SURVEY

OF

TIDES AND CURRENTS

IN

CANADIAN WATERS

REPORT OF PROGRESS

BY

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OTTAWA
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OTTAWA, 15th December, 1898.

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. With regard to the investigation of the currents on our coasts, the regions in which this is most required at present, were pointed out in my last report; but no arrangements were made for carrying on this branch of the Survey during this season. Some information on the behaviour of the currents in the Bay of Fundy, however, was obtained incidentally, while carrying on tidal work in that region.

Two of the principal tidal stations were put in thorough repair this year; and improvements were made in the method of calculation and in the publication of the tide tables, which are now issued by this Survey.

During the summer season, an investigation of the tides in the Bay of Fundy was made; and eight secondary tidal stations were established in that region; and from these, three to five months of continuous record have been obtained. The tide levels at several of these stations have been referred to permanent bench marks. The question of mean sea level in the Bay of Fundy has also been investigated; and the values as determined from the best available surveys, are given in this report.

The leading marine periodicals and geographical publications, which give reviews of the reports of this Survey and summaries of the results obtained, were mentioned in my last report. In addition to these, two further summaries have appeared in the Dutch periodical, "De Ingenieur." These occupy five quarto pages, and are accompanied by two maps, reproduced from the reports. The Liverpool "Journal of Commerce," in a review of the last annual report of this Department, continues to express its high appreciation of the work of this Survey, and the importance of the results from a commercial point of view.

The tide levels at St. John, N.B., which were given in my last report, with reference to the Tidal Survey bench mark on the Custom house, have been of much service there. By connecting his levels with this bench mark, Mr. Wm. Murdock, C.E., the Superintendent of Water Works, has obtained the true elevation of mean sea level, low water datum, &c., for his purposes. The tide levels required in the construction of wharves this season, have also been obtained in the same way, from this bench mark. The tide gauge at St. John has also afforded the level of the tide, moment by moment, for the reduction of an extensive series of soundings in the harbour, taken this season by Mr. E. T. P. Shewen, Resident Engineer of Public Works. For this purpose 3,800 special readings have been taken from the gauge-record by Mr. D. L. Hutchinson, the tidal observer; during September and October, 1898.

The tidal record at the mouth of the Fraser River has also been of service in the construction of an important coaling wharf at Vancouver. The record was examined for this purpose by Mr. H. J. Cambie, Resident Engineer on the Pacific division of the C. P. Railway; the object being to ascertain the level of the loading stages which would secure the greatest number of hours of work. The irregular and unequal character of the Pacific tide, makes this difficult to determine without a tidal record for reference; and the difference of a foot in the wharf level, one way or the other, would make a wide difference in the number of hours per week for which it could be used. The character of the tide at the Fraser River is so closely similar to the tide at Vancouver as to afford reliable data for the purpose.

These instances may serve as examples of the accessory ways in which this Survey often proves of value, in addition to its direct service to the shipping interest.

The total expenditure on the Survey during the fiscal year 1897-98, was $3,081.45.

THE PRINCIPAL TIDAL STATIONS.

At these stations there has been little interruption of consequence in the continuity of the tidal record obtained during the year, with the exception of Forteau Bay in the Strait of Belle Isle. At that station, the cribwork on which the tide gauge stands, was found to be in a precarious condition when the station was visited in 1897, but the necessary repairs could not then be made for want of means. A number of minor improvements were made however, and the improved type of recording instrument was substituted for the former one; but in the month of November a severe storm occurred which damaged and shifted the cribwork so much, as to put the gauge out of working order. Arrangements were again made in the hope of carrying out the repairs this season, by having additional cribwork built to enclose the old crib on two sides. Levels were also needed to re-determine the datum plane after the settlement that had taken place, and the sight gauge required adjustment to this datum. A new barograph of superior make was to be substituted for the present one, and the dipleidoscope was to be tested and adjusted if necessary, to secure accuracy in the time used at the station. This work was entrusted to Captain Douglas, R.N.R., who had superintended the erection of the tide gauge at Forteau Bay, when it was first placed there. He was also furnished with a complete outfit of instruments and fittings required to establish a secondary tidal station at Chateau Bay, which could be done while the cribwork at Forteau Bay was being built. The comparison with Chateau Bay at the outer end of the strait, by means of a few months of simultaneous observations, would be very valuable; because there are indications that the time of the tide at Forteau Bay is influenced by the outgoing tide from the Gulf of St. Lawrence. The amount of this influence could thus be ascertained and allowed for. Unfortunately however, difficulties arose which prevented the above arrangements from being carried out. An endeavour was next made to direct an officer of the Department who was then at Belle Isle, to erect the cribwork required; which would at least prevent the gauge from being carried away in the winter storms. Instructions were sent by mail; and the attempt was also made to intercept him at Tilt Cove, the nearest telegraph station, should he return by the ordinary route of travel by way of St. John's, Newfoundland, 2,120 miles to Ottawa. This endeavour also failed. Meanwhile information reached Ottawa on the 16th of August that Commander H. E. Purey-Cust, R.N., of H.M.S. "Rambler," engaged in making surveys this season in the Strait of Belle Isle, had called at Forteau Bay at the end of June, and had very kindly taken the trouble to overhaul the gauge, and to put the recording instrument in working order. The thanks of the Department are due to him for this service, which is all the more appreciated in so isolated a place, when other arrangements had failed. We were glad to forward at his request, a copy of the tidal record there obtained, for use in connection with his own surveys this season. To secure the erection of the cribwork, a description and plan was prepared for the third time, and forwarded to the tidal observer at Forteau Bay, Mr. A. Hart. The material had already been sent by the annual trip of the supply steamer from Quebec; and in September, after the pressing part of the fishing season was over, Mr. Hart was able to secure men in the locality for this work. In building the new cribwork, the tide house was levelled up, which further alters the elevation of the zero of the sight gauge. The gauge is thus again in order, but without the means of obtaining a correct datum level for the observations, while the other improvements at the station, and the comparative observations which it was hoped to obtain this season, have not been secured.

At St. Paul Island, the cribwork erected in 1893 was eaten away and partly undermined, owing to the severe exposure there. This was replaced by additional cribwork, which was built in front of it in September, under the supervision of Captain Douglas. The new work is set to butt securely against the rocky cliffs on either side;

and it is heavily ballasted and faced with iron plating. The opportunity was also taken to test and adjust the dipleidoscope, and to set the barograph correctly by means of a simultaneous comparison on a favourable day, transmitted by cable from the Meteorological observatory at Sydney, Cape Breton.

At South-west Point, Anticosti, the cribwork which protects the tide gauge in front, was in a precarious condition when visited in the summer of 1897. Consequently in December of that year, a severe gale shifted the iron casing which incloses the tide pipes; and the gauge was out of order until the end of January, when the ice took in the bay, and kept the sea quiet. It has been found that the difference in the time of the tide between Anticosti and Quebec is fairly constant; and as a record on a good scale has been obtained there already, during three years, it was decided to forego the expense of thorough repairs, and merely to continue the observations as long as the gauge will work. As the shifting of the casing threw it out of the vertical, the tide pipes were removed, and the whole casing, three feet in diameter, has been used as a tide well. It has fortunately continued to work in this condition throughout last summer, and up to the present date; which has secured this additional record.

At Father Point the tide gauge works by siphoning at the low tides; and to complete the connection, an intake pipe extends seawards along the bottom for about two hundred feet. This pipe was carried away by the ice in the spring, and again by an unusually heavy gale on October 15th. It was fortunately possible to replace it before winter set in; which should secure the record of the lowest of the tides during the winter season.

At Halifax the only interruption occurred through the breaking of the hair-spring in the clock of the gauge, and the delay in obtaining another to replace it. This hair-spring was of palladium, as steel springs rust so badly as to interfere with the rate of the clocks. It is probable, however, that steel hair-springs when gilt, or the alloy used for non-magnetic hair-springs, will prove the best on the whole, because less liable to break. Where the new type of gauge is used with the interchangeable clock cylinder, the danger of interruption from such accidents is avoided.

The tide gauge at the Levis Dry Dock, in Quebec harbour, is the only one which stands upon masonry; and being in a sheltered harbour, it has given scarcely any trouble. Some interruption had occurred from the tide floats sticking in the tide pipes, since the confined space in which these pipes had to be placed, reduced their diameter to three inches. Brass tide pipes $3\frac{1}{4}$ inches inside diameter, have been substituted for the iron ones, and specially designed copper floats of $2\frac{1}{2}$ inches diameter were made to correspond. As these pipes will keep clean, this size of float will have sufficient play; and it is ballasted with an outside lead weight which will keep it truly vertical and prevent it from jamming in the pipe. The float has also 50 per cent greater area than the old one, which was only two inches in diameter, and even then was liable to stick in the pipe when it became rusted.

Pacific Coast Record.—In addition to the seven principal tidal stations on our eastern coasts, there are also two tidal stations on the Pacific, which are under the supervision of the Department of Public Works; one at Sand Heads, at the mouth of the Fraser River, in the Gulf of Georgia; and the other at Victoria, afterwards removed to the neighbouring harbour of Esquimalt. The record obtained at these stations, extends in all from February, 1895 to date; a period of over three years. A copy of the record has been furnished to this Department in the form of a set of blue prints, reproduced from the originals. In the fire of February, 1897, which destroyed the attics of the Marine Department, in which the Tidal Survey office then was, these copies were lost; as the first attention had to be given to the original tidal records on our eastern coasts, which were all saved, with the accompanying comparisons for datum level, barograph records, and meteorological abstracts.

The copies were afterwards replaced through the kindness of the Chief Engineer of Public Works. The Superintendent of the United States Coast and Geodetic Survey, hearing of the existence of these records through the reports of the Tidal Survey, made request for the loan of them in April, 1897; as they are the only points at which tidal observations have been secured, between the Pacific coast of the United States and Alaska. This request was complied with; and subsequently, in March, 1898, the copies were lent to the Meteorological observatory at Toronto, for examination in the investigation of secondary tidal undulations undertaken by Mr. F. N. Denison, of the Meteorological staff. They went and returned safely in both cases.

In September, 1898, the whole of the original tidal record for the Pacific coast was lost in the destructive fire at New Westminster; and the copies supplied to this Department are thus the only ones that remain in existence. The record thus supplied, extends from February, 1895, to July, 1898, inclusive; with a gap of one month at each of the two stations.

The Department of Public Works has therefore applied for a duplicate set of copies to be made to replace their own originals. A request has also been received from the Hydrographer to the Admiralty for one complete year of the record at each station. It has thus become necessary to secure a duplicate of the record in some way, either by reproduction or tabulation.

From the above circumstances, it is evident that a serious risk is taken in allowing a tidal record of such value to stand over from year to year, without making the necessary tabulations and reductions, and submitting it to harmonic analysis, because of inability to meet the expenditure required. Until this is done, no permanent results are derived from it; and it would then become available as a basis for tide tables for ports on the Pacific coast.

IMPROVEMENTS IN THE TIDE TABLES FOR 1898.

Tide Tables for St. John, N.B.—These were issued for the first time for the year 1898. They are based upon the record extending from April, 1894, to May, 1896, or two full years. The earlier record which extends from December, 1892, to March, 1894, was not included; as it was uncertain whether the inlet to the tide pipes was always working freely, and the tide may not therefore be correctly recorded. After the gauge column was removed and refitted in March, 1894, the record has been quite satisfactory.

Following upon Halifax and Quebec, St. John is the third port in Canada for which full tide tables showing both the time and height of the tide, have now been prepared and issued since the Tidal Survey was begun in 1893. These tables are derived from direct observation of the tides at those ports, and although they are still based on a comparatively short record, they are incomparably better than anything previously available. The height of the tide as now given in these tables, is of much value where the rise and fall is so great as at St. John and Quebec. When the observations secured this season at the secondary stations around the Bay of Fundy are worked out, they will furnish tidal differences with reference to the St. John tides, which will extend the usefulness of these tables to this whole region.

The Lower St. Lawrence and River.—The tide tables for Father Point, the Pilot station on the Lower St. Lawrence, are computed by difference of time from Quebec. The difference in the time of high water is based upon simultaneous observations during two full years, as given by the tide gauges at the two places, and this has now been revised throughout and corrected for time errors. The difference in the time of low water has now been worked out also from simultaneous observations during one complete year. The high water difference, as already explained, has not been found to vary with any regularity in accordance with the moon's phases, that is to say, in accordance with the change in the range of the tide from springs to neaps, as might be expected in a long estuary. The low water difference is greater than the high water difference, and also varies more widely from its average value. The greatest values occur chiefly at times when the moon's perigee coincides nearly with full and change. It would thus appear that the lowest low waters take the longest to ascend the river, which accords with the theory of the progress of tidal undulations. This may afford a clue to the law which governs the variation in these differences when they are more closely worked out; so far as the variations may depend on astronomical causes, rather than on wind disturbance, which appears to have the greater influence. In the mean time the average values are used for the computation of the tide tables at Father Point. The resulting differences in standard time, are given below.

These differences were worked out in time to use them in computing the tide tables for Father Point for the season of navigation of 1898.

Father Point and Quebec.—(Father Point earlier than Quebec.) Average difference in time of High Water:—

From observations of 17th December, 1894, to 31st January, 1896.... $4^h\ 21^m$
" " 1st February, 1896, to 31st January, 1897...... 4 19

Mean value .... $4^h\ 20^m$

Average difference in time of Low Water:—
From observations of 1st Feb., 1896 to 31st Jan., 1897.............. $5^h\ 30^m$

Tide tables were again computed for Ste. Croix bar, in the St. Lawrence River above Quebec, which is still the shallowest point in the ship channel, until the present dredging operations are completed. These tables are based upon differences in the time of the tide from Quebec; the difference varying with the height of the water in the river according to the season, from spring to autumn. Revised values of the differences used, were obtained from the record of the semaphore signals which are given at Cap Santé, opposite this bar. The rise of the tide there, is from 12 to 15½ feet, and every half-foot of rise and fall is noted to the nearest five minutes. From such a record however, the time of high water and low water can be found pretty closely. The extent of the record was only from August 14th to November 22nd, 1897; and being for the day tides only, it gave the time of high water at 84 tides, and low water at 93 tides, for comparison with the simultaneous record of the tide gauge in Quebec harbour. An improvement in the accuracy of these tables was thus secured. They are of much service in enabling steamships to know in advance the time when high water on the bar may be expected; and the amount of the rise there makes an important difference in the available draught. With these tables, the difference in the time of the tide for the next shoal at St. Augustin, is also given.

