SURVEY

OF

TIDES AND CURRENTS

IN

CANADIAN WATERS

BY

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In charge of Tidal Survey.

OTTAWA
GOVERNMENT PRINTING BUREAU
1902

TIDE

W. P. ANDERSON, Esq
Chief Engin

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OTTAWA, December 6, 1901.

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. The principal tidal stations have been maintained in continuous operation throughout the year, and considerable progress has been made in the reduction of the results, and in the use made of them to improve the tide tables now regularly issued The most important step in advance as regards the tide tables, has been the issue of the new tables for British Columbia, which have been received with the highest expressions of appreciation. These were issued as soon as the increased appropriations of last year made it possible to do so. During the season, tidal observations have been taken at Vancouver, and observations of the current at the First Narrows, forming the entrance to that harbour. The results have been worked out promptly for issue with the tide tables for 1902 ; as well as additional information from other sources, in those regions. The further information thus embodied in the tide tables will be of much service to navigation on our West Coast.

The tidal observations secured last season on the Lower St. Lawrence have been fully worked up ; and the outcome is given in the present Report. To make the information immediately available to navigators, it was issued in a preliminary form as a 'Notice to Mariners' in April last, before the opening of navigation on the St. Lawrence. These observations were so carried out as to make practically available for the first time the relations between tide and current previously determined during the progress of the Admiralty surveys of 1885 to 1889.

During this season, additional tidal observations have been taken in Northumberland Strait and in Cabot Strait. The observations in Northumberland Strait at Pictou, Charlottetown and Summerside, supplement those of 1896 and 1897; and will serve to extend the basis from which the tide tables for this region are calculated; and also to secure better tidal data for Summerside harbour. The tidal observations in Cabot Strait were taken with the object of obtaining the best tidal relation between St. Paul Island, and one or other side of the strait; because of the severe exposure at that station, and the difficulty of maintaining the gauge there. These relations with the two sides of the strait will also serve to define more correctly the nature of the oceanic tidal undulation at its entrance into the Gulf of St. Lawrence; as it is this undulation which gives rise to the whole of the tides in the Gulf area and throughout the St. Lawrence river.

Extended levels were taken in September around the head of Cumberland Basin, on the Bay of Fundy, with the object of reducing to the same basis of comparison a number of valuable observations of the extreme height of the tide which have been recorded at different points there in different years. The result of this work is given in the present report; and it is of the first importance with relation to the protection of the extensive dyked marshes in this region.

A considerable amount of tabulation from the tidal record already secured, has been done during the year; as noted below. This will be submitted to analysis as the means to do so will allow; in order to extend the basis from which the tide tables are calculated, which will be of permanent benefit in improving the accuracy of the tide tables in all future years. In the office work of this Survey, and in the erection of the summer tidal stations, I have had the assistance of Mr. R. Angus and Mr. S. C. Hayden.

The total expenditure on this Survey during the fiscal year from June 30, 1900, to June 30, 1901, was $7,060.20. This total expenditure is classified as follows:—

(1.) General expenses: maintenance of the seven principal tidal stations, with repairs, heating and supplies; salaries of observers and assistants; office work and travelling expenses; $2,910.35.

(2.) Summer tidal stations; on the Lower St. Lawrence in 1900, and in Northumberland Strait in the early part of the season (up to June 30), 1901; erection of gauges, salaries of observers, and inspection, $1,503.25.

(3.) Tide tables; calculations and printing; analysis of further tidal record to improve their accuracy, which is of permanent benefit for all future years, $2,646.60.

THE PRINCIPAL TIDAL STATIONS.

The seven principal stations in Eastern Canada, established by this Survey, are at Quebec, Father Point, Belle Isle Strait, St. Paul Island in Cabot Strait, Halifax, Yarmouth, N.S., and St. John, N.B. These have all been maintained in continuous operation throughout the past year, with some minor interruptions. The stations inspected this season by myself, were St. Paul Island, Halifax, Yarmouth and St. John, N.B. At all these stations, careful instrumental levels were taken to insure the continuity of the datum to which the height of the tide is referred; and at all four, auxiliary Bench-marks were established for future reference. The detailed levels it is unnecessary to give at present; their eventual use being the determination of the low water datum, and mean sea level at these localities. Several adjustments and improvements were also made; to insure correct time for the observations; and for the barographs or self-recording barometers there used. The cribwork at Forteau Bay in Belle Isle Strait, also required repair, by a heavy sheating of hardwood. The chief trouble has occurred at St. Paul Island from threatened chokage of the inlet to the tide pipes. This station was visited by Captain Douglas, R.N.R., early in the spring, to make sure that everything was in good working order before the comparative observations in Northumberland Strait were begun. This autumn, special inlet fittings have been made, in the hope of averting this chokage in future.

