1 25	9 "	7 38	16 "	
		13 50	11 "	19 57	14 "	
" 23	Sat.	2 04	11 "	8 15	19 "	
		14 27	12 "	20 34	19 "	
" 24	SUN.	2 45	13 "	8 55	19 "	
		15 08	14 "	21 15	24 "	
" 25	M.	3 29	15 "	9 39	21 "	
		15 53	16 "	22 03	24 "	
" 26	Tu.	4 18	16 "	10 29	15 "	First quarter.
		16 43	11 "	23 00	19 "	
" 27	W.	5 15	14 "	11 25	16 "	
		17 39	10 "	.....	.....	
" 28	Th.	6 17	7 "	0 03	14 early.	
		18 42	10 "	12 28	11 "	
" 29	F.	7 21	13 "	1 10	14 "	Maximum declination south.
		19 50	9 "	13 36	12 "	
" 30	Sat.	8 27	12 "	2 16	13 "	
		20 56	6 "	14 43	0 "	
" 31	SUN.	9 30	14 "	3 19	15 "	
		21 57	5 "	15 47	12 "	Perigee.
Aug. 1	M.	10 29	11 "	4 17	18 "	
		22 55	6 "	16 44	15 "	Full moon
" 2	Tu.	11 24	6 "	5 12	18 "	
		23 47	5 "	17 37	14 "	
" 3	W.	.....	.....	6 05	17 "	
		12 17	7 early.	18 27	14 "	
" 4	Th.	0 39	3 "	6 56	14 "	
		13 08	4 "	19 16	15 "	
" 5	F.	1 28	4 "	7 44	13 "	
		13 57	5 "	20 04	17 "	
" 6	Sat.	2 16	12 "	8 31	13 "	
		14 45	0 "	20 53	14 "	
" 7	SUN.	3 06	8 "	9 20	12 "	
		15 34	2 "	21 45	14 "	
" 8	M.	3 59	7 "	10 11	12 "	
		16 26	3 "	22 39	8 "	
" 9	Tu.	4 55	4 "	11 06	4 "	Last quarter.
		17 21	0 "	23 36	6 "	
" 10	W.	5 53	4 "	.....	.....	
		18 19	0 "	12 05	0 early.	
" 11	Th.	6 54	4 "	0 37	4 "	Maximum declination north.
		19 22	1 late.	13 09	5 late.	
" 12	F.	7 57	0 "	1 40	6 early.	
		20 22	5 "	14 12	3 late.	
" 13	Sat.	8 57	0 "	2 40	6 early.	Apogee.
		21 16	0 "	15 08	0 "	
" 14	SUN.	9 49	0 "	3 31	11 "	
		22 03	1 early.	15 56	2 "	
" 15	M.	10 33	0 "	4 16	13 "	
		22 43	1 "	16 38	4 "	
" 16	Tu.	11 10	1 late.	4 57	12 "	
		23 19	1 early.	17 16	5 "	
" 17	W.	11 43	0 "	5 33	7 "	New moon.
		23 52	0 "	17 51	1 "	
" 18	Th.	.....	.....	6 07	10 "	
		12 15	2 early.	18 24	7 "	

TABLE C.

QUEBEC.—*Comparison of Tide Tables with tide as observed.*

Tide Tables based upon harmonic analysis of two years of tidal record, compared with observed tides as recorded by self-registering tide gauge.