The Gulf of St. Lawrence and Northumberland Strait.—From the observations of the tides obtained in 1896 in the south-western portion of the Gulf of St. Lawrence and Northumberland Strait, it has been ascertained that the tides in this region can best be derived from St. Paul Island, which is one of the principal tidal stations, situated in the main entrance through which the tides enter the Gulf from the Atlantic. One complete year of the tidal record at that station was accordingly prepared for analysis in the spring of 1897, from which tide tables are now calculated for St. Paul Island itself; and from these in turn, tide tables for Pictou and Charlottetown are successively computed. In this way, correct results are obtained; whereas tide tables for places within the Gulf, when based upon a *constant* difference from some Atlantic port, as given in local almanacs, are liable to be in error by as much as one and a half hours, early or late. This is well illustrated by the following comparison of simultaneous observations in standard time at Pictou and Halifax, which shows the manner in which the difference in the time of high water varies:—

Date.	Time of High Water.		Difference.	Remarks.
	Pictou.	Halifax.		
	H. M.	H. M.	H. M.	
1896, July 8	7 10	6 15	0 55	Moon's declination maximum north.
" " 8	21 11	18 02	3 09	
" " 9	8 02	6 50	1 12	
" " 9	22 07	18 55	3 12	
" " 10	9 00	7 50	1 10	
" " 10	23 15	19 30	3 45	New moon.
" " 11	9 45	8 35	1 10	
" " 11	23 57	20 22	3 35	
" " 12	10 35	9 15	1 20	

The tidal observations of 1896 show that the south-western portion of the Gulf, south of Chaleurs Bay, requires to be divided into two regions. One of these is the open shore of the Gulf; comprising the Gulf coast of northern New Brunswick and the north coast of Prince Edward Island. This region can be referred to St. Paul Island by giving the time of the tide as *earlier* than at that station. Otherwise the difference in the time of the tide varies so widely as to be practically valueless. The other region is Northumberland Strait, in which also the time of the tide can best be referred directly or indirectly to St. Paul Island.

The difference in the time of the tide between points in Northumberland Strait and St. Paul Island is not constant. The variation in the difference is chiefly due to diurnal inequality in the tide which is there strongly marked; and this inequality also appears to change with the progress of the tide along the Strait. After making a long series of comparisons between points in the Strait and other ports, by means of the simultaneous observations of 1896, it was found that Pictou was the best point to select as a port of reference for this region. Pictou is centrally situated; and the change in the diurnal inequality along the Strait will be better divided, if differences are taken in the two directions from there. It will probably be found also to stand in the best relation to the tidal currents in the Strait when these come to be examined systematically.

The advantage of referring Pictou to St. Paul Island rather than to Halifax became still more evident when final results were reached. When the whole series of 275 simultaneous tides obtained in 1896 at Pictou, Halifax and St. Paul Island, were tabulated and averaged, the difference in the time of high water between Pictou and Halifax was found to range from 0 hr. 55 min. to 3 hrs. 28 min.; whereas the difference between St. Paul Island and Pictou was found to range only from 1 hr. 05 min. to 1 hr. 55 min. There is a similar variation in the difference in the time of low water, but it is less in amount. These variations can also be reduced to law, as it was ascertained that the difference varies in accordance with the declination of the moon. This enables the variation itself to be allowed for in computing tide tables.

To obtain a more extended basis for the computation of the tides in this region, further observations were taken at Pictou in 1897, from June 21st to November 30th. Unfortunately the tide gauge at St. Paul Island was out of order in that autumn, after September 16th. The further number of simultaneous tides secured, however, was 146; increasing the total to 421 for high water, and 412 for low water; comprising in all a period of nine months in the two seasons.

The method of dealing with the tides in Northumberland Strait, as the final outcome of the observations obtained is, therefore, to compute tide tables first for Pictou; and in this computation the leading variation in the tidal difference with St. Paul Island is allowed for. Constant differences from Pictou are then used for places lying in each direction from it, towards the two ends of the Strait; and the change in the inequality is thus so distributed as to be practically eliminated from the result. These constant differences are derived from the simultaneous observations at Souris, and at Cape Tormentine, which is as far as the tide has a marked range in its progress westward. In the western end of the Strait beyond Cape Tormentine, from Shediac to Richibucto, the rise and fall of the tide is so slight, owing to tidal interference there, that the time of high and low water is quite uncertain. The investigations made in arriving at this method, and an explanation of some anomalous features in the Gulf tides, are given in a paper contributed by me in May last to the Royal Society of Canada, entitled, "Character and Progress of the Tides in the Gulf and River St. Lawrence." They need not, therefore, be enlarged upon here.

The tide tables for St. Paul Island itself, are based at present upon a continuous tidal record during one complete year only; namely, from October, 1895, to November, 1896. This record has been submitted to harmonic analysis, and from it the tables are calculated in the Nautical Almanac office, London.

The series of variable differences in the time of the tide between Pictou and St. Paul Island, is derived from the simultaneous observations at the two places which extend from June to November in 1896, and from June to September in 1897; as above explained. The differences for high water and for low water were separately tabulated in draconitic months; that is, in accordance with the declination of the moon; and the mean differences resulting, were plotted as diagrams in order to obtain graphically the best average values. These values, which are not the same for high water and low water, are given in the following table; and in applying them, care is taken to distinguish between upper and lower transit tides. The differences are in absolute time; and they thus give the time of the tide at Pictou in Standard time, for which the St. Paul Island tides are also calculated. It is to be noted that after the moon souths at St. Paul Island, low water occurs first, and high water afterwards. In using the table it is found best to set tide Number 13 centrally at the moon's maximum declination, and to allow any overlap to adjust itself at the nodes, where the differences are more nearly constant.

It will be noticed in the table that the difference for high water is constant for all similar tides; that is, for upper transit tides when the moon is in north declination, and for lower transit tides when the moon is in south declination. Also, the least differences or minimum values for both high water and low water, occur at the third tide after the moon's maximum declination; which is the same as the interval at spring tides after full and change of the moon.

TABLE FOR CALCULATION OF PICTOU TIDES FROM ST. PAUL ISLAND.

Differences to be *added* to the time of the tide at St. Paul Island; for Standard time.

In the numbering, the lower transit tides are enclosed in brackets. The moon's nodes indicate the points at which the moon crosses the equator, in passing from N. to S. declination; and S. to N.

The central tide, nearest to the maximum declination of the Moon is marked thus:—*

For High Water.				For Low Water.			
Moon North. — Number of Tide after Ascending Node.	Difference. H.	M.	Moon South. — Number of Tide after Descending Node.	Moon North. — Number of Tide after Ascending Node.	Difference. H.	M.	Moon South. — Number of Tide after Descending Node.
(0)	1	41	0	0	1	31	(0)
1	1	41	(1)	(1)	1	31	1
(2)	1	41	2	2	1	31	(2)
3	1	41	(3)	(3)	1	31	3
(4)	1	41	4	4	1	31	(4)
5	1	41	(5)	(5)	1	31	5
(6)	1	41	6	6	1	31	(6)
7	1	41	(7)	(7)	1	31	7
(8)	1	38	8	8	1	31	(8)
9	1	41	(9)	(9)	1	25	9
(10)	1	30	10	10	1	25	(10)
11	1	41	(11)	(11)	1	15	11
(12)	1	20	12	12	1	15	(12)
*13	1	41	(13)*	*(13)	1	15	13*
(14)	1	12	14	14	1	08	(14)
15	1	41	(15)	(15)	1	08	15
(16)	1	10	16	16	1	08	(16)
17	1	41	(17)	(17)	1	08	17
(18)	1	12	18	18	1	08	(18)
19	1	41	(19)	(19)	1	12	19
(20)	1	17	20	20	1	12	(20)
21	1	41	(21)	(21)	1	12	21
(22)	1	22	22	22	1	20	(22)
23	1	41	(23)	(23)	1	20	23
(24)	1	30	24	24	1	20	(24)
25	1	41	(25)	(25)	1	31	25
(26)	1	38	26	26	1	31	(26)
Descending Node....			Ascending Node....	Descending Node....			Ascending Node.....

The differences in the time of the tide from Pictou throughout the length of Northumberland Strait, which are based directly upon simultaneous observations reduced to standard time, are as follows :—

LOCALITY.	Difference in time of High Water.		Difference in time of Low Water.	
	H.	M.	H.	M.
Souris, P. E. I. Tide earlier than at Pictou	1	17	1	15
Pictou Harbour.	0	00	0	00
Charlottetown. Tide later than at Pictou	1	04	1	04
Cape Tormentine. Tide later than at Pictou	0	23	0	43

The tide tables for Charlottetown are computed from the Pictou tables by means of the above average difference in the time of the tide. The observations at Charlottetown and Pictou in 1896 comprised only three and a half months in all, affording comparisons for 144 simultaneous tides at the two places ; and as the tide at Charlottetown appears to be affected by tidal interference from the western end of Northumberland Strait, the length of the observations was not sufficient to enable this to be fully allowed for. There are accordingly certain times in the course of the month at which the time of the tide as given in the tables may differ from the actual time by as much as half an hour, early or late ; but usually the time as given will be closely correct.

These tide tables for Charlottetown, Pictou and St. Paul Island, form a series which was published for the first time for the season of navigation of 1898. They were printed as an eight-page pamphlet ; the tables being for the eight months April to November inclusive.

The tables are accompanied by the following tidal differences for the time of high water at fourteen places in the south-western part of the Gulf. Those for the open Gulf shore are derived from the simultaneous observations of 1896, and are referred directly to St. Paul Island ; and those in Northumberland Strait are referred to Pictou, for the reasons already explained. These latter differences are based primarily upon the results above given for the tidal stations at the two ends of the Strait, which are then compared with the difference in Establishment as given in the Admiralty list, for the intermediate places. When applied to the tables, they give the time of high water in Standard time in all cases.

FROM ST. PAUL ISLAND TIDE TABLES.

For the open Gulf shore, including the Miramichi region, and the north coast of Prince Edward Island.

For the time of H. W. in Standard time for the 60th Meridian, subtract the following amounts from the time given in the St. Paul Island Tables :—

		H.	M.
Lower Neguac, and the entrance to Miramichi Bay	Subt.	3	21
Alberton, P.E.I.	"	2	33
Richmond Bay ; within the entrance	"	2	26
Grand Rustico ; at the Lighthouse.	"	2	31
St. Peter's ; at entrance to Bay	"	2	10

FROM PICTOU TIDE TABLES.

For Northumberland Strait.

For the time of H. W. in Standard time for the 60th Meridian, apply the following differences to the time given in the Pictou Tide Tables :—

		H.	M.
Souris	Subt.	1	17
Port Hood	"	1	00
Cape Bear	"	0	55
Cape George	"	0	50
Tatamagouche	Add	0	13
Pugwash	"	0	32
Cape Tormentine	"	0	23
Bay Verte	"	0	27
Bedeque Bay	"	0	34

PUBLICATION OF TIDE TABLES FOR 1898.

Quebec, Halifax and St. John, N.B.—The tide tables for these principal harbours were furnished to the leading British and Canadian Almanacs, as far as they were willing to publish them. The tables show the time of high water and low water for all tides, both day and night, and the height of the tide at high and low water. The depth of water on the sill of the Dry Docks at Quebec and Halifax is also given with relation to the tide, so that vessels may know the depth of water available for entrance to those docks at any high tide. They are also accompanied by tidal differences for other places. In most cases the almanacs published only a portion of this information.

The only almanac in which the tables for all these ports appeared in full, was in *Greenwood's Almanac*, published by Mr. W. N. Greenwood of Lancaster, England. The tables for Halifax and Quebec appeared in full, accompanied with the tidal differences for other places, in the *Canadian Almanac*, published by the Copp, Clark Co. of Toronto. The tide tables for Halifax, showing the time of high and low water only, without the height of the tide, were given in *Belcher's Almanac*, published by the McAlpine Co., and also in *Cogswell's Almanac*, published by Mr. R. H. Cogswell of Halifax. The time of high water at Halifax was given in *Brown's Almanac*, published by Messrs. J. Brown & Son of Glasgow, as one of sixteen tide tables for colonial and foreign ports. The tide tables for St. John, N B., reduced to the time of high water only, without low water or the height of the tide, were given in one of the columns in *McMillan's Almanac*, published by Messrs. J. and A. McMillan, of St. John. The time of high water at Quebec was given in a sheet tide table, issued locally by Messrs. T. J. Moore & Co., of Quebec.

In the *Tide Tables* published by the United States Coast and Geodetic Survey, the Halifax tables, since the year 1896, are calculated from the tidal constants furnished by this Survey. They have also made request for the tidal constants for Quebec and for St. John, N.B.; but these have not yet appeared in their issue of tide tables up to the year 1899. The tide tables for Quebec for the season of navigation on the St. Lawrence are given in the publication prepared by the Montreal Harbour Commissioners for the use of the Pilot service. In all the above, due acknowledgment is made to the Tidal Survey branch of the Marine Department for the tables supplied.

Inquiry was also made as to which of the newspapers were willing to publish the tide tables for their own localities. Copies of the tables in manuscript were sent to six leading newspapers, but only three of these gave them space. The Quebec *Chronicle* and the St. John *Telegraph* published the tables in full for those ports, one month at a time; and in the St. John *Globe*, the time of high water from the tables, was given daily in a miniature almanac. Mr. Hurd Peters, C.E., the City engineer of St. John, N.B., says of these tide tables: "During the year 1898, the tables for St. John were published monthly by one of the city newspapers, and proved very useful to all interested in vessels, in the harbour, and in tide work generally." The tables for Halifax were not published by the Halifax papers.

Some two dozen copies of these tide tables were supplied by Mr. Greenwood, reprinted from his almanac, and these were sent to steamship companies and others interested, as far as the number permitted. Further application received later for these tables could not be met.

Ste. Croix Bar.—These tide tables which show the time of the tide during the season of navigation at this point, were published in company with the tide tables for Quebec, by the Montreal Harbour Commissioners, in their publication entitled: "Tide Tables and other information connected with the Ship Channel between Montreal and Quebec," which is prepared for the use of the St. Lawrence pilots.

Father Point.—Tide tables were prepared in manuscript, and posted at the lighthouse at Father Point; where they are accessible to all the pilots. These tables give the time of both high water and low water; which is important with relation to the strong tidal currents of the Lower St. Lawrence.

Charlottetown, Pictou and St. Paul Island.—These tide tables for 1898, being computed from revised data by the new method above explained, were printed and widely distributed. This distribution was similar in its scope to that outlined below for the tide tables of 1899, but with some modification for the advantage of the region on the south-western side of the Gulf of St. Lawrence, to which the tidal differences extended that accompanied the tables. Copies were also sent to ten Lower Province newspapers and to twenty-six vendors of almanacs and marine publications abroad, to make known these tables, as they were then issued for the first time. The number of copies thus sent out was 242.

TIDE TABLES FOR 1899; PUBLICATION, &C.

The tide tables for Halifax and Quebec have become well known by their publication in the *Canadian Almanac* since 1896; and also in the *Star Almanac* for 1896, which was the last year that it was issued. The Quebec tables have also appeared in the publication issued by the Harbour Commissioners of Montreal, and have thus become known to the Pilot service and the steamship companies of the St. Lawrence. There was less facility for making known the new St. John tables; and their publication in 1898 was unsatisfactory. The only almanac in Canada in which they appeared, was McMillan's, published in St. John itself; but the abstract of the tables which was given in it, was very meagre. The tables appeared in full in the St. John *Telegraph*, which served to make them known in New Brunswick; but the St. John papers have little circulation on the Nova Scotia side of the Bay of Fundy, and from a tidal point of view, St. John is the principal station for the whole of that bay.