It was expected that the tidal gauge at Father Point could be moved this season onto the new wharf there, as a better site for it; but no further work was done this year in extending this wharf, which does not yet reach to low water mark.

REDUCTION AND TABULATION OF TIDAL RECORD.

In order to utilize the tidal record for the calculation of tide tables by the modern method of harmonic analysis, it is necessary that it should be tabulated in hourly ordinates, which give the height of the tide at each hour throughout the year. With this object in view, it is of primary importance to secure an uninterrupted record, day and night, during the course of the year. Every endeavour in the way of foresight and vigilance, is made to ensure this. The number of hourly ordinates throughout the course of a year is 8,760; and these must be reduced to a uniform datum and freed from time errors. The steps accordingly necessary to prepare the tidal record for analysis are as follows:—(1) Reduction to datum by comparison with a scale of feet or sight gauge, and with reference to the Bench-mark; and the ruling-in of the datum line on the tide-diagrams. (2.) Correction of the hour lines for the want of fit of the tide diagram around the cylinder, due to lap or shrinkage of the paper. This sometimes varies with the season. (3) Correction of time error due to the error and rate of the driving clock. (4.) Interpolation of any breaks in the tide curves. If these do not exceed a day in duration, they can be filled in with advantage on the tide-diagrams themselves, rather than by calculation in making the analysis. (5.) Examination of the record for storm-tides, or anything exceptional which should not be included in the analysis.

The tabulation of this character done during the twelve-month since last report, and the year from which the tide tables will be benefited thereby, may be stated concisely as follows:—

Victoria, B.C.—One year's tidal record, from May 1, 1896, to April 30, 1897; extending the basis of these tide tables from one to two years and benefiting them from 1902 onwards.

St. John, N.B.—Two years' tidal record, from May 15, 1896, to May 31, 1898; extending the basis of these tide tables from two to four years; and thus improving their accuracy from 1903 onwards; and benefitting the whole Bay of Fundy region which depends on them.

Quebec.—Two further years of tidal record from March 1, 1898, to March 15, 1900; extending the basis of calculation from four to six years, and thus benefitting the tide tables for Quebec and Father Point from 1903 onwards, as well as the whole tidal estuary of the Lower St. Lawrence, which depends indirectly upon these.

Halifax.—Three years, from December 14, 1896, to January 15, 1900, extending the basis from which these tide tables are calculated from one to four years of recent observations. This, together with four years of old observations, obtained between 1851 and 1861, will give a total basis of eight years observations for these tide tables, and thus benefit all the ports on the Atlantic coast of Nova Scotia which depend upon them.

St. Paul Island.—Two years, from May 20, 1899, to May 31, 1901; which will benefit the tide tables for the ports in Northumberland Strait, and the south-west side of the Gulf of St. Lawrence, which depend directly or indirectly on St. Paul Island.

The tabulation for these last two places has not yet been submitted to analysis; but this will be done as soon as the finances of the Survey will admit of it.

When these analyses are made, the tide tables for our three principal tidal harbours, Quebec, Halifax and St. John, will be based upon a longer period of observation than any other harbours in North America, with the exception of New York, where a tidal record of eleven years in all has been obtained, either at Sandy Hook or Governor's Island. It is highly desirable that the record be extended however; as the irregularities due to storm disturbance can only be got rid of by a long series of observations which eliminates them eventually by a process similar to averaging. There are also long-period elements in the tide itself, which require to be determined; the longest, which is also of much importance, having a period of nineteen years. The periods of observation on which the tide tables for India are based, range from six to twenty-seven years.

PUBLICATION OF TIDE TABLES AND OTHER INFORMATION.

The publications of this Survey during the past year, have been reviewed in British and foreign periodicals, which is of service in making them widely known; and the new tide tables for British Columbia, issued for the first time for the year 1901, have been much appreciated.