Date. 1898.	Day of week.	HIGH WATER.		LOW WATER.		Moon.
		Time in Tables.	Variation from actual time.	Time in Tables.	Variation from actual time.	
		H. M.	Minutes.	H. M.	Minutes.	
July 18	M.	5 49	14 early.	0 16	31 early.	
"		18 27	6 "	13 07	40 "	New moon.
" 19	Tu.	6 27	17 "	1 00	37 "	
"		19 05	0 "	13 45	40 "	
" 20	W.	7 02	15 "	1 42	28 "	
"		19 30	3 "	14 21	34 "	
" 21	Th.	7 35	16 "	2 22	24 "	
"		20 09	4 "	14 56	34 "	
" 22	F.	8 07	———	3 01	24 "	
"		20 38	———	15 30	———	
" 23	Sat.	8 40	———	3 40	———	
"		21 08	17 early.	16 04	26 early.	
" 24	SUN.	9 18	22 "	4 21	26 "	
"		21 42	25 "	16 40	25 "	
" 25	M.	10 03	17 "	5 05	17 "	
"		22 25	10 "	17 21	15 "	
" 26	Tu.	10 58	14 "	5 56	10 "	First quarter.
"		23 22	15 "	18 10	6 "	
" 27	W.	.....	.....	7 00	10 "	
"		12 10	7 early.	19 09	4 "	
" 28	Th.	0 32	10 "	8 13	15 "	
"		13 53	3 late.	20 18	8 late.	
" 29	F.	1 45	2 early.	9 23	17 early.	Maximum declination south.
"		14 44	0 "	21 31	6 late.	
" 30	Sat.	2 54	8 "	10 30	28 early.	
"		15 46	13 "	22 36	16 "	
" 31	SUN.	3 56	18 "	11 32	36 "	
"		16 42	9 "	23 34	———	Perigee.
Aug. 1	M.	4 50	———	.....	.....	
"		17 38	13 early.	12 26	43 early.	Full moon.
" 2	Tu.	5 40	26 "	0 25	30 "	
"		18 21	10 "	13 15	47 "	
" 3	W.	6 28	22 "	1 15	40 "	
"		19 06	8 "	14 01	47 "	
" 4	Th.	7 14	24 "	2 04	36 "	
"		19 49	9 "	14 44	46 "	
" 5	F.	7 59	21 "	2 52	45 "	
"		20 30	16 "	15 24	37 "	
" 6	Sat.	8 46	22 "	3 39	41 "	
"		21 14	14 "	16 03	27 "	
" 7	SUN.	9 36	6 "	4 25	30 "	
"		22 02	2 late.	16 41	23 "	
" 8	M.	10 30	7 early.	5 12	32 "	
"		22 53	5 "	17 20	20 "	
" 9	Tu.	11 29	6 "	6 01	24 "	Last quarter.
"		23 49	3 "	18 01	21 "	
" 10	W.	.....	.....	6 53	27 "	
"		12 34	3 late.	18 47	26 "	
" 11	Th.	0 54	0 "	7 56	36 "	Maximum declination north.
"		13 45	3 early.	19 51	26 "	
" 12	F.	2 01	12 "	9 09	40 "	
"		14 50	25 "	21 00	31 "	
" 13	Sat.	3 03	19 "	10 10	60 "	Apogee.
"		15 47	18 "	22 03	39 "	
" 14	SUN.	3 56	24 "	11 05	65 "	
"		16 35	20 "	22 59	45 "	
" 15	M.	4 43	22 "	11 53	58 "	
"		17 20	18 "	23 49	42 "	
" 16	Tu.	5 24	16 "	.....	.....	
"		18 01	14 "	12 35	50 early.	
" 17	W.	6 00	15 "	0 34	39 "	New moon.
"		18 36	4 "	13 13	42 "	
" 18	Th.	6 33	20 "	1 16	31 "	
"		19 05	12 "	13 49	41 "	

TABLE D.

SUMMARY of Tidal Record obtained at Principal Stations; showing also how far it is worked up.