In order to make the tide tables more widely known, it was arranged to have them reprinted from *Greenwood's Almanac* for 1899, as an 8-page pamphlet. This almanac published in full the tide tables for the three ports, Halifax, Quebec and St. John; and 350 of the copies reprinted from it, have been widely distributed. These have been sent to the agents of this department, harbour commissioners, harbour masters, port wardens and collectors of customs, corporations of pilots and pilot commissioners, boards of trade, and to thirty-seven steamship companies and their agencies, running to our eastern ports. Also to twenty-six leading vendors of almanacs and nautical publications, in Great Britain, Europe and the United States, and twenty nautical and allied periodicals, mostly foreign; as well as to the newspapers in our eastern cities. It is hoped that these tide tables will thus become better known. The *Canadian Almanac* will also publish in full the tide tables for 1899 for all three ports.

On the other hand, further improvement in the accuracy of the tide tables themselves has come to a standstill, for want of sufficient assistance, and the means to meet the expense of the analysis of further tidal record. This affects the tide tables as far forward as 1900, as they have to be calculated so long in advance. The tables up to that year have thus only two years of tidal record, at Quebec and St. John respectively, as their basis. At Halifax the tide tables up to 1897 were based upon four years of old record obtained between 1851 and 1861, and only one year of new record has yet been incorporated for the improvement of the tables there. The tide tables for St. Paul Island are based upon one year's record only. On these four principal tide tables, the others which are computed for the season of navigation, necessarily depend for their accuracy.

SECONDARY TIDAL STATIONS IN THE SEASON OF 1898.

In this season, an investigation of the tides in the Bay of Fundy was made. This bay has a length of 154 miles from Bryer Island to Cumberland Basin, and a width of 36 miles. The chief object of the investigation was to determine the relation between the tides in the bay, and the principal tidal station at St. John, N.B., by means of simultaneous observations at a series of points around the bay, obtained with self-registering tidal instruments. Another object was to ascertain where the dividing line should be drawn, on the south-western coast of Nova Scotia near the mouth of the bay, between the ports that can be referred to St. John on the one hand, or to Halifax on the other, as their port of reference. The tidal data obtained will also serve as a basis for the investigation of the tidal currents of the Bay of Fundy, when this is undertaken.

In making a selection of the places around the bay most suitable for the purpose, the points at which the Establishments had already been determined by the Admiralty, were given the preference. Consideration was also given to places at which there were wharves extending to low water; but the best information that could be obtained in advance as to this, was found to be quite misleading when the places were visited.

The positions of the stations, and the points at which Establishments had previously been determined by the Admiralty, are shown on the accompanying map, Plate I. The stations chosen were all equipped with self-registering instruments, in order to obtain a continuous record of the tide.

Tidal Stations in the lower part of the Bay of Fundy.—In this part of the bay below St. John, four stations were established; at Yarmouth, at Westport on Bryer Island, and at Digby, on the Nova Scotia side; and at Campobello, on the New Brunswick side. Tidal data at Yarmouth are not only important for that harbour itself, but they will also enable comparisons to be made in the two directions with Halifax and St. John, as above mentioned, to show how far tidal differences from those two ports of reference should be extended along that coast. Westport may properly be considered as at the mouth of the Bay of Fundy; and the tidal data at Yarmouth and Westport should prove to be the most closely related to the strong tidal currents at the mouth of the bay, when these come to be investigated. The station at Digby is at the new pier at the town of Digby, inside Annapolis Basin. Although the Admiralty Establishment was determined at the entrance to Digby Gut, the practical advantage of this position had the greater weight; as the Digby pier is now used by the recently established steamship service, which makes through connection from St. John to Halifax.

To obtain comparisons with the tide of the open bay, measurements of the range of the tide were made during two periods of spring tides at Prim Point, outside of Digby Gut, on the south side. These measurements were made by William Ellis, light-keeper at the Point. They were taken from a beam set to project over a vertical cliff at the lighthouse, the level of the water being measured directly from it with a standard tape. The comparison with the simultaneous tidal record at Digby within the Basin will show the effect of the narrow entrance in modifying the tide in the basin relatively to the tide in the open.

On the New Brunswick side there was more difficulty in the choice of a position for a tidal station. The western part of the New Brunswick coast, which is the limit of Canadian territory next to the State of Maine, is broken into islands forming channels which lead into large water areas enclosed behind them. These occasion much local interference with the general course of the tides, and give rise to irregularities which are already manifest from the Establishments which have there been determined. The southern end of Grand Manan Island would have been very suitable, as it is nearest to the mouth of the bay, and stands in best relation to Westport on the other shore. Unfortunately, however, there is no wharf there which extends to low water. The choice of Campobello Island was finally made, as giving on the whole the best advantages, and the tide gauge was placed at Welchpool. This was formerly the residence of Admiral Owen, and the Establishment is there well determined from tidal observations which extend from October 13th, 1845, to October 21st, 1847, with less than three months' interruption in all. Welchpool is also on a channel directly opposite Eastport in the State of Maine, where tidal observations have been obtained during one complete year in 1862, by the United States Coast Survey, and the present observations there will thus serve to make connection with the United States series. There is also a good depth of water at the wharf at the lowest tides, contrary to the information obtained before the place was visited.

The chief disadvantage of this station from a tidal point of view, is its proximity to the large area of Passamaquoddy Bay, which may have a very appreciable effect in modifying the tide. This may account for the difficulty already met with in the endeavour to determine a constant difference in the time of the tide between Eastport and St. John. A comparison between the tide as calculated for Eastport and the tide as observed at St. John, was made for a period of eight months in 1893; and the difference in absolute time with the omission of some extreme values, was found to have the following range:—High water at Eastport, 37 minutes earlier to 29 minutes later than at St. John. It is hoped that the comparison which will now be available between simultaneously observed tides at the two places, will give a more satisfactory result.

At all the four stations in the lower part of the bay, the whole tide to low water was obtained; except at Westport where the end of the wharf dries at the lowest of the spring tides.

Tidal Conditions in the upper part of the Bay.—In the Bay of Fundy above St. John, after personal examination and careful inquiry, there were no wharves to be found which extend to low water; nor are there any cliffs rising out of the deep water to which a tide gauge can be attached, except at one point which is several miles distant from the nearest house. To obtain a record of low water would therefore require special arrangement, and more outlay than can at present be met by this survey. The value of obtaining low water is also of less importance in this region than it usually is elsewhere, if the question of navigation is alone considered; as steamboats have to time their arrival for high water, and leave before the tide falls; while sailing vessels which are mostly of the smaller sizes, can lie conveniently on the bottom alongside the wharves to unload. It is for this reason that so little endeavour is made to extend wharves to low water. Instead of lying afloat and rising 30 or 40 feet against the side of a wharf, a vessel runs in at high water as far as its draught will allow, and lies aground during the greater part of the tide, with little change in its level, which much facilitates unloading. The bottom throughout the upper arms of the bay, below the first few inches of soft red mud, has the consistency of stiff clay and is almost devcid of stones, which much favours this practice. Where there are any local difficulties, a bench or stage of mattress-work is placed in front of the wharf, for vessels to lie on, while the tide is out.

In these conditions, it is the time of high water which is of primary importance to navigation; and next to this, the period of time during which the tide remains sufficiently high to give floatation for a vessel of moderate draught. These data can be deduced from a tidal record which gives the upper half of the tide only.

On the other hand, the form of the complete tide curve is not obtained, nor the data for mean sea level; and the time of low water can only be obtained roughly between the upper parts of the tide as registered.

To obtain a complete record of the tide with a self-registering instrument, it is necessary to have the whole tide rising and falling in one vertical column. In a region where the range of the tide is from 40 to 50 feet, special construction for the tide gauge would be required. If readings on a graduated staff were sufficient, it would not be necessary to have the whole height at one point. One staff could be set at low water mark with a height of some 12 feet, and another further up the slope of the beach, and so on in succession. The cost of taking observations by this method would be several times greater than with a self-registering instrument, and the information obtained would be less than half, as the night tides would be lost.

The wharves, which extend to about half-tide, are already long; and the tide recedes nearly quarter of a mile beyond their end, exposing wide mud flats. In these circumstances the choice seems to lie between the following alternatives: To build an erection of some 50 feet in height at low water mark, to support a vertical pipe which would serve as a tide column for the gauge. Such an erection would need to be substantially braced to withstand the strong tidal currents; and it would have to carry a light, as a warning to shipping. The other alternative would be to take advantage of existing wharves to get as far out as possible; and to sink a tide-well at the end of the wharf, in which the tide would rise and fall by means of a siphon connection, extending to low water. For this siphon to work satisfactorily, the well should not be more than 20 or 25 feet deep, taking up that height at the lower part of the range of the tide. The siphon pipe should also be large relatively to the tide-well; as the rate of rise and fall is as much as eight feet per hour. The chief difficulty arises from the excessively muddy character of the water, which would soon choke up the pipes, unless special provision were made for cleaning them out.

This method of siphoning was tried at Moncton with success; although the height siphoned was only nine feet. The difficulty there was to make arrangement to enable the siphon to work inwards, and fill the tide-well during the rapid rise after the arrival of the bore. The rise then was at the rate of 18 feet per hour for more than half an hour. The tide well was 12 inches in diameter, of rivetted iron plate ; and 12 feet deep. The ground in the river bank through which it had to be sunk, was tough and stony. From the top of this tide-well, a tide column of the usual construction was carried up to the top of the wharf. The siphon was of 1½ inch pipe, which was the largest size that could be had there. The inner leg was vertical and passed down inside the tide-well nearly to the bottom, to allow some margin for the deposit of mud there. With these sizes of pipe, there was still room for the tide-float of six inches in diameter to work freely. The outer leg of the siphon formed a long incline extending 55 feet to the channel of the river. The bend of the siphon passed through the side of the tide-well at two feet below the top, and at the summit an air-cock was placed to allow any air to escape, while it was completely covered by the tide. For this purpose a ball-cock was used, made to remain open when covered; and to close when the tide fell to its level, before it fell to the bend of the siphon. In this way the ball-cock worked automatically, but from the excessive muddiness of the water there was so much deposit on the valve-seat that it did not close properly when left open for so long at a time. It had, therefore, to be re-arranged to open by hand by means of a chain extending to the top of the wharf. This was repeatedly tampered with, by unemployed persons who frequented the wharf, and the chain had to be boxed in completely for its whole height. At the outer end of the siphon, the water in the river was so shallow that cover could not be secured for it at all tides. The end of the siphon was therefore let into a cask to form a terminal well, and its level was carefully adjusted with relation to the bottom of the tide-well to keep the siphon from "breaking." This cask was bolted to a platform of planks, heavily ballasted to enable it to withstand the force of the bore. The front of the bore was almost always high enough to cover the cask over at once, so that the time of arrival of the bore was thus recorded on the gauge. With these arrangements the siphoning worked quite satisfactorily.

This was the only trial made of the method of siphoning during this season. If either of the above methods were to be used on a more extensive scale, the work should be begun earlier in the season to obtain full advantage of the expenditure upon them ; as they would not be likely to last through the winter for use another year. During this season the record obtained at the stations towards the head of the bay, was accordingly limited to the upper part of the tide.

In Minas Basin, the upper end of Cobequid Bay is cut off at low water by sand bars. The water is thus ponded in, and it does not fall to the true level of low water. Hence, although the highest tides make themselves felt nearly to Truro, the full range of the tide cannot be obtained above Noel Bay, which is 22 miles below. In this end of Cobequid Bay the level of low water, according to the chart, is eighteen feet above true low water.

The same remark applies to the Avon River, below Windsor. The bars across it form, at low water, a series of partial dams which pond the water in, in steps. Although there is still some depth at low water around bridge piers at Windsor, this does not represent the true low tide level. Accordingly, the furthest points for which the Admiralty Establishments and the range of the tide are given, are Horton Bluff at the mouth of the Avon, and Noel Bay.

The Petitcodiac River at the head of Chignecto Bay, is more truly an estuary. As far up as Moncton, the tide continues to fall at a slow rate, up to the moment that the rising tide arrives as a bore. Yet at low water there is a water-slope all the way up from the mouth of the river. Accordingly, at Grindstone Creek, four miles below Moncton, the level of low water is about twelve feet higher than at the mouth of the river, as noted on the chart. The lower part of the tide is thus cut off by that amount. The spring range at Moncton is given in the Admiralty list as 47 feet ; but this is purely theoretical, as the actual rise at spring tides, from the level to which the water falls in the river, is only 30 feet. The three points, therefore, at which the extreme range of the tide can best be measured, are in Cumberland Basin ; and at Horton Bluff and Noel Bay in Minas Basin. We will give figures for these ranges, further on.

Choice of Tidal Stations in the upper part of the Bay of Fundy.—In the choice of stations in this region, the above conditions had to be taken into consideration, and also the greatest direct advantage to navigation. In Minas Basin the two points of most importance in these circumstances were Parrsboro and Windsor. In the other arm of the bay, Hopewell Cape and Moncton were chosen. The gauge at Parrsboro is at Parrsboro Pier, beside Partridge Island; and there is an Establishment determined at West Bay, on the other side of Partridge Island, within two miles of the pier. Before deciding upon Windsor, the neighbouring coast was examined, as far as Kingsport; but there proved to be no wharf or bridge pier at which low water could be obtained. The choice thus fell to Windsor itself as the most important point. In Cumberland Basin at the head of Chignecto Bay, some tidal observations for the level of high and low water have been taken at the end of the proposed Ship Railway, but the Establishment in that basin is determined at Sackville. In the other branch of Chignecto Bay there is an Establishment at Folly Point which shows that the time of the tide differs only six minutes with Cumberland Basin. Hence either branch of the bay will serve the purpose in view. At Folly Point the cliffs are not suitable for the attachment of a tide gauge; and Hopewell Cape, which is directly opposite, was chosen as affording the best local facilities. Moncton may be considered as the extreme head of the Bay of Fundy; and it is hoped that the time of arrival of the bore there, which is a well marked moment, may throw some light upon the progress of the tide throughout the Bay of Fundy as a whole.

Next in importance to these as tidal stations, Noel Bay may be mentioned, being the point at which the greatest range of tide is found; and Herring Cove, a point on the New Brunswick coast directly opposite Cape Chignecto, where a breakwater is now being erected. A station in this vicinity would divide the distance between St. John and the head of the Bay of Fundy. These points can only be reached by stage, and the delay in receiving the last of the recording instruments from the makers, did not admit of time being found to place gauges there without neglect of the other stations.

Equipment of the Tidal Stations, and Description of the Stations Established.— The instrument used to record the tide at most of the stations is the Richard self-registering gauge. It is of a small size and simple in construction. It was placed for protection in a shelter box with a zinc cover, which was set on top of the tide column in which a float rose and fell with the tide to actuate the instrument. The scale gives a range of 16 feet; but as this was insufficient even for the upper half of the tide at most places, a wheel or tide pulley of double the diameter was attached to the instrument, to give twice the range on the height of the tide sheet. The score of this wheel was turned to the exact diameter required when the thickness of the cord was taken into account. This cord was attached to the tide float at one end, and after passing over the tide pulley which it turned by friction only, it was attached to a counter weight at the other end. The cord for the purpose was carefully selected; as a cord of galvanized iron used in previous seasons was so stiff as to throw itself off the wheel, and it was not durable in sea-water. A flexible copper cord was therefore used, made up of the finest wire. The float was of sheet zinc, six inches in diameter, ballasted with shot. The tide column was usually 10 inches square inside, and made of $1\frac{1}{2}$ inch board, planed on the inside. Sometimes tongue-and-groove sheathing was used, or such other material as could be obtained in the locality. The column required to have some strength, as the faces of the wharves were seldom truly vertical, and it could only be supported at intervals; and in pile wharves, it had to be braced between the piles or from their walings. For the upper part of the bay, a small cistern or pan was placed in the bottom of the tide column, below the level of the inlet; so that when the tide left the foot of the column, the tide-float remained floating in it, without upsetting.