Currents in the Gulf of St. Lawrence, including the Anticosti region, and Belle Isle and Cabot Straits.—The pamphlet with this title which was issued in June, 1900, gives in a condensed form, adapted for reference, the information derived from the investigations in the Gulf of St. Lawrence made by this Survey during the seasons of 1894, 1895 and 1896. It has now been reviewed in the following periodicals:—The *Geographical Journal*, London, December, 1900, gives a notice of it, half a page in length. The *Annalen der Hydrographie*, by Dr. Schott, Hamburg, gives an extensive summary occupying seven pages. It is noticed in the *Fortschritte der Ozeanographie*, by Dr. Krummel, Kiel. The *Annales de Géographie*, Paris, gives a concise review. Also, two articles of three columns each, based upon this pamphlet, were prepared by me by request, and published in *Nature*, London and New York, January 24 and April 18, 1901.

Tide Tables for British Columbia.—These comprise complete tide tables for Victoria, B.C., and for Sand Heads in the Strait of Georgia, a locality centrally situated in that strait, and well suited as a reference station for the ports around it. Tidal differences for Vancouver, New Westminster and Nanaimo are given with these tables. They have met with so much appreciation that the demand for them has been greater than could be supplied, from an edition of 500 copies.

The Provincial Engineer for British Columbia, referring to the original erection by the Public Works Department of the tidal gauges at Victoria and in the Strait of Georgia, says: 'It is very gratifying to find that previous efforts are at last bearing fruit.' The Agent of this department at Victoria says: 'The publication of tide tables for this province has been a long-felt want.' The Resident Engineer of Public Works at New Westminster also remarks that they will fill a long-felt want, and asks for twenty-five or fifty copies; a request which could be only partially met. Mr. F. N. Denison, who is continuing the tidal observations at Victoria, writes: 'Your Victoria tidal predictions are almost perfect, as proved by plotting them upon the actual records; and are greatly admired and appreciated by those who have seen the comparison.' These tide tables have been reprinted one month at a time, by the *Times* and the *Colonist* of Victoria. The editor of the *Daily Province* of Vancouver, speaks of them as invaluable.

Improvements have been secured during the year by working out the relation of the tide at Esquimalt to Victoria, and also of New Westminster to Sand Heads, from simultaneous observations at those places. A similar relation was worked out for Baynes Sound, from six months of tidal record obtained there; which is of value in affording some knowledge of the run of the tide throughout the length of the Strait of Georgia; as this Sound is 80 miles from Sand Heads, and nearly as far north as the southern tide runs before meeting the contrary tide from the other direction. Observations have also been obtained for some months at Vancouver; and simultaneously with these, the turn of the current in First Narrows at the entrance to that harbour. The results of these observations have been worked out promptly, in time to issue with those above mentioned, to accompany the tide tables for 1902.

Quebec, Father Point, Halifax and St. John, N.B.—In this set, the accuracy of the tide tables for Quebec has been improved by extending the basis from which they are calculated for 1902, from two to four years of observation. This is an important improvement, in view of the full information now issued with these, for the whole of the tidal portion of the St. Lawrence, from Three Rivers to Gaspé. Accurate tide tables for Father Point have also been prepared, and issued for 1902 for the first time. These are calculated from the Quebec tide tables by the method described further on. Tidal differences are also given with these tables for the whole of the Bay of Fundy, based upon observations in that region, and for the Atlantic coast of Nova Scotia.

These tide tables were again supplied to the leading Canadian and British almanacs willing to publish them in whole or in part. An edition of 600 copies, reprinted from

Greenwood's Almanac and now including the Father Point tables, has been widely distributed. The various newspapers have also done something in the way of re-publishing these tide tables, or in giving the time of high water daily, much in the same way as in former years.

Charlottetown, Pictou and St. Paul Island.—These tide tables are of the same character as last year, and they again include the whole twelve months. An improvement in them will be obtained, when the observations taken in Northumberland Strait during this season, are worked out. The tidal relation of Charlottetown to Pictou, and of Pictou to St. Paul Island, will thus be more accurately determined; and also when the tabulation of the tidal record from St. Paul Island itself, is submitted to analysis, the improvement secured will benefit this set of tables which are dependent upon it as a principal station.