Principal Tidal Stations.	Period.	Tidal Record Obtained. Date.	For Tidal Differences. Time of High Water Tabulated.	For Tidal Differences. Time of Low Water Tabulated.	For Harmonic Analysis. Tabulated in Hourly Ordinates.	For Harmonic Analysis. Analysis made.	Remarks.
Quebec	Year 1894	1893, Nov. 7; to 1895, Jan. 15			...Done	...Done	Tide Tables for Quebec, up to 1900, are based upon these two years of analysis.
	" 1895	1895, Jan. 15; to 1896, Jan. 31	...Done		...Done	...Done	
	" 1896	1896, Feb. 1; to 1897, Jan. 31	...Done	...Done	...Done		
	" 1897	1897, Feb. 1; to 1898, Jan. 31			...Done		
	" 1898	1898, Feb. 1; to 1899, Jan. 31					
Halifax	Year 1896	1895, Oct. 15; to 1896, Nov. 30	...Done		...Done	...Done	Tide Tables for Halifax are based upon this one year; and upon old record.
	" 1897	1896, Dec. 1; to 1897, Nov. 30					
	" 1898	1897, Dec. 1; to 1898, Nov. 30					
St. John, N. B	Year 1893 to 1894	1892, Dec. 5; to 1894, Mar. 12	...Done		...Done		Unreliable. Gauge not working satisfactorily.
		Gauge column renewed; March, 1894.					
	" 1894	1894, April 30; to 1895, May 15			...Done	...Done	Tide Tables for St. John are based upon these two years of analysis, at present.
	" 1895	1895, May 15; to 1896, May 15			...Done	...Done	
	" 1896	1896, May 15; to 1897, May 15			...Done		
	" 1897	1897, May 15; to 1898, May 15			...Done		
	" 1898	1898, May 16, and onward	...Done	...Done			
St. Paul Island (Cabot Strait)		1893, Sept. 25; to 1894, Jan. 21					(Record unsatisfactory.)
		January.—Clock of Gauge failed.					
		August.—Improved Gauge put in.					
	Year 1895	1894, Aug. 20; to 1895, Feb. 4	...Done				
		February.—Gauge carried away; instrument lost. September.—Rebuilt.					
	" 1896	1895, Sept. 15; to 1896, Nov. 30	...Done	...Done	...Done	...Done	This analysis furnishes basis of Tide Tables for Northumberland Strait, and adjoining regions.
	" 1897	1896, Dec. 1; to 1897, Sept. 20	...Part	...Part			
		Oct. and Nov.—Record unreliable.					
	" 1898	1897, Dec. 11; to 1898, Dec. 31			...Done		
		1899, Jan. 1, and onward					
Father Point	Year 1895	1895, Feb. 4; to 1896, Jan. 6	...Done				
	" 1896	1896, Jan. 6; to 1897, Jan. 25					

		1899, Jan. 1, and onward			Done		umberland Strait, and adjoining regions.
Father Point	Year 1895	1895, Feb. 4; to 1896, Jan. 6	Done				The difference in time of H.W. and L.W. from Quebec, is used as a basis for Tide Tables for Father Point.
	" 1896	1896, Jan. 6; to 1897, Jan. 25	Done	Done	(Lost on S.S. "Labrador")		
	" 1897	1897, Jan. 25; to 1898, Jan. 31					
	" 1898	1898, Jan. 31, and onward					
South-west Point (Anticosti)		1893, July 17; to 1894, Sept. 17	Part				(Early record, unsatisfactory.)
		Nov.—Improved Gauge put in.					
	Year 1895	1894, Nov. 12; to 1895. Oct. 7	Done				The difference in time of H.W. from Quebec, is used as a basis for Tidal Differences in the Lower St. Lawrence.
		Oct.—Inlet fittings improved.					
	" 1896	1895, Nov. 11; to 1896, Oct. 26	Done	Part			
	" 1897	1896, Oct. 26; to 1897, Dec. 25					
		Dec.—Gauge damaged by storm.					
	" 1898	1898, Feb. 3; to 1899, Jan. 16					
		Jan.—Inlet partially choked; record unreliable.					
		April.—Station closed.					
Forteau Bay (Strait of Belle Isle)	Year 1895	1894, Aug. 11; to 1895, Sept. 7	Part				The time of H.W. has been used for comparison with the current in the Strait; and for trial Tidal Differences with other ports.
	" 1896	1895, Sept. 7; to 1896, Sept. 19	Done		(Lost on S.S. "Labrador")		
	" 1896	1896, Sept. 19; to 1897, Jan. 9					
		Jan. to April.—Pencil of Gauge not marking record not obtained.					
	" 1897	1897, May 15; to 1897, Nov. 13					
		Nov.—Gauge damaged by storm.					
		July.—Gauge refitted; and protected by new crib-work in September.					
	" 1898	1898, July 9, and onward					
Yarmouth, N. S	Year 1898	1898, June 25; to 1899, Feb. 2	Part	Part			The time of H.W. and L.W. used for comparison with other ports, for Tidal Difference.
		Gauge not heated. Record in Feb. and Mar. not obtained because of frost.					
	" 1899	1899, Mar. 10, and onward					