At Yarmouth and Digby the recording instruments were of the larger type designed by myself for the principal tidal stations. These were used because of delay in receiving the last two Richard gauges from the makers, and because it is hoped that the observations at Yarmouth can be continued throughout the winter. These gauges are provided with interchangeable gearing, which enables them to be set for a range of 9, 18, 27 or 36 feet, with a tide sheet of nine inches in height for all these scales. This was a convenience, while on the other hand a good deal of special planning was required in fitting up these larger instruments. The arrangements adopted to meet the special requirements, it will not be necessary to describe in detail, however.

The instrument of either type made its record by a pencil line, which is afterwards inked in, with a series of coloured inks to represent the different days of the week. The observers were instructed to change the tide-sheets twice a week to avoid confusion of the tide curves. They also made a comparison each day, between the height of the tide as shown on the tide scale and the reading of the recording instrument. From these comparisons a base line is obtained as a uniform datum for the true height of the tide, which avoids placing dependence upon the correct setting of the tide sheet for height on the instrument. When this comparision was made, the time as shown on the instrument was also compared with the true time; and the error, fast or slow, carefully noted. All time errors can thus be allowed for, in reducing the observations. As the tide sheet is changed twice a week, and the clock cylinder is then set correctly to time, the time error cannot become very large in the half week, and is usually inappreciable if the clock-work is well regulated.

A list of the stations established, with the length of the record obtained, and the height of the tide recorded, is given below:—

Yarmouth, N.S.—Gauge situated in the town of Yarmouth, at a wharf belonging to the Yarmouth Steamship Company, known as Baker's Wharf. Gauge placed in the south west corner of a freight shed, which stands across the front of the wharf. The wharf is built on piles, and the gauge column is braced in between them.

Tidal record from June 24th to date. The total range of the tide is recorded to low water. Observer, Captain J. E. Murphy, Meteorological observer.

Westport, Bryer Island, N.S.—Gauge placed at the end of Captain Payson's wharf, immediately in front of the Central House; which is situated on Water Street, 620 feet north-eastward from a cross street running inland past the Baptist Church.

Tidal record, from July 7th till the end of December, with some weeks interruption. The total range of the tide is obtained, except at the lowest spring tides. Observer, Frank Morrell, Signal officer.

Digby, N.S.—Gauge placed at the north side of the Digby pier about 40 feet from the end.

Tidal record, from June 30th till December 18th. Total range of tide is recorded. Observer, N. A. Turnbull, Meterological observer and station agent.

Campobello, N.B.—Gauge placed at the back of the "L" at the head of the steamboat wharf at Welchpool, Campobello Island.

Tidal record, from July 15th till November 15th. Total range of tide is recorded. Observer, A. J. Clark, Customs officer.

Parrsboro, N.S.—Gauge at Parrsboro pier, near to Partridge Island. Attached to the east side of the pier, at about one-third of the distance from the shore end, where the side is most vertical.

Tidal record, from July 22nd till October 14th. Height of tide recorded, 21 feet below extreme high water, nearly down to mean sea level. Observer, Dr. W. H. Magee, Meteorological observer.

Windsor, N.S.—Gauge placed at the west corner of the railway wharf; forming part of the property which extends to the water front from the railway station.

Tidal record, from August 16th till November 18th. Height of tide recorded, 13 feet below ordinary high water at spring tides. When the tide falls to this level, the wharves at Windsor are left dry. Observer, Charles Cook, Midland railway office.

Hopewell Cape, N.B.—Gauge placed in the angle, behind the head of the pier, for protection, the foot of the tide column being set three feet into the clay. Inlet for the tide obtained by an iron pipe led around the corner of the wharf to the front.

Tidal record, July 30th till November 15th. Height of tide recorded, 14 feet below high water. Observer, Captain J. L. Pye, Customs officer.

Moncton, N.B.—Gauge placed at the upper corner of Dunlap's wharf, at the foot of Pleasant street. Tide column attached to the side of the wharf, and continued down 12 feet into the ground as a tide-well, made of 12-inch iron pipe. The tide empties and fills this tide-well by siphoning, as already described.

Tidal record, August 10th till November 18th. Height of tide recorded, 27 feet below high water. Observer, G. W. McCready, C.E., former City engineer.

The first six of these gauges, beginning with those of the most importance, were thus erected between June 20th and July 30th or in just six weeks, which includes the time occupied in travelling, and sufficient time to instruct the observer in his duties. This amount of time was too limited; and it is also advisable to revisit the stations about a week after they are put in operation, to meet any difficulties which the observer may encounter in work which is new to him; but this could not be done. As it was, it was well on in July before simultaneous results began to be obtained, which are of the most value in work of this character. To avoid such pressure, the work should have been begun earlier; but towards the close of the fiscal year which ends on June 30th, the funds were nearly exhausted.

Data for time and height.—The most important requirement for the success of tidal observations, in the means of obtaining the time accurately at the various stations, and in the present instance this proved the chief difficulty. Next to this, it is important that the height of the tide should be referred to a permanent bench mark, especially in towns of any importance; as this furnishes a lasting record for the height of the tide, and makes the observations available for reference in any future harbour works, or for the determination of Mean Sea Level. As we are still without any uniform system of connected levels in Canada, these bench marks are necessarily isolated in the mean time, but they are at once available for local purposes, and they will be of the highest service in furnishing the value of Mean Sea Level, when a general system of levelling throughout the country comes to be made. An International Geodetic Conference has recently been held at Struttgart, and one of its tasks is to ascertain how far such levelling has been carried in the various countries of the world, and at what points on the various oceans, Mean Sea Level has already been determined.

On one side of the Bay of Fundy, in the province of Nova Scotia, standard time for the 60th meridian is now used everywhere; although it is known by the misnomer of "local time," to distinguish it from Eastern standard time, one hour later, which is used on the railways. On the other side of the bay, in the province of New Brunswick, the question of which standard time to use, whether for the 60th or 75th meridian, has not yet been decided, and consequently in some places local time is still used. In these circumstances it was found best to use at the tidal stations such time as could best be obtained. Where there were railway stations on one of the principal railways, the noon signal, sent along the line by telegraph, was taken advantage of. But this signal is not sent along the branch lines as a rule. At some places there was no existing means of getting correct time, and special arrangements had to be made to obtain it. The character of the time used at the tidal stations, and the way in which it was obtained, are as follows:—

St. John; the principal tide station or port of reference. Local time; the longitude of the St. John observatory being 4 hrs. 24 min. 16 sec. W.

Yarmouth.—Standard time for the 60th meridian. The tidal observer, Captain J. E. Murphy, has charge of the Meteorological station, which is also equipped with chronometers, and he is thus able to furnish the time with accuracy for the tide gauge.

Westport, Bryer Island.—Standard time for the 60th meridian. The arrangement made for Westport, was to have the railway time sent on twice a week by long-distance telephone, 41 miles, from the Digby railway station. On this telephone connection there are three repetitions; but with care, the time thus transmitted could be depended upon within a minute. To keep the time during the course of the week, the observer was also provided with a Seth Thomas engine-room clock, a make which it was expected would prove reliable; but unfortunately this one gained over ten minutes a day, and was so sensitive to its regulator that it could not be regulated. The uncertainty in the time which resulted from this, has made the observations of comparatively little value up to the middle of August. When the station was revisited early in September, to avoid any further uncertainty, a meridian mark was set out, by which the sun's meridian passage can be readily obtained to the nearest minute; and to accompany this, a table was calculated for the observer, which gives standard time at apparent noon. In preparing this table, the difference of longitude from the standard time-meridian was allowed for, as well as the equation of time; so that the observer has merely to see that his watch shows the time given in the table at the moment of apparent noon. In this way the character of the time used was not changed; and the time signals by telephone could still be made use of in dull or foggy weather, without confusion.

Campobello. Tidal station at Welchpool.—At first, Eastport local time was used, as there is communication several times a day by ferry with Eastport, which is only two miles across the water. The time thus obtained, varied so much as to be uncertain within two or three minutes. This uncertainty obtains in the earlier part of the observations; but as soon as it was reported by the observer, an arrangement was made with Captain Ingersoll of the steamer "Flushing," to bring St. John local time with him once a week, on his regular trips; which he kindly consented to do. As the "Flushing" is not in port at the hour that the time-ball drops on the St. John observatory, he obtained the time from a leading watchmaker in St. John who keeps a chronometer running on local time, which is regulated direct from the observatory. It may be noted that the sun-dial erected by Admiral Owen at Welchpool was on a wooden pillar, and is now broken down. The time used at this station is, therefore, as follows:—

Up to August 11th, Eastport local time, corresponding to longitude 4 hrs. 27 min. 56 sec.; and from that date forward, St. John local time, corresponding to longitude 4 hrs. 24 min. 16 sec. W.

Windsor.—Standard time for the 60th meridian; one hour faster than railway time as obtained by noon signal at the railway station.

Parrsboro.—Standard time for the 60th meridian, as above.

Hopewell Cape.—Local time, obtained from a meridian mark, set out at the Custom house. The observer was provided with a table which shows local mean time at apparent noon; based upon the equation of time. This place is in communication with Moncton by long-distance telephone; but the connections are not sufficiently direct to enable the telephone to be used for time signals. The longitude of Hopewell Cape is 4 hrs. 18 min. 20 sec.

Moncton.—Eastern standard time for the 75th meridian, or railway time, which is used generally in Moncton. The moment of noon is struck on the bell of the City Building, from the office of the Chief engineer of the Intercolonial railway.

Bench Marks, Tide Scales and Tide Levels.—At the stations which were considered of sufficient importance, bench marks were established, to which the zero of the tide scale used for the observations, was referred. This tide scale consisted of a painted board, divided into feet and parts of a foot, attached to the tide column; and by it the recording instrument was set for height.

It was not thought necessary to establish a bench mark at Welchpool on Campobello Island, at Westport on Bryer Island, or at Hopewell Cape. At these stations the height of the tide was measured on a scale of feet which has its zero at the level of the inlet at the foot of the tide column. At Moncton there are existing bench marks to which the Moncton City datum is referred; and these were made use of, in establishing a plane of reference for the tide levels there.

The new bench marks established this season by the Tidal Survey, and those made use of at Moncton, are described below; as these serve to fix permanently the levels of the tide as found by the observations. Some leading tide levels are also given with these, as well as the elevation of the zero of the tide scale at each station.

Yarmouth.—There was difficulty in finding anything suitable for a permanent bench mark, in the vicinity of the tide gauge, all the buildings and wharves there being of timber. The brick chimney of the Kentville Lumber Company was selected, as it stands on a stone base built in cement; and as the foundation is carried down to the rock, it is not liable to settlement.

	Feet.
Bench Mark ; the joint between the stone base and the brickwork, at the north-west corner of the above chimney. Elevation	108·53
Top of rail at the railway crossing at the foot of Forrest street. Average elevation at both sides of track	100·00
Surface of planking of wharf at the tide gauge	91·85
Highest high water observed in the season of 1898 : July 4th, p.m.	90·45
Lowest low water observed : July 5th, a.m	74·15
Zero of Tide Scale, at the level of the inlet at foot of tide column	72·36

Westport.—Between July 7th and November 24th :—

Highest high water on tide scale : 1898, Aug. 2nd, p.m	18·80
Lowest low water : August 3rd, a.m	— 1·60

The greatest range here observed is thus, 20·40 feet.

Digby.—There was the same difficulty here as at Yarmouth. A bench mark was cut on the masonry of a high flight of stone steps of red granite, in front of Mrs. Marshall's house. The mark is a chisel line and broad arrow, cut in the middle of a long granite block, on the back of the steps, facing the east. The house is a wooden one with a stone foundation, on the north side of the road which leads back, landwards, from the head of Digby pier. It stands at a distance of about 340 feet from the shore end of the pier.

The granite-work of these steps is heavy and well built above ground, but the foundation below the ground level is of small and poor rubble. The granite-work has cracked through, along joint lines, in two places, and some settlement may have occurred. This is, however, the best stone-work to be found in the neighbourhood.

	Feet.
Bench Mark, as above. Elevation	105·80
Top of timber cap, north side of pier at shore end, nearly opposite the high water mark on the beach	98·75
Top of cap, north side of pier, opposite upper end of landing slip	99·10
Top of cap, north side of pier, at the tide gauge column. Elevation taken as 100·00 for convenience in tide measurements ; the other elevations being determined relatively to this	100·00
Highest high water observed up to the end of November : on July 3rd, p.m.	93·90
Lowest low water observed : July 5th, a.m	64·20
Inlet at foot of tide column	63·00

Campobello.—Heights on tide scales used ; not referred to a bench mark.

Highest high water on tide scale in the season of 1898 : August 2nd, p.m.	29·00
Lowest low water : August 3rd, a.m	5·50
In the observations of 1845 to 1847, the highest high water recorded on the tide scale then used, occurred in 1846, January 27th, a.m.	27·00
The lowest low water occurred in 1846, December 20th, p.m	1·40

Hence the extreme range then observed was 25·60 feet.

Windsor.—Bench Mark A. On the Wilcox building ; a brick building situated on the south-east side of Water street, corner of Gerrish street. The point used as a bench mark is the top of the cut sandstone plinth, on the Water street front, at the end next Gerrish street ; being the joint between the sandstone and the brickwork above.

Bench Mark B. On a brick building bearing the name of W. H. Roach & Co., situated on the north-west side of Water street, directly opposite the above. The point used as a bench mark is the top of the cut sandstone plinth, at the east corner of the building, below the brickwork.

	Feet.
Bench Mark A, as above described. Elevation adopted	100·00
Bench Mark B, as above described	100·03
Rail level on Water street, opposite foot of King street	98·26
Cap of Wharf at the tide gauge	95·19
Highest tide observed in the season of 1898 : September 1st, a.m	93·70
Zero of Tide Scale, at the level of the inlet to the tide column	81·07

The surface of the mud beach in front of the wharf is one foot below the inlet to the tide column. The beach is there at much the same level as at the other wharves. Hence the greatest rise of the tide against the wharves is nearly 14 feet.

The buildings above described were burnt when the town of Windsor was destroyed, in the autumn of 1897; but as they have been rebuilt on their old foundations, it is not likely that any settlement will occur to effect the elevation of the points used as bench marks.

Parrsboro.—Bench mark for the tide guage at Parrsboro pier, near Partridge Island. The mark is a chisel line and broad arrow, cut on a sound stone in the south wall of a small stone building, formerly used as a school, now used as an ice house, situated as follows: At 290 feet from the shore end of the pier, along the main road leading northward to the town of Parrsboro, a cross road turns off to the westward; and the buiding is on the north side of this cross road, at 200 feet along it from the corner.