The time of high water for Charlottetown, taken from these tables, has been published a month at a time by the *Patriot*, the *Examiner* and the *Guardian*. The tide tables for Pictou have also been published in full by the *Advocate* one month at a time, and accompanied by the tidal differences for the dependent places in Northumberland Strait.

Ste. Croix bar.—Tide tables were again computed for this locality, and with them the difference in time for St. Augustin Bar is given. These tide tables are published in company with the tide tables for Quebec, by the Montreal Harbour Commissioners, in the publication they prepare annually for the information of the St. Lawrence pilots. The new information regarding the tides and currents of the Lower St. Lawrence, was also supplied in a condensed form for this publication.

Tadousac, Cacouna and Little Métis.—Tide tables for the months of July, August and September were again computed for these seaside resorts to meet the demand of the summer residents and tourists. This was done by a little extra work, without expense; as the tide tables were prepared in manuscript only, and posted at the leading hotels.

THE TIDAL ST. LAWRENCE AND ESTUARY.

In the season of 1900 an important series of simultaneous observations was secured, from Quebec to Point de Monts, 260 miles below; this being properly to be considered as the mouth of the St. Lawrence estuary. The tidal stations established and the record secured were :—

Quebec	Continuous record
Grosse Isle	May 4 to Oct. 15
L'Islet	" 12 to " 15
Orignaux Pt	June 22 to Sept. 11
Rivière du Loup	" 30 to Oct. 17
Tadousac	July 6 to Sept. 15
Father Point	Continuous record
Cape Chatte	July 17 to Oct. 1

The two principal tidal stations in this region are Quebec and Father Point, and the first endeavour in reducing the observations was to find in what part of this region the tides could best be referred to Quebec, and in what part to Father Point. To ascertain this, trial comparisons were made for L'Islet and Orignaux Point, the time of the tide at these places being compared with Quebec on the one hand, and Father Point on the other. Without giving the resulting differences in detail, it was found that the upper part of the estuary as far as L'Islet could best be referred to Quebec, and that Orignaux Point and the Traverse and all points below, to the mouth of the estuary, could be referred to Father Point with greater accuracy than to Quebec. This corresponds with the natural features of the estuary; as the deep-water channel, which is 100 fathoms off Father Point, extends uninterruptedly to Orignaux Point, where it still has a depth of 20 fathoms. Above this the river becomes relatively shallower.

The tidal observations secured in 1896 at Carleton in Chaleurs Bay, and in 1897 at Chicoutimi at the head of the Saguenay, were also compared with Quebec and Father Point, to ascertain with which of these stations there was least variation in the difference of the time of the tide. The result showed that Carleton, and with it probably the whole of Chaleurs Bay, can better be referred to Father Point than to Quebec. On the other hand, Chicoutimi can best be referred to Quebec; this being probably due to the character of the tide, its form or type at the head of the long Saguenay estuary being more nearly similar to the tide at Quebec.

The results arrived at, from the reduction of all the observations, are given below; the localities above Quebec being still referred to it as before. The data for some additional localities are secured by a careful comparison with the values of the 'Establishments' in the Admiralty list. A further improvement in accuracy results from the extension of the basis for the Quebec tide tables themselves to a period of four years of continuous observation at that port. The value for South-west Point, Anticosti, is based upon a long series of simultaneous observations with Father Point.

Tidal Differences throughout the tidal estuary of the St. Lawrence; and for Chaleurs Bay.—These differences, when applied to the tide tables for Quebec and Father Point, give the time of high and low water at the places named, in Eastern Standard time, for the 75th meridian west of Greenwich.

Localities referred to Quebec.	Difference to be applied to Quebec Tables.		Rise of Tide.	
	For High Water.	For Low Water.	Springs.	Neaps.
	H. M.	H. M.	Feet.	Feet.
Three Rivers	Add 4 45	Add 6 15	1	
Champlain	" 4 12	" 5 33	3	2
Batiscan	" 3 41	" 4 51	3½	2
Cape Roche	" 2 44	" 3 50	6	4
Grondines	" 2 20	" 3 19	9	6
Point Platon	" 1 41	" 2 11	14½	9½
Ste. Croix	" 1 31	" 2 00	15	10
St. Augustin	" 0 46	" 0 52	16½	11
St. Nicholas	" 0 35	" 0 35	17	11½
Quebec	" 0 00	" 0 00	17½	12
St. Laurent	Sub. 0 16	Sub. 0 24	17½	14½
Berthier	" 0 40	" 1 00	17½	14
Grosse Isle	" 0 57	" 1 19	19	13
Beaujeu Channel	" 0 55	" 1 44	18½	13
L'Islet	" 1 15	" 2 05	18	13
Coudres Island	" 2 16	" 3 10	18	13
Murray Bay	" 2 52	" 3 50	17	12
Chicoutimi, at head of Saguenay	" 3 31	" 3 18	12	8