	Feet.
Elevation adopted for this Bench Mark	100·00
Top of timber cap of pier, at shore end	57·02
Top of cap, at outer end of pier	52·55
Extreme high water which overflows the greater part of the pier:—Highest point reached by the tide on planking of the pier, as pointed out by Dr. Deerborne who has occupied a cottage close to the head of the pier for several seasons	56·69
Beach of coarse gravel which slopes back on the inland side; extending in a wide sweep from the pier to Partridge Island. It is overflowed at extreme tides. Elevation of top of beach near the pier	56·30
High tide which overflowed the pier in July, 1898, as marked near the top of a mooring post by the crew of the steamer, "Evangeline," which makes daily trips to Kingsport	55·53
Highest tide recorded on the guage during the season of 1898: August 3rd, a.m.	54·85
Zero of Tide Scale, at the level of the inlet to the tide column	34·15
Surface of beach at outer end of the pier; dry at low water	18·25
Low water spring tides, observed when levels were taken, July 23rd, 1898	14.53

According to the best information that could be obtained, the tide falls at extreme low water about five feet below this low water of July 23rd. The difference between this level and the elevations for the extreme high tides as above given, would thus give 47 feet for the extreme range at Parrsboro.

Moncton.—The Moncton City datum was here made use of, which has been carefully established and referred to bench marks by Mr. G. W. McCready, while he occupied the position of City engineer. To avoid negative values, however, in extending the elevations to include tide levels, a plane of reference was adopted at 100.00 feet below the City datum. This merely amounts to adding 100 feet to the elevations, as measured from the City datum. The addition is made in all the elevations here given.

City Bench Mark.—Surface of the stone door-sill of the City Building, at the east side of the entrance, where it is not worn. Elevation, 128·16.

On a brick building on a stone foundation, at the south-east corner of Duke and Main streets; diagonally opposite the Post Office. The point used as a bench mark is the top of the stone foundation at the corner of these streets; which is about an inch above the level of the asphalt side walk. Elevation, 133·54. (This bench mark was used for reference in determining all the tide levels of this season.)

Bench Mark of the Public Works Department; at the front end of the Sugar Refinery. Surface of the door sill at the east side of the eastern entrance. Elevation, 119·33. (The elevation of this bench mark above the Public Works datum is 101·27; high water spring tides being taken as 100.00.)

	Feet.
The Saxby Tide at Moncton; the highest tide known in the Bay of Fundy; which occurred October 5th, 1869	126·09
Exceptionally high tide, October 12th, 1887; as marked by the Harbour Master	119·66
Exceptionally high tide, October 8th, 1896; from levels taken by the I.C.R. Engineers at the time, by request of the Tidal Survey	118·91

	Feet.
Highest high water observed in the season of 1898; August 31st, p.m.	117·06
Tide levels adopted by the Public Works Department, for the construction of wharves:—	
High water spring tides	118·06
High water neap tides	108·56
Cap of Dunlap's wharf, at the south-west corner, where the tide gauge was placed. Elevation in August, 1898.	118·98
Top of 12-inch iron pipe, forming the tide-well of the tide guage	100·66
Zero of Tide Scale of the guage; being the level of the bottom of the tide-well, which is twelve feet deep.	88·66
Low water spring tides: lowest observed during the spring tides at the begining of August and at the end of September, 1898	87·88
Lowest low water during the season of 1898: October 20th	87·81
Extreme low water, opposite the mouth of Hall's Creek; as determined by Mr. McCready while City Engineer	87·75

The Bore at Moncton.

Moncton is situated on the Petitcodiac River, immediately above the point known as "The Bend," where its direction turns sharply at a right angle. This is at 19 miles above the mouth of the Petitcodiac, at Folly Point, where it enters the Bay of Fundy. This part of the river is more correctly an estuary, which continues 13 miles further up, as far as Salisbury Junction. At high tide the river at Moncton forms a sheet of water half a mile in width; while at low tide it consists of mud banks and flats, with a stream about 500 feet wide running with a strong current in a devious channel amongst the bars and mud flats, which are left dry at low water.

The run of the rising tide first breaks into a bore at Stony Creek, eight miles below Moncton; and it continues to the head of the estuary at Salisbury, 13 miles above. The total distance on the river that a bore occurs is therefore 21 miles.

With regard to the time of arrival of the bore at Moncton, this really corresponds with the time of half tide. At the central moment between the previous and the following high water, which we may term the theoretical time of low water, the level of the water in the river is still falling; and it continues to fall, though at a much slower rate, for about three hours longer before the bore arrives. The time of the arrival of the bore is, thus, only about three hours before the next high water, which serves to account for the very rapid rise which takes place after the bore passes.

The rate at which the tide falls, amounts at its maximum, to eight feet per hour; but after the theoretical time of low water, the rate of fall soon becomes very slow, and the river appears to a casual observer, to remain at the same level for some two hours before the arrival of the bore. The flow, however, continues to be fairly swift; and it no doubt still consists of tide water. The rate of fall in the level of the water, as measured shortly after spring tides, was found to be as follows:—

From $4\frac{1}{2}$ to $2\frac{1}{2}$ hours before arrival of bore, rate of fall	*six inches*	per hour.
" $2\frac{1}{2}$ to 1 hour " " " " "	*four inches*	"
" 40 m. to 15 m. " " " " "	*three inches*	"

The first observation of the bore was made on the evening of August 4th. The standpoint was the wharf furthest down stream, nearest to the bend. It commands a view of some two or three miles down stream below the bend, as well as the foreshore up-stream, opposite Moncton. The moon was a little past the full, and was well risen before the bore arrived; and the sky was then clear also. There was a very slight breeze and in the stillness sounds could be distinctly heard. It was thus at the spring tides, and 24 hours after the lowest of the tides at that moon.

The first sound of the approaching bore was heard at $23^h\ 08^m$, in 60th meridian time, and two minutes later the sound was quite distinct. This sound was very similar to the noise of a distant train when heard across water. It afterwards increased to the usual hissing and rushing sound of broken water, as in a rapid on a river; but there was no mingling in this sound, of any roar such as a waterfall makes when falling into deep water, even from a moderate height. The bore arrived at the wharf at 23^h 19^m, or eleven minutes after its sound was first heard. The rapidly-flowing layer of incoming tide advanced over the current of the river in the opposite direction, with a front of broken and foaming water, which had a height of perhaps two or three feet. The front edge was by no means straight. The higher part of the bore extended across the waterway, and this was bent back and also heightened in the middle by the opposing current of the river, which is naturally swiftest at the centre of the stream. Beyond this, the bore formed a long sweep where it broke over the flats, retarded and decreasing in height towards the further bank of the river.

The surface current of the water following the main front, has the same speed of flow as its rate of advance; and after the main front passes, there usually follow a series of others, stepped up a few inches of additional height. These form irregular lines of curve across the surface of the advancing tide, which do not extend far without interruption. These may be due in part to back-wash from the flats, into the main channel. As seen in the day time, the water forming the bore is excessively muddy and reddish-yellow in colour, just as the outflowing water of the river also is. The actual broken water in the front is nearly white, except at the shore end; but the long edge of the advancing water on the flats appears nearly black in strong sun-light. With a stiff breeze down stream, the sound of the bore cannot be heard till it has approached within a few hundred yards.

During the neap tides, the bore still appears; and the front edge usually breaks a few inches high. But there are times when it consists merely of a heavy ripple, like the side waves from the bow of a steamer, when they are advancing over still water; and it then only breaks occasionally, except in passing over the flats.

Rate of Travel of the Bore.—Its rate of advance was timed from a point of observation on one of the upper wharves, which commands a view around the bend of the river; and the moment of its successive arrival at a series of points was exactly noted. The distances between these points were taken from a plan of the river front at Moncton; but the distance to the lowest of the points could not be ascertained with certainty; and it is therefore omitted. The following result was obtained, from observations at the 3rd and 5th tides after the highest spring tide at the beginning of August.

Intervals.	Distance between the points.	On Friday, 5th August.		On Saturday, 6th August.	
		Interval of time.	Speed in miles per hour.	Interval of time.	Speed in miles per hour.
	Feet.	m. s.		m. s.	
From mouth of Hall's Creek to Public Wharf	1,550	1 50	9·61	1 57	9·03
From Public Wharf to Sumner's Wharf	1,175	1 45	7·62	1 45	7·62
Mean Values	....	....	8·61	....	8·33

General average 8·47 miles per hour.

An endeavour was made to obtain a measurement of the time taken by the bore in passing up the river from Stony Creek to Moncton; but the simultaneous observations required could not be arranged for.

Form of the Bore.—To ascertain the form of the bore, and its rate of rise, a graduated board 13 feet high, was set up in front of the wharf, at which the tide gauge was placed. It was attached to the corner of the crib-work and brush, set at a low level in front of the wharf for vessels to lie on at low tide; and it was braced against the current. This current, after the bore passes, appears to have the same surface velocity as the rate of advance of the bore itself, which is given above. In these circumstances, the graduated board had to be renewed from time to time; but the elevation of its zero was correctly determined in each case, in relation to the levels established at the tide gauge. It would no doubt have been better to have set the graduated board well out in the bed of the river, where the water has freer course, if it had not been so difficult to do so. But as soon as the low crib work was covered, the board stood in the open water, at almost 20 feet from the end of the wharf. The water in the rapid current was rather rough on the surface, although sometimes it would smooth down for a few moments. It was therefore best to take the observations by noting the time at which its average level rose to each of the divisions on the board. When the tide rose to the top of the board, its further rise could be read from the scale on the tide column itself, if desired.

The height of the bore, as observed at spring and neap tides, and the rise of the water following it, are shown in the accompanying diagram, Plate II. The rise is by no means uniform. There are at times distinct steps, which are sometimes visible as such, on the surface of the incoming water. At other times the water holds its level for a short interval, and then rises rapidly afterwards to make up. These irregularities in the rise were noted as correctly as possible, and they are shown in the diagrams.

These diagrams may also be taken to represent the form of the bore, or its profile along the river at any given moment. Strictly speaking, this involves the assumption that the whole mass of water moves forward at the same speed as the broken front which forms the bore itself; which in all probability is not very far from the truth. To assist this view, a scale of distances is given on the diagram, which is based upon the average rate of advance of the bore in running up the river. An abstract of the observations is also given in the following table, in order to show some of the results more clearly in figures. In this table, only the even feet and half feet are given, and the irregularities in rise are omitted; as to show these it would be necessary to tabulate the observations for each date separately, and they are already represented in the diagrams.

THE BORE IN THE PETITCODIAC RIVER AT MONCTON.

RATE of Rise at Spring and Neap Tides, as observed on a Scale of Feet at the Tide Gauge. The time is Standard Time for the 60th Meridian. Year, 1898.

Height on Scale of Feet, &c.	Saturday, 6th Aug. — 5th tide after highest springs.	Time in rising one foot.	Tuesday, 9th Aug. — 11th tide. (Neap tide).	Friday, 30th Sept. — 1st tide before highest springs.	Saturday, 1st Oct. — Highest spring tide.
Elevation of Zero of scale of feet...	88·13	....	88·13	88·26	88·26
Level of low water when Bore arrived..........	3″ below 0	....	0′ 0″	0′ 8″	0′ 8½″
	h. m. s.	m. s.	h. m. s.	h. m. s.	h. m. s.
Time of arrival of Bore at gauge...	12 29 50	....	14 44 05	9 21 07	10 02 02
Height, 1 foot..........	....	....	14 44 25	....	....
" 1½ "	....	....	45 40	....	....
" 2 feet..........	12 30 00	....	46 45	....	....
" 2½ "	....	0 45	48 40	9 21 12	10 02 10
" 3 "	12 30 45	....	50 35	9 21 30	02 25
" 3½ "	....	3 45	52 25	21 40	02 40
" 4 "	12 34 30	....	55 40	22 20	03 35
" 4½ "	....	2 45	....	23 35	04 42
" 5 "	12 37 15	....	15 00 20	25 30	06 35
" 5½ "	....	3 35	02 00	27 10	08 20
" 6 "	12 40 50	....	04 30	28 40	10 20
" 6½ "	12 41 40	2 50	07 35	....	11 35
" 7 "	12 43 40	....	11 20	31 15	13 15
" 7½ "	....	3 35	14 00	32 30	14 20
" 8 "	12 47 15	....	17 35	34 05	15 55
" 8½ "	12 48 00	3 55	19 25	....	....
" 9 "	12 51 10	....	22 00	38 40	19 25
" 10 "	....	....	26 40	43 30	24 00
" 11 "	....	....	15 33 45	46 30	28 15
" 12 "	....	....	....	50 00	31 20
" 13 " 3 inches..........	....	....	....	9 55 30	10 37 15

It thus becomes evident that the bore itself is, in reality, the broken water at the front edge of a long water-slope which advances up the river. The greatest rate of rise at spring tides after the bore had passed, amounted to 3·00 feet in 10^{m} 05^{s} ; and if we take for the average speed $8\frac{1}{2}$ miles per hour, the equivalent water-slope is 2·10 feet per mile. This slope appears very moderate in the circumstances, although it is really greater than in most rivers, except where rapids occur. Also, as a question of hydraulics, this slope would undoubtedly prove to be in correspondence with the speed of the current following the bore, if the problem were fully worked out.

Height of the Bore.—It is said that formerly the bore used to be higher than at present, owing to changes that have taken place in the bars in the river, which now obstruct the channel at low water and interfere with its development. No very definite information could be obtained as to this. It was stated by the master of a schooner, that in the old days when his schooner lay on the step in front of the wharf, which was four feet above low water, the schooner drawing nine feet would be floated by the first rush of the bore. This is an evident exaggeration, through failure to notice the rapid rise of the water after the bore passes. On the 22nd August, 1892, a good photograph of the bore was obtained, which has been published in a report of the Geological Survey. Its height as then measured, was 5 feet 4 inches. In quoting this figure, it is to be noted that the rise of the water immediately after the bore passes, is so rapid that a few minutes delay in taking a reading on a graduated staff, would greatly increase the height which would be observed. From the observations above tabulated, it is clear that in 3 to 4 minutes after the bore passes, the water has already risen an extra foot. The greatest height which was measured in the above observations was 3 feet 3 inches, although it would be a little higher at the middle of the river. This may probably be taken as a fair average at ordinary spring tides. The maximum no doubt occurs when the moon is in perigee at full or change, and also at its maximum declination, as this gives the greatest difference in favour of one of the two tides in the day. Something also depends on the level to which low water falls, as this practically adds to the height of the bore. The total difference, however, in the level of low water between spring and neap tides, and between one set of spring tides and another, was found to be little more than one foot altogether, as observed in the summer season. Late in the autumn, when the fresh water outflow of the Petitcodiac is increased, the water surface at low tide does not fall so low.

Time of arrival of the Bore.—The time of its arrival with reference to the time of high water, was worked out from the observations obtained while the tide gauge was being erected. The time of high water at Moncton was obtained by difference of Establishment, from the tide tables for St. John. The comparison shows that the time of arrival of the bore varies from 3^{h} 01^{m} to 3^{h} 34^{m} before the time of high water. This result may be subject to revision, as the arrangement of the gauge itself with its siphon attachment should secure a more extended record of the time of the arrival of the bore, as well as the true time of high water at Moncton itself for comparison.

It is hoped that the arrival of the bore, being a well defined moment, may serve to throw light on the whole question of the progress of the tide in the Bay of Fundy. When the entire series of observations are worked out, it may thus furnish information of value, as well as being in itself an interesting phenomenon ; and it was largely with this hope that as much attention was given to it.