Localities referred to Father Point.	Differences to be applied to Father Point Tables.		Rise of Tide.	
	For High Water.	For Low Water.	Springs.	Neaps.
	H. M.	H. M.	Feet.	Feet.
Orignaux Point	Add 1 35	Add 1 48	17½	13
Rivière du Loup	" 0 56	" 0 59	16	10½
Brandy Pots	" 0 46	" 0 49	17	10
Tadousac	" 0 32	" 0 36	17	10
Green Island	" 0 35	" 0 39	16	9½
Bic Island	" 0 05	" 0 08	14	8½
Father Point	" 0 00	" 0 00	14	8½
Little Metis	Sub. 0 03	Sub. 0 03	13	8
Matane	" 0 05	" 0 05	11	7
Point de Monts	" 0 08	" 0 10	12	6
Cape Chatte	" 0 08	" 0 10	13	8
Gaspé Basin	" 0 03	.....	5	3
South-west Point, Anticosti Island	" 1 04	" 1 02	6	4
Carleton Point, Chaleurs Bay	Add 0 22	Add 0 16	8	5
Dalhousie "	" 0 33	" 0 27	9	6
Campbellton "	" 1 25	.....	10	7

Tide Tables for Father Point.—It is evident from this that it is necessary to have tide tables for Father Point itself, in order to be able to apply these differences. Heretofore, tide tables have been prepared in manuscript and posted at the lighthouse for the information of the pilots; but these tables were computed merely by means of constant differences of time with Quebec, for high water and low water respectively, as determined by the observations secured. There was, however, a considerable variation in these differences from their average value during the course of the month; especially in the time of low water which usually varies most in estuaries. This variation is shown in the following table, in which the results are all in Standard or absolute time. The method by which the limiting values of these differences is found, to eliminate exceptional values and make them truly comparative, has been explained in a paper communicated to the Royal Society of Canada, and need not here be given as it might be considered technical.

See *Character and Progress of the Tides in the Gulf and River St. Lawrence*—Transactions of the Royal Society of Canada, vol III, 1897.

Father Point to Quebec.	Variation in the difference for High Water.	Range in the Difference.
	H. M. H. M.	H M.
One year.—1894, December 17, to 1896, January 31—601 simultaneous observations	3 45 to 4 43	0 58
One year.—1896, February 1, to 1897, January 31—649 simultaneous observations	3 44 „ 4 41	0 57
	Low Water.	
One year.—1896, February 1, to 1897, January 31—627 simultaneous observations	4 38 to 5 57	1 19
One year.—1897, February 1, to 1898, January 31—653 simultaneous observations	4 33 „ 5 58	1 25

In the endeavour to obtain tidal differences for Father Point with less variation than the above, trial comparisons for a period of one month in the year 1900 were made with Wilhelmshaven, in Germany ; Harwich, on the North Sea, and Portsmouth, on the English Channel. The tide at these harbours is similar to Father Point, in having nearly the same range ; and it might, therefore, be expected that one of these differences might prove to be more nearly constant than the difference with Quebec. But this did not prove to be the case, which makes it unnecessary to give the results of these trials.

On making a close examination of the whole series of differences in the time of the tide at Father Point and Quebec, as observed during two complete years, it appeared that in the case of low water a double variation in the difference of time occurred; firstly, in the period of the synodic month with the moon's phases, and secondly, in the period of the anomalistic month with the moon's distance. The amounts of these variations in the difference were ascertained by four series of analyses, in the periods of each of these months, and for high and low water, respectively.