The bore elsewhere.—The only other place in the Bay of Fundy at which the bore has been seen, is in the upper part of Cobequid Bay. The tide there used to arrive as a bore at Maitland, at the mouth of the Shubenacadie River ; but a change in the position of the sand bars below Maitland now prevents this. In running up the Shubenacadie, however, the tide still breaks occasionally into a ripple or miniature bore.

RESULTS OF THE SUMMER OBSERVATIONS.

The results of the observations of this year, with reference to the time of the tide and tidal differences, cannot yet be given, immediately at the close of the working season. The chief purpose of the observations is to determine a series of "tidal differences" with reference to the principal station at St. John. This will serve to give correctly the time of high water throughout the Bay of Fundy by difference of time, from the tible tables now issued by this Survey for St. John itself. In working out these differences, the tidal stations of this season will form the primary basis of the comparisons with St. John; and the Admiralty Establishments will then be used to interpolate tidal differences for intermediate points. The value to shipping of correct information with regard to the time of high water, is too evident to require emphasis.

A certain amount of information was also obtained this season with reference to currents in the Bay of Fundy; from captains and others who have had long experience there. This can be more suitably given with the information on the time of the tide, when the results of the tidal observations themselves are worked out.

The total cost of these observations was $951.44. This includes the establishment of the eight tidal stations, with travelling expenses, and the salaries of the observers during the season; but it does not include the cost of the tidal instruments used, or the salary of the Engineer in charge. The average cost per station is thus $119. This represents the amount expended in establishing the summer stations in the relatively cheap manner described; by which a record of the upper part of the tide only is obtained towards the head of the Bay of Fundy, where the greater range occurs. A much greater outlay would be required to secure a record of the full range of the tide there, by such methods as have been already pointed out in this report.

The length of tidal record obtained was just four months on the average at each station, after making deduction for interruptions, and also for any unreliable record resulting from uncertainty in the time used for the observations. The whole of the record obtained, can be utilized for simultaneous comparison with the principal tidal station at St. John, N.B., as no interruption occurred there during the season.

CONNECTIONS BETWEEN MEAN SEA LEVEL IN THE BAY OF FUNDY AND THE GULF OF ST. LAWRENCE.

Comparison based upon the original surveys of the European and North American Railway.—When the railway from St. John, N. B., to Shediac on Northumberland Strait was built, about 1859, the levels were taken more carefully than on most railway surveys; and the profiles and reports in which they are given, held out some hope of affording a connection of value between tide levels in the Bay of Fundy and in the Gulf of St. Lawrence. This railway was originally termed the European and North American, and such records as exist are now in the head offices of the Intercolonial railway at Moncton. Several days were given to the examination of this material and its reduction; and special tidal observations were taken at St. John, and instrumental levels, in the endeavour to re-determine the original railway datum, and to connect it with the tide levels as now determined by the gauge at that station.

The distance from St. John to Shediac is 108 miles, and continuous levels are shown on an old profile representing a preliminary survey in 1848. This is the only profile which is continuous, in the sense of being reduced to one uniform datum throughout. It is neatly drawn and has the appearance of being accurate, but there are no figures given for the heights, which have therefore to be found by scale. There are several horizontal lines on this profile, which represent the elevations of high tides, freshets, &c.; and two of these extend continuously throughout.

From careful measurements of the differences in level between these lines, as shown by special vertical scales which are given at the two ends of the profile itself, the level of high water spring tides at Shediac is found to be 20·00 feet below high water spring tides at St. John. This amount is altogether excessive, as shown by the later surveys when the railway came to be built. It is at least *seven feet* too much, and how this error came to be made must remain unexplained. We can only consider the result as quite unreliable.

A later source of information is afforded by a report by Mr. A. L. Light, Chief Engineer of the European and North American railway, which is dated 2nd February

1859, and is included in the "Report of the Railway Commissioners of the Province of New Brunswick for the year 1858." The railway was still under construction at that date, and it was expected that it would be completed in the spring of 1860. In this report there is a table occupying five octavo pages, which is entitled "Table of Gradients on Revised Location from St. John to Shediac." This table shows the length and inclination of each grade, and gives a series of elevations at each change of grade, in a column which is headed "Elevation above high water, spring tides, St. John." At the end of the table, there is a note which reads as follows:—"N. B. It will be observed that the Level of Rails on Shediac wharf is 6·70 below high water at St. John, and the level of high tide at the latter place is 10·70 feet *above* that at Shediac Harbour."

This difference of 10.70 feet between high water at St. John and at Shediac, when allowance is made for the different range of the tides at the two places, would make the elevation of mean sea level very nearly the same for both. This conclusion has been too readily accepted as reliable, since it is based upon a report which gives the levels on this railway with so much detail. These levels, however, are themselves derived from the construction profiles of 1857, as was proved by a careful comparison, grade by grade, which was made this summer at Moncton. This comparison also revealed a number of minor discrepancies in level which are not accounted for in the report. The conclusion arrived at in the report must, therefore, be taken with much reserve.

The construction profile unfortunately, does not extend to the water at either end, so that it gives no direct connection with tide levels. It also appears that at the Shediac end of the railway there is one further grade beyond the point at which the construction profile ends. In a comparison of tide levels made by the Intercolonial Engineers at Moncton, this last grade was omitted; and as the descent upon it is 4.50 feet, the result they arrive at is incorrect by that amount.

The railway is divided into 21 sections, and where the ends of these sections come together, there is sometimes a discrepancy in the connection of the levels, which affects the continuity of the datum. There were six points found in all, at which a change in the datum plane occurs from this cause, and at one of these points there is also a change of 40 feet in the elevation of the datum used. This change is allowed for in the levels in Mr. Light's report; but on the other hand, he has overlooked all the minor discrepancies except one, for which he has made a partial correction. The remaining discrepancies in level are sometimes up and sometimes down, at the points where the various sections meet; and as closely as can be arrived at, their amount when summed up, is 2.03 feet. This correction, therefore, requires to be applied to the levels as given in the report. The result then shows, as nearly as the information under consideration will give it, the difference in elevation between high water at Shediac and high water at St. John, which was the datum plane used by Mr. Light for the levels on the railway.

There is further difficulty, attended also with some uncertainty, in ascertaining at the present time what the elevation was which Mr. Light adopted as "High water at spring tides," at St. John; since there are no permanent bench marks, and no plans of wharves or structures of that date exist, on which the level taken for high water is shown. To arrive at a value for this elevation, an examination of the ground was made by me in the autumn. The tide levels at the St. John gauge were carried over to Marsh Creek bridge at the other side of the city of St. John, by means of simultaneous observations of the water level at high water spring tides on 3rd October; and to connect these with the beginning of the railway profile, instrumental levels were run for a mile and a half along a level stretch of the track, where it crosses a wide marsh immediately east of the St. John railway station. A stretch of track there which is nearly three miles long, is shown as level on the construction profile; and although called a marsh it is not swampy as its name might be taken to imply; but consists of flat hay land, of firm clay soil; and there is therefore no settlement to be expected. The grade on this marsh, which was originally level in construction, now varies as much as 0·91 of a foot in elevation. In deciding upon the original elevation of rail level, every indication was noticed which would furnish any guide to the parts of the track which have probably been least disturbed since construction. The average level of seven points extending over a mile of the track, was taken as a basis for determining the elevation of the track relatively to high water spring tides as given in Mr. Light's report.

This is the best method that is now available to obtain a comparison between the original railway levels of 1859, and the tide levels as obtained from the present gauge at St. John. Without giving the results in detail, it will be sufficient to say that the comparison shows the level adopted by Mr. Light as high water at spring tides to be 11·85 feet above Mean Sea Level as now determined by the tidal observations at St. John. It thus appears that the level he adopted as high water, is rather too low; as it makes the corresponding range at spring tides less than it should be on the average. The result, however, when allowance is made for the uncertainties involved, is probably correct within half a foot; which is fairly satisfactory in the circumstances, since the high water mark varies so much, owing to the great range of the tide at St. John. If then, the elevation which Mr. Light adopted as high water spring tides at St. John is taken as 100·00, the elevation of Mean Sea Level above his datum, as found from the above difference of level, is 88·15. The spring range at Shediac may be taken as 4·00 feet without appreciable error. We thus obtain the comparisons given in the following table between mean sea level at St. John and Shediac, according as the difference in Mr. Light's report is accepted without correction, or the correction as determined from the construction profile is applied. The reason for making this alternative comparison is, that it may be held, on the one hand, that these corrections were overlooked by Mr. Light; or on the other hand, it may be argued that the apparent discrepancies on the construction profiles did not in reality affect the continuity of the datum, but that the differences were taken up on the ground by arbitrary alterations in the grades.

Elevation of Mean Sea Level at St. John above Mr. Light's Datum; determined as explained	88·15	88·15
Elevation of High Water spring tides at St. John, as adopted by Mr. Light	100·00	100·00
High Water spring tides at Shediac below High Water at St. John:—		
(*a*) As given in Mr. Light's Report	10·70	
(*b*) With corrections for minor discrepancies found on Construction Profiles, amounting to 2·03 feet	....	12·73
High Water spring tides, at Shediac	89·30	87·27
Half-range of spring tides at Shediac	2·00	2·00
Elevation of Mean Sea Level at Shediac above Mr. Light's Datum	87·30	85·27

It is evident from the explanations above given, that there is still some uncertainty in this comparison. It is possible that the value for mean sea level with reference to Mr. Light's datum at St. John is too high, by an amount which would not exceed the probable limit of error in its determination. On the whole, these railway levels can only be taken as showing that there is no very great difference in elevation between mean sea level at St. John and Shediac. Any more definite conclusions can be better based upon the accurate levels of the Chignecto Ship Railway, which are given further on.

The difficulty met with in obtaining a reliable result from these railway levels, serves also to emphasize the unfortunate character of the practice which still prevails on railways, of using nothing but temporary and perishable bench marks during construction. There would be very little extra trouble, when extensive levels are being taken, to connect them with permanent bench marks, at least at junctions and terminal points. Through this neglect a large amount of valuable information is lost, which in after years it is impossible to make good.

A further endeavour was made to obtain a connection between the levels of the European and North American Railway, and those of the Chignecto Ship Railway, which runs from Cumberland Basin, in the Bay of Fundy to Baie Verte in Northumberland Strait. Such a connection would afford a valuable comparison of the tide levels at four points: St John and Cumberland Basin, in the Bay of Fundy; and Shediac and

Baie Verte, in the Gulf of St. Lawrence. The Intercolonial Railway should afford this connection; as it crosses the former European and North American Railway at Painsec Junction, and also the Ship Railway near Amherst, the distance between the two points being 37 miles. An original profile of this part of the Intercolonial still exists, which extends from Painsec Junction to the boundary between New Brunswick and Nova Scotia, and thus falls short by about a mile of the point at which it crosses the Ship Railway. To make up the gap, instrumental levels were run by me in October. In the absence of bench marks on the Intercolonial, and because of changes in level when the original timber structures were rebuilt, the best points from which original levels could be obtained were "grade points" on the earthwork at the ends of cuttings. By averaging the elevations of several of these, extending over two miles of the track, and carrying the levels across the gap above mentioned to bench marks which establish the levels on the Ship Railway, a very fair connection was obtained.

When the levels came to be worked out, however, to connect with those on the European and North American Railway, by means of the profile above described, there was a discrepancy of about five feet at Painsec Junction, which appeared when the levels were carried through to tide water. Every endeavour was made to account for this, and the levels were worked out according to a variety of hypothetical explanations, but none of these would account satisfactorily for the discrepancy. It was not therefore possible to obtain the desired connection, which would have given a valuable comparison of the tide levels.

Tide levels at the head of the Bay of Fundy and in the Gulf of St. Lawrence, from the levels of the Chignecto Ship Railway.—The Ship Railway, which still remains unfinished, runs across the isthmus which connects Nova Scotia with the continent. Its southern end is at Fort Lawrence dock, on Cumberland Basin, at the head of the Bay of Fundy; and its northern end at Tidnish, on Baie Verte, in Northumberland Strait. The levels on this railway are accurate; and they are also connected with the tides by a series of simultaneous observations at the two ends. The results are much more reliable than any that ordinary railway profiles can afford.

There are two bench marks on masonry culverts in the vicinity of the Intercolonial Railway, which record the Ship Railway levels. These are of inestimable value in this region, where extensive hay lands are protected by dykes from overflow at the high tides. They furnish the only permanent marks from which to obtain the level of high water, or extreme tides, with reference to the height required for dykes, and the protection of the country from overflow. They are not easy to find without a description; as the stone on which they were cut is now much weathered owing to its soft character. We therefore give the following description of them from personal inspection. Their elevations are taken from the working profile of the Chief Engineer, the late Mr. H. G. C. Ketchum, on which they are given with reference to the Ship Railway datum. This datum is at 100·00 feet below the level at Fort Lawrence dock, of the highest tide known; the Saxby tide of 5th October, 1869.

(1). Bench Mark at the west end of a masonry box culvert on the Ship Railway, at 2,120 feet south of the crossing of the Intercolonial railway. The bench mark was made by dressing a small square on the top of the coping at the south west corner. Elevation above the Ship Railway datum, 97·42.

(2). Bench Mark on a masonry box culvert, on the north side of the Intercolonial Railway track. This culvert is one of a pair, at each side of the track at the crossing of the railway, to carry the water in the side ditches. A small square as above, on the south-west corner of the coping at the west end of the culvert. Elevation above the Ship Railway datum, 100·86.

(This elevation is incorrectly marked on the profile as 100·36, instead of 100·86, which was checked by instrumental levels carried from the other bench mark, and by comparison with the level of the track.)

A series of tide levels at the two ends of the Ship Railway, are given as a large wall diagram, in the company's office at Amherst. On this, the elevations of high water and low water on successive days during a period of nearly five months, are shown on a scale of an inch to the foot. A reduction of this diagram is given as Plate III. The value of this is evident, as the observations are simultaneous, and they are reduced to the same datum level in both Cumberland Basin and Baie Verte. The original observations could not be procured in the form of notes; but as the diagram is on so large a scale, the elevations of the tide, day by day, can be very closely scaled. The observations extend from 13th August to 31st December for Cumberland Basin; and at Baie Verte from 11th August to 16th November, with a good many omissions, however, in September. The year of the observations is not stated; but it must be 1893, from the recollection of the officer at present on the works, and from comparison of the spring tides with the moon's phases in that year.

These tide levels furnish the best means available for obtaining the elevation of Mean Sea Level at the head of the Bay of Fundy as compared with the Gulf of St. Lawrence. It is to be noted, however, that from such observations, the value obtained for mean sea level is based upon the average half-range from low water to high water, while the form of the tide is ignored. The tidal curve at the head of the Bay of Fundy, as usual in estuaries, is wider and flatter at low water and sharper at high water, instead of being symmetrical; which it still is as far up as St. John. It is therefore to be assumed that the elevation of mean sea level in Cumberland Basin, as obtained in this way, will be higher than the true elevation which would be found by hourly observations, or by the bisection of the area of the tide curve. In Baie Verte, any difference from this cause is probably quite inappreciable, as the range of the tide is more moderate, and its form presumably symmetrical. Although the period of the observations at Baie Verte is shorter, the result for these reasons will be quite as accurate in proportion as in Cumberland Basin. Mean sea level in Baie Verte is in all probability the same as in the Atlantic. If there is any difference, it should be higher than in the Atlantic, as the lighter density of the water of the Gulf of St. Lawrence should make the water surface stand a few inches higher than in the ocean.

We add also a table taken from these observations, to show the range at springs and neaps in Cumberland Basin. It appears probable that these observations are day tides only; and this would help to account for the apparent irregularities in the intervals of time between the spring and neap tides. According to the Admiralty tide tables the range in Cumberland Basin is the highest in the Bay of Fundy, with the exception of Noel Bay and Horton Bluff in Minas Basin. The range at spring tides and the rise at neap tides, as given in the Admiralty list, are as follows:—Noel Bay: springs 50½, neaps 43½ feet; Horton Bluff: springs 48, neaps 40 feet; Cumberland Basin at Sackville; springs 45¼, neaps 38 feet.

I. Mean Sea Level at the head of the Bay of Fundy and on the Gulf of St. Lawrence, being the average elevation of half-tide above the datum of the Chignecto Ship Railway.

At Fort Lawrence dock, Cumberland Basin, Bay of Fundy: Mean Sea Level from observations on 116 consecutive days, divided into lunar months, or periods of 29 days.

29th Aug. to 26th Sept.—Elevation of Mean Sea Level	70·26
27th Sept. to 25th Oct.— " " "	70·67
26th Oct. to 23rd Nov.— " " "	71·12
24th Nov. to 22nd Dec.— " " "	71·01
Mean Elevation	70·76

At Tidnish, Baie Verte, Gulf of St. Lawrence: Average elevation of half-tide on 78 days on which both high water and low water were obtained, between 11th August and 16th November.

Mean elevation	71·02

II. Spring and Neap Range at Fort Lawrence dock, Cumberland Basin; with the elevation of high and low water above the datum of the Chignecto Ship Railway.

Tides and Date. (Year not stated; probably 1893.)	Elevation of H.W.	Elevation of L.W.	Spring Range.	Neap Range.
Neap tides, 20th Aug.	85·05	55·65	....	29·40
Spring " 29th "	92·45	48·40	44·05	....
Neap " 5th Sept.	86·50	50·50	....	36·00
Spring " 10th "	90·80	51·90	38·90	....
Neap " 17th "	85·00	55·75	....	29·25
Spring " 27th "	94·60	47·60	47·00	....
Neap " 4th Oct.	86·55	53·65	....	32·90
Spring " { 9th "	90·00	50·35	39·65	....
Spring " { 10th "	90·70	51·15	—	....
Neap " 17th "	85·00	58·55	....	26·45
Spring " 25th "	96·00	47·00	49·00	....
Neap " 3rd Nov.	87·40	54·50	....	32·90
Spring " { 7th "	88·75	53·30	35·45	....
Spring " { 8th "	88·80	53·65	—	....
Neap " 16th "	85·25	57·10	....	28·15
Spring " 24th "	94·40	47·00	47·40	....
Neap " 30th "	86·00	54·70	....	31·30
Spring " 7th Dec.	88·75	53·95	34·80	....
Neap " 15th "	86·85	55·85	....	31·00
Spring " 22nd "	94·15	47·20	46·95	....
Mean Range	....	....	42·58	30·82

For comparison with the above, we may mention an exceptionally high tide which occurred on 8th October, 1896, which reached the elevation 96·13 at the Fort Lawrence dock. This tide, as noted by myself at the time, overflowed the dykes at many places between Amherst and Sackville, and also broke over the dykes in places along the Petitcodiac River, as far as Moncton. There was no storm disturbance at the time, but on the other hand, it occurred under a combination of astronomical conditions which makes it probable that this is as high a tide as is possible, due to astronomical conditions alone, apart from storm disturbance. It is a little higher than the tide of 25th October, the highest in the above series of observations. The same tide at St. John, reached an elevation of 73·10 on the St. John scale; and at Moncton the elevation reached was 118·91, or 18·91 above the Moncton City datum. The relation between the datum planes at these three places, is at present undetermined.

The standard values for the tide levels, as adopted by the Engineers of the Ship Railway, are as follows:—

Elevation of the Tide from the Ship Railway Profiles.	Cumberland Basin, Bay of Fundy.	Baie Verte, Gulf of St. Lawrence.
Saxby tide, highest known; occurred 5th Oct., 1869	100·00	
Exceptional H. W., highest known		79·00
High water, spring tides	96·00	
Ordinary high water	89·00	74·00
Ordinary low water	52·59	68·40
Extreme low water to which the Ship Railway soundings are reduced	47·20	65·60

LEVELS REQUIRED FOR THE CONNECTION OF MEAN SEA LEVEL, IN THE BAY OF FUNDY, THE GULF OF ST. LAWRENCE AND THE ATLANTIC

At several ports, mean sea level has already been determined by the Tidal Survey, and the observations of this summer afford further material for this purpose. Although these determinations are by no means the primary object of this Survey, they result, with little additional labour, from the careful and continuous observations required for the determination of a uniform datum level for the tidal record itself, this being essential to make the record of use as a basis for tide tables. In this climate, readings on exposed tide scales can be obtained for summer observations, but they cannot be had throughout the winter, on account of the accumulation of ice. The datum has therefore to be determined from comparisons with sight gauges which are sheltered and supplied with heating in winter, in the same way as the recording instrument itself. The arrangements used for this purpose have already been described in these Reports. The sight gauges are connected by instrumental levels with permanent bench marks.

As regards the comparison of tide levels in the Bay of Fundy with the Gulf of St. Lawrence and the Atlantic coast, determinations of mean sea level have already been made at the following ports:—

At St. John, N.B., from two years of continuous tidal record; mean sea level is referred to the Tidal Survey Bench Mark on the Custom house.

At Halifax, from tidal record during one complete year, referred to the Admiralty Bench Mark in the Dock yard.

The results obtained there, as well as those for Quebec, are given in the report on this Survey for last year. The further material now available is as follows:—

At Yarmouth and Digby in the Bay of Fundy, five months of continuous tidal record in 1898, the datum of the observations being referred to permanent bench marks as described in this report. Also, in Cumberland Basin, the determination of mean sea level from four months observation of tide levels, as above given; and connected with this, by the levels of the Ship Railway, the determination at Baie Verte from observations of tide levels during a period amounting to 2½ months in all.

To make connection between these determinations, accurate instrumental levels would be required from St. John to Moncton, 90 miles; and from Moncton to the Ship Railway bench marks near Amherst, 48 miles. By taking this route, connection would be made with the well-determined city levels of Moncton, and the tidal observations at the head of the Petitcodiac; and the levels around the head of the Bay of Fundy, from Moncton to Amherst would also enable bench marks to be established with reference to tide levels, for use in the better protection of the extensive dyked marshes from flooding at extreme tides.

If levels were run from the bench mark now established at Digby to the Admiralty bench mark at Halifax, a direct connection could be obtained between the tide levels in the Bay of Fundy and in the Atlantic. These levels could also be made to afford the same service as above, to the dyked marshes on Minas Basin. A further check on the relative levels could be obtained from the simultaneous observations of this season at Digby and St. John, by assuming that mean sea level has the same absolute elevation at these two places, as they are directly opposite each other on the two sides of the Bay of Fundy. With this connection, a comparison of the tide levels at St. John could be made both with the Gulf of St. Lawrence and the Atlantic at Halifax. The same advantage could be obtained, but with more trouble, by continuing the instrumental levels from Amherst to Halifax, a distance of 138 miles.

The connection of the bench mark at Yarmouth with Digby, 75 miles, would also be valuable; as mean sea level at Yarmouth must be closely the same as in the open Atlantic. Whether this is accurately correct, would also be ascertained by means of the comparison with Halifax.

When a connected series of elevations for mean sea level were determined at Yarmouth, Digby, St. John, and Cumberland Basin, they would also afford a basis from which to obtain the actual elevations of high water and low water at successive points in the bay, and thus to trace the progress of the tide as regards change in level, throughout the Bay of Fundy.

To carry out such a system of levelling can hardly be considered as within the province of the Tidal Survey; but it may be well to point out the way in which this could best be accomplished, to take advantage of work already done, and observations already obtained.

I have, sir, the honour to remain,
Your obedient servant,

W. BELL DAWSON,
In charge of Tidal Survey.

Table of Tidal Constants.

Constants.	Halifax, N.S. 1851 and 1852. (Two years).	Halifax, N.S. 1860 and 1861. (Two years.)	Halifax, N.S. 1895 to 1896. (One year.)	Halifax, N.S. Mean Value.	St. John, N.B. 1894 to 1896. (Two years.)	Quebec. 1894 and 1895. (Two years.)	Constants.
A_0	4·643 ft.	3·829 ft. 4·391 ft.	3·391 ft.	....	13·951 ft.	8·582 ft.	
S_1 .... H	0·021 ft.	0·024 ft.	0·029 ft.	0·024 ft.	0·015 ft.	0·030 ft.	.... S_1
K	3°	66°	322°	20°	85°	183°	
S_2 .... H	0·445 ft.	0·447 ft.	0·484 ft.	0·454 ft.	1·622 ft.	1·373 ft.	.... S_2
K	257·5°	260·1°	254·3°	257·9°	4·1°	228·2°	
S_4 .... H	0·021 ft.	0·021 ft.	0·020 ft.	0·021 ft.	....	0·046 ft.	.... S_4
K	324°	306°	306°	313°	....	22°	
M_1 .... H	0·008 ft.	0·015 ft.	0·015 ft.	0·012 ft.	....	0·041 ft.	.... M_1
K	48°	56°	75°	57°	....	289°	
M_2 .... H	2·013 ft.	2·014 ft.	2·122 ft.	2·035 ft.	10·042 ft.	5·803 ft.	.... M_2
K	223·9°	223·5°	222·9°	223·5°	324·7°	179·3°	
M_3 .... H	0·003 ft.	0·012 ft.	0·003 ft.	0·007 ft.	....	0·056	.... M_3
K	83°	55°	158°	87°	....	230°	
M_4 .... H	0·121 ft.	0·114 ft.	0.109 ft.	0·116 ft.	0·098 ft.	0·900 ft.	.... M_4
K	28·2°	23·6°	21·5°	25·0°	151·9°	269·6°	
M_6 .... H	0·016 ft.	0·011 ft.	0·013 ft.	0·014 ft.	0·096 ft.	0·232 ft.	.... M_6
K	79°	69°	65°	72°	176°	237°	
M_8 .... H	0·005 ft.	0·007 ft.	0·005 ft.	0·006 ft.	....	0·172 ft.	.... M_8
K	115°	52°	171°	101°	....	340°	
K_1 .... H	0·342 ft.	0·331 ft.	0·346 ft.	0·338 ft.	0·496 ft.	0·759 ft.	.... K_1
K	58·7°	60·8°	58·3°	59·5°	128·8°	270·1°	
K_2 .... H	0·129 ft.	0·141 ft.	0·137 ft.	0·136 ft.	0·470 ft.	0·392 ft.	.... K_2
K	252·0°	261·3°	260·2°	257·4°	7·2°	229·0°	
O .... H	0·155 ft.	0·164 ft.	0·141 ft.	0·156 ft.	0·369 ft.	0·713 ft.	.... O
K	40·9°	39·7°	29·0°	38·0°	109·2°	242·3°	
P .... H	0·106 ft.	0·094 ft.	0·110 ft.	0·102 ft.	0·142 ft.	0·175 ft.	.... P
K	60·9°	65·8°	60·2°	62·7°	129·9°	279·6°	
J .... H	0·020 ft.	0·024 ft.	0·029 ft.	0·023 t.	0·022 ft.	0·033 ft.	.... J
K	110°	46°	83°	79°	139°	331°	
Q .... H	0·014 ft.	0·028 ft.	0·014 ft.	0·019 ft.	0·063 ft.	0·093 ft.	.... Q
K	74°	60°	350°	51°	82°	221°	

Table of Tidal Constants—*Concluded.*

Constants.		Halifax, N.S. 1851 and 1852. (Two years.)	Halifax, N.S. 1860 and 1861. (Two years.)	Halifax, N.S. 1895 to 1896. (One year.)	Halifax, N.S. Mean Value.	St. John, N.B. 1894 to 1896. (Two years.)	Quebec. 1894 and 1895. (Two years.)	Constants.
L..........	H	0·124 ft.	0·108 ft.	0·079 ft.	0·109 ft.	0·734 ft.	0·540 ft.	L
	K	244°	312°	178°	258°	14°	231°	
N..........	H	0·425 ft.	0·447 ft.	0·519 ft.	0·453 ft.	2·296 ft.	0·929 ft.	........N
	K	203°	210°	198°	205°	295°	150°	
2 N........	H	0·078 ft.	* ·089 ft.	0·064 ft.	0·077 ft.	0·297 ft.	0·254 ft.	.......2 N
	K	181°	197°	172°	183°	292°	186°	
ν...........	H	0·172 ft.	0·157 ft.	0·112 ft.	0·154 ft.	0·604 ft.	0·290 ft.	...........ν
	K	213°	201°	178°	200°	295°	181°	
μ	H	0·058 ft.	0·060 ft.	0·075 ft.	0·062 ft.	0·059 ft.	0·401 ft.	..........μ
	K	192°	194°	200°	196°	59°	305°	
2 SM	H	0·005 ft.	* ·003 ft.	0·007 ft.	0·005 ft.	0·023 ft.	0·090 ft.	......2 SM
	K	218°	68°	160°	166°	280°	93·6°	
MS.........	H	0·057 ft.	* ·065 ft.	0·063 ft.	0·060 ft.	0·050 ft.	0·427 ft.	........MS
	K	159°	148°	152°	154°	198°	320·5°	
M_2N......	H	0·060 ft.	* ·050 ft.	0·069 ft.	0·060 ft.	0·053 ft.	0·322 ft.	.......M_2N
	K	332°	342°	320°	331°	112°	247·3°	
2 M_2K_1....	H	0·006 ft.	* ·005 ft.	0·007 ft.	0·006 ft.	0·036 ft.	0·198 ft.	....2 M_2K_2
	K	0°	33°	52°	21°	128°	311·6°	
M_2K_1.....	H	0·035 ft.	* ·021 ft.	0·007 ft.	0·025 ft.	0·128 ft.	0·164 ft.	.....M_2K_1
	K	103°	232°	274°	178°	138°	347·3°	
Mm.......	H	† ·029 ft.	....	† ·113 ft.	....	0·104 ft.	0·333 ft.	........Mm
	K	215°	....	64°	....	97°	28°	
Mf.........	H	† ·025 ft.	....	† ·042 ft.	....	0·053 ft.	0·101 ft.	.........Mf
	K	324°	....	178°	....	196°	81°	
MSf.......	H	† ·073 ft.	....	† ·060 ft.	....	0·108 ft.	0·569 ft.	.......MSf
	K	302°	....	175°	....	90°	56°	
Sa.........	H	0·170 ft.	0·156 ft.	0·098 ft.	0·150 ft.	0·065 ft.	0·483 ft.	..........Sa
	K	244°	254°	266°	252°	76°	65°	
Ssa........	H	0·108 ft.	0·222 ft.	0·132 ft.	0·158 ft.	0·130 ft.	0·380 ft.	.......Ssa
	K	109°	118°	277°	146°	141°	126°	

* For the year 1861 only.