In the case of High Water, the variation with the moon's phases is not great, and the variation with the moon's distance is only 2 minutes more or less than the mean value, and may be neglected. The time of high water can, therefore, be found from the Quebec tides by the following simple rule:—

Time of high water at Father Point, from high water at Quebec—

About the time of new or full moon, substract..... 4h. 22m.
" " the moon's quarters " ..... 4h. 18m.

In the case of Low Water, the variation in the difference is larger, and the outcome of the analyses which were made, is given in the table opposite, which is used for the calculation of the tide tables.

The following synopsis shows the proportion of the range in the difference for high water and for low water, which can be reduced to law, and which is allowed for by the use of this table. The greatest outstanding error which can occur at any time is *half* of the remainder unaccounted for, which includes weather disturbance, and the diurnal inequality occurring for a few days at the moon's maximum declination :—

Father Point and Quebec.	High ater.	Low Water.
Range in the difference in the synodic month	5 m.	32 m.
" " anomalistic month	4 m.	25 m.
Diurnal inequality in the difference	14 m.	14 m.
Remainder unaccounted for (weather, &c)	34 m.	11 m.
Total range in the difference (average as above)	57 m.	82 m.

TIME OF LOW WATER AT FATHER POINT, FROM LOW WATER AT QUEBEC.
TABLE OF DIFFERENCES IN TIME.

Synodic Month.				Anomalistic Month.			
Moon's Phases.	Difference for Low Water.	Moon's Phases.	Difference for Low Water.	Moon's Distance.	Correction in Minutes.	Moon's Distance.	Correction in Minutes.
Age of tide		Age of tide		Age of tide		Age of tide	

TIME OF LOW WATER AT FATHER POINT, FROM LOW WATER AT QUEBEC.

TABLE OF DIFFERENCES IN TIME.

Synodic Month.

Moon's Phases.	No. of tide	Difference for Low Water. H. M.	Moon's Phases.	No. of tide	Difference for Low Water. H. M.
Full Moon.			New Moon	0	5 41
	28	5 41		1	5 42
	27	5 42		2	5 43
	26	5 43		3	5 43
	25	5 45		4	5 42
	24	5 42		5	5 41
	23	5 41		6	5 40
	22	5 40		7	5 38
	21	5 38		8	5 35
	20	5 35		9	5 32
	19	5 32		10	5 29
	18	5 29		11	5 26
	17	5 26		12	5 22
	16	5 22		13	5 19
	15	5 18		14	5 16
	14	5 15		15	5 14
	13	5 12		16	5 12
	12	5 11		17	5 11
	11	5 11		18	5 11
	10	5 12		19	5 12
	9	5 15		20	5 15
	8	5 18		21	5 18
	7	5 22		22	5 22
	6	5 26		23	5 26
	5	5 29		24	5 29
	4	5 32		25	5 32
	3	5 35		26	5 35
	2	5 38		27	5 38
	1	5 40		28	5 40
New Moon.	0	5 41	Full Moon.		

Total length of Synodic month = 57·06 tide-intervals.

Anomalistic Month.

Moon's Distance.	No. of tide	Correction in Minutes.	Moon's Distance.	No. of tide	Correction in Minutes.
Apogee.			Perigee.	0	+14
	26	—08		1	+16
	25	—08		2	+17
	24	—08		3	+17
	23	—08		4	+17
	22	—08		5	+16
	21	—08		6	+14
	20	—07		7	+12
	19	—07		8	+10
	18	—06		9	+09
	17	—06		10	+07
	16	—05		11	+06
	15	—05		12	+04
	14	—04		13	+03
	13	—03		14	+02
	12	—02		15	+01
	11	—01		16	0
	10	0		17	—01
	9	+01		18	—02
	8	+02		19	—03
	7	+03		20	—04
	6	+04		21	—05
	5	+06		22	—05
	4	+07		23	—06
	3	+09		24	—06
	2	+10		25	—07
	1	+12		26	—07
Perigee.	0	+14	Apogee.		

Total length of Anomalistic month = 53·24 tide-intervals.