† These do not accord well, and are omitted from the mean value.

(For explanation see next page.)

TABLE OF TIDAL CONSTANTS.—EXPLANATION.

These constants are determined from old observations at Halifax as indicated; and from the tidal record obtained by this Survey, reduced to a uniform datum, and tabulated in hourly ordinates. The analysis of the record and the determination of the constants has been made by Mr. Edward Roberts, F.R.A.S., Chief Assistant in the Nautical Almanac office, London.

HALIFAX. *Datum.* The varying values of A_0 correspond with the difference in datum used in the old observations. In the present series, 1895 to 1896, the height is referred to the Admiralty datum as established by the Bench Mark in the Dock yard.

The K's are referred to the meridian of the place.

With regard to these constants as now determined, Mr. Roberts makes the following remarks: "A few of the smaller components were not evaluated for the year 1860, as the observations were broken, and a better mean value is probably obtained by excluding them. The lunar and luni-solar long-period tides, in 1861, are also omitted. The results for these long-period tides do not accord well, and the results cannot be regarded as genuine. No mean value, therefore, has been taken for them from the three years' results. The results for the solar annual tide agree very well; and those for the solar semi-annual, fairly so. The whole of the short-period terms are, I think, good; and the mean values exceedingly so. They are a very reliable set of constants."

ST. JOHN, N.B. *Datum.* The datum to which the tides are referred is 55·60 feet below the Tidal Survey bench mark at the south-east corner of the Custom house. The values of the harmonic tide plane, mean sea level, &c. as now determined, are given in the last report of this survey.

The K's are referred to the meridian of St. John Observatory, its longitude being $4^h\ 24^m\ 16^s$ W.

QUEBEC. *Datum.* The tides are referred to the original Admiralty datum, as established by the Bench Mark on the Marine and Fisheries building in Quebec. The scale of heights used at the tide gauge was the outside scale cut on the masonry of the Dry Dock at Lévis; and on this scale a slight error has been found in the spacing of the figures as cut. The true zero of the scale, corresponding to the mean position of the figures, is thus 7·78 below the Admiralty datum, instead of 7·80 feet as assumed in the tabulation of the tidal record. Hence, height of mean sea level above Admiralty datum $= A_0 + 0{\cdot}020 = 8{\cdot}602$.

The K's are referred to the 75th meridian west, to correspond with Eastern Standard time.

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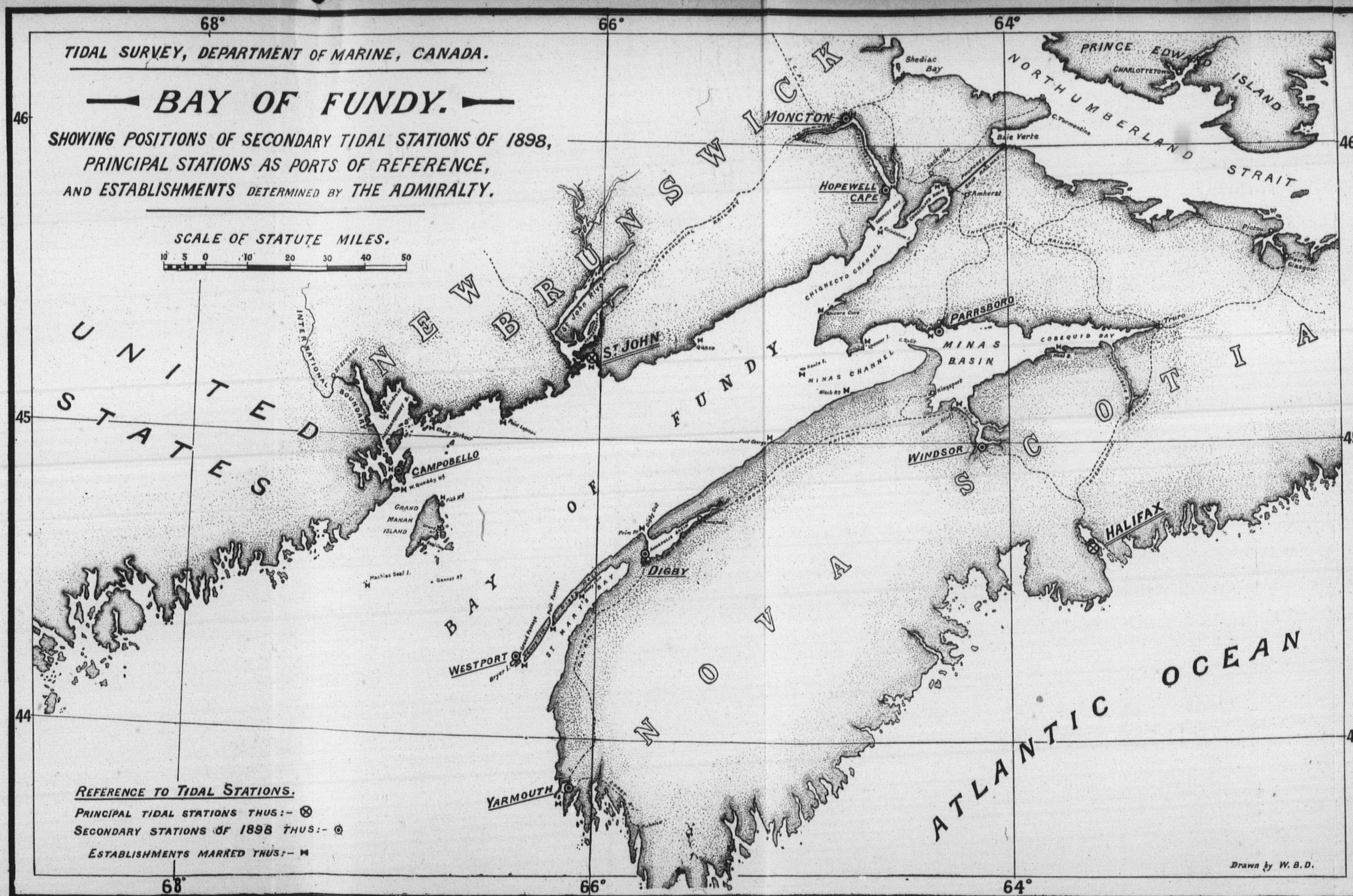

TIDAL SURVEY, DEPARTMENT OF MARINE, CANADA.
BAY OF FUNDY.
SHOWING POSITIONS OF SECONDARY TIDAL STATIONS OF 1898,
PRINCIPAL STATIONS AS PORTS OF REFERENCE,
AND ESTABLISHMENTS DETERMINED BY THE ADMIRALTY.
SCALE OF STATUTE MILES.
10 5 0 10 20 30 40 50
68°
66°
64°
46
45
44
NEW BRUNSWICK
UNITED STATES
NOVA SCOTIA
PRINCE EDWARD ISLAND
CHARLOTTETOWN
NORTHUMBERLAND STRAIT
Shediac Bay
MONCTON
HOPEWELL CAPE
Baie Verte
Amherst
Pictou
CHIGNECTO CHANNEL
PARRSBORO
MINAS BASIN
MINAS CHANNEL
COBEQUID BAY
Truro
ST. JOHN
St. John River
BAY OF FUNDY
CAMPOBELLO
GRAND MANAN ISLAND
Machias Seal I.
WINDSOR
HALIFAX
DIGBY
WESTPORT
ST. MARYS BAY
YARMOUTH
ATLANTIC OCEAN
REFERENCE TO TIDAL STATIONS.
PRINCIPAL TIDAL STATIONS THUS:- ⊗
SECONDARY STATIONS OF 1898 THUS:- ⊙
ESTABLISHMENTS MARKED THUS:- ⋈
Drawn by W. B. D.

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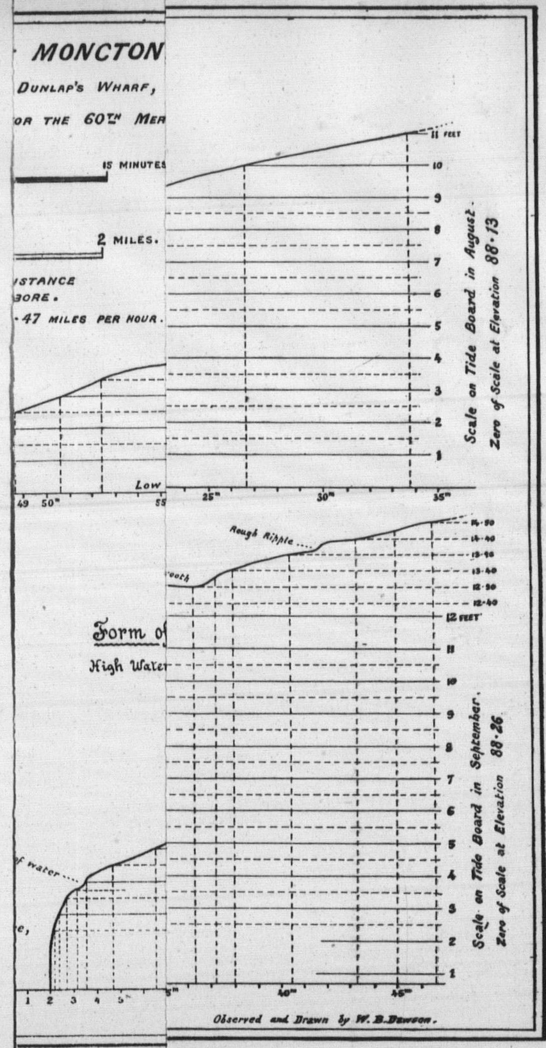
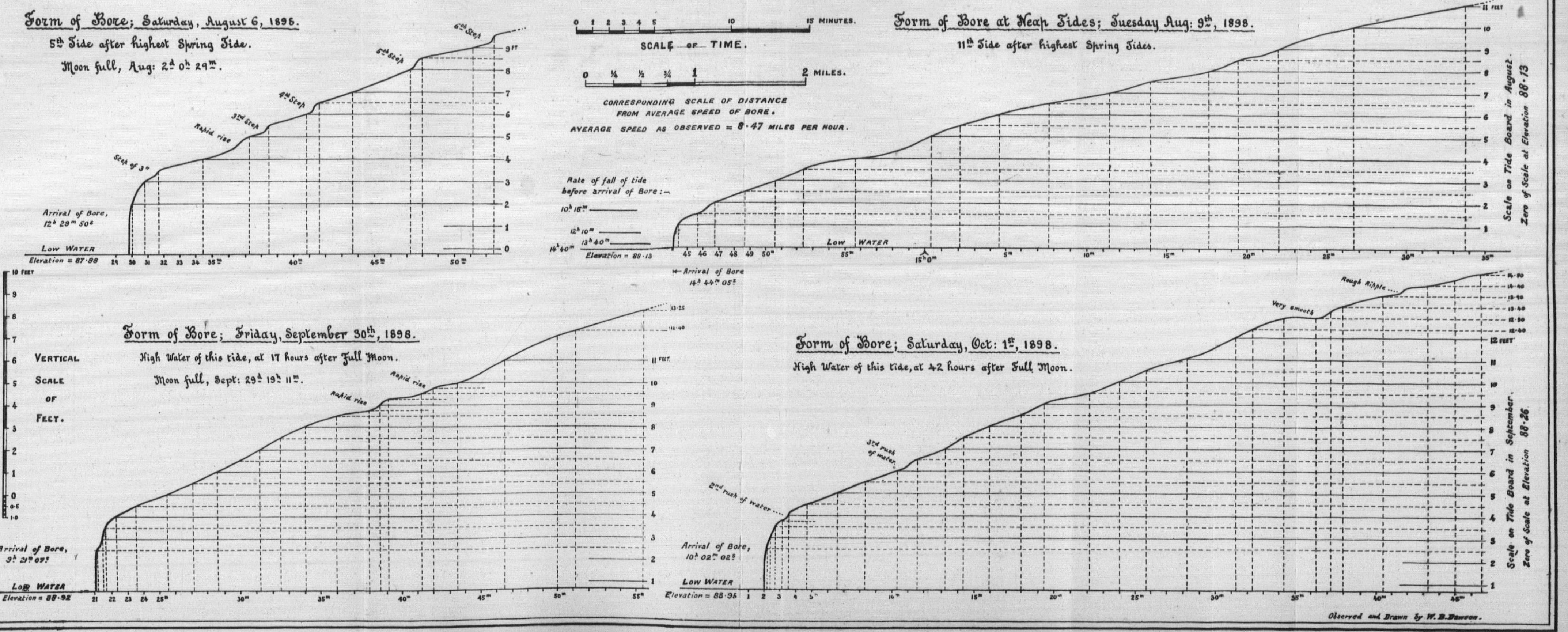
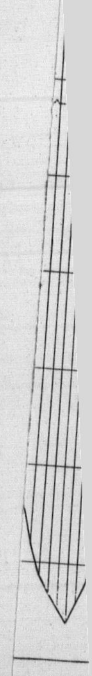

MONCTON
DUNLAP'S WHARF,
OR THE 60TH MER
15 MINUTES
2 MILES.
ISTANCE
BORE.
·47 MILES PER HOUR.
Low
49
50m
55
25m
30m
35m
11 FEET
10
9
8
7
6
5
4
3
2
1
Scale on Tide Board in August.
Zero of Scale at Elevation 88·13
Rough Ripple
ooth
14·90
14·40
13·90
13·40
12·90
12·40
12 FEET
11
10
9
8
7
6
5
4
3
2
1
Form of
High Water
of water
e,
1
2
3
4
5
40m
45m
Scale on Tide Board in September.
Zero of Scale at Elevation 88·26
Observed and Drawn by W. B. Dawson.

THE BORE IN THE PETITCODIAC RIVER AT MONCTON, N.B. CANADA.

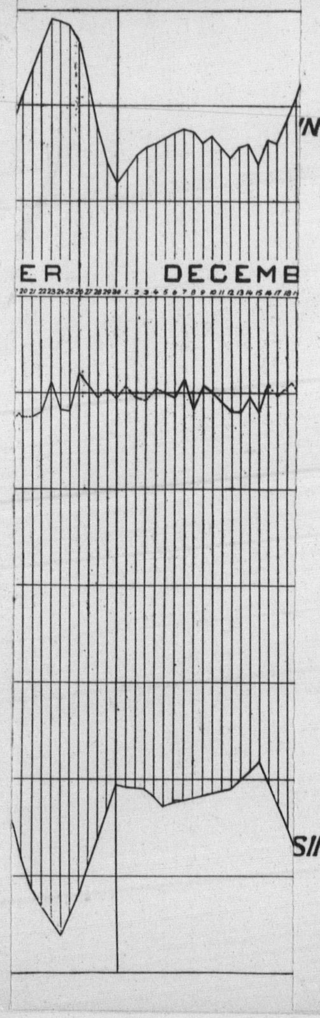
FORM AND RATE OF RISE AS OBSERVED ON A SCALE OF FEET AT DUNLAP'S WHARF, MONCTON, IN AUGUST AND SEPTEMBER 1898.

THE TIME THROUGHOUT IS STANDARD TIME FOR THE 60TH MERIDIAN WEST.





T LAWRENCE.



TIDE LEVELS IN THE BAY OF FUNDY AND THE GULF OF ST LAWRENCE.