In using this table, the new moon is taken as the central point of the month, and the tide falling nearest to it in time is marked 0. The tides are then numbered successively from this in each direction; and the full moon will always fall between two numbers as indicated, since the number of tide-intervals in the synodic month is odd. In the same way, the moon's perigee is taken as the central point of the anomalistic month, and the numbering is carried both ways from it. For greater convenience in calculation a combined table was prepared from these two; by making the perigee fall successively upon each lunar day throughout the synodic month. In this way, a series of twenty-five 'types of month' were obtained, which covers all cases possible, with sufficient accuracy for practical purposes. These types are designated by the letters of the alphabet for reference. It is this combined table which is used in the Survey office for the calculation of the tides at Father Point from the Quebec tide tables; but it is not necessary to publish this here.

It is to be noted however, that a closer degree of accuracy has now been secured for the whole series of St. Lawrence tides; as the basis from which the Quebec tide tables themselves are calculated, has now been extended to four years of tidal observations. These observations afford 35,064 individual heights of the tide hour by hour; the whole of these being reduced to one uniform datum throughout, and corrected for all errors in time which occurred, from variation in the driving clock of the recording instrument.

The current in the Traverse.—A very good series of observations of the turn of the current in the Upper and Lower Traverse, were obtained in the season of 1900. This may be considered as the crucial point on the Lower St. Lawrence; as the currents there attain their greatest strength. Care was taken to secure correct time for the observations, by the use of a chronometer at the Pier in the Upper Traverse, and a time signal thence to the light-ship in the Lower Traverse, in the manner described in last Report. There is no slack water at the turn of the current; but it veers completely round in turning. The time of the turn of the current was therefore taken as the moment at which the current in veering runs directly across its direction at flood or ebb, in the general line of the channel. The observations extended from May 16 to September 15. They were taken during daylight only, in the Upper Traverse; but in the Lower Traverse the swing of the light-ship enabled both the day and night tides to be noted. The swing of the buoys at the opposite side of the channel was also observed; and from the double observations, the true time of the turn of the current in mid-channel was deduced.

On the Admiralty chart of the Traverse, the turn of the current is referred to the time of the tide at Orignaux Point; which was itself unknown however, until the present observations were taken by this Survey. Accordingly, a comparison was first made with Orignaux Point; but the observations there were of shorter duration than elsewhere, as they only extended from June 23 to September 11. Further, the time of the tide at Orignaux Point itself is referred to Father Point; and it was found that the difference in the time of the tide between these two places, was unusually free from variation, on account of the continuous deep channel which runs from the one to the other. The time of the turn of the current in the Traverse was therefore referred directly to the tide at Father Point; for which tide tables are now available. A similar comparison was also made with Quebec in the other direction; but the reference to Father Point was found much the better of the two. The Lower Traverse was selected for the comparison, because both day and night observations were obtained there. The great constancy in the monthly averages of the difference in time, appears from the following summary.

*See map of Lower St. Lawrence, Plate I.

Lower Traverse and Father Point. Observations for 3½ months.

Ebb Stream in Lower Traverse begins, after H. W. at Father Point :—

June 1 to 30.—56 observations.	Turn of current	3h. 35m.	after H. W.
July 1 to 31.—50 "	" "	3h. 32m.	" "
Aug. 1 to 31.—58 "	" "	3h. 34m.	" "
Sept. 1 to 15.—29 "	" "	3h. 34m.	" "
	General average	3h. 34m.	" "

Flood Stream in Lower Traverse begins, after L. W. at Father Point :—

June 1 to 30.—53 observations.	Turn of Current	3h. 52m.	after L. W.
July 1 to 31.—52 "	" "	3h. 58m.	" "
Aug. 1 to 31.—56 "	" "	3h. 59m.	" "
Sept. 1 to 15.—29 "	" "	3h. 53m.	" "
	General average	3h. 56m.	" "

The method of comparison with Father Point being established, an extensive series of observations of the turn of the current in the Upper Traverse was taken in hand for reduction. These had been made in former years, by Mr. E. Lebel, the light keeper of the light-ship ; and they have been preserved at the Quebec Agency. The time of the turn of the current is noted to the nearest quarter of an hour during the seasons of navigation from April to October in each year. On working these out, with reference to the tidal record at Father Point, for the two years 1896 and 1897, the following result was obtained for the turn of the current in mid-channel :—

From 684 observations in the two years. Ebb Stream in the Upper Traverse begins 3h. 13m. after High Water at Father Point.

From 679 observations in the two years. Flood Stream in the Upper Traverse begins 3h. 55m. after Low Water at Father Point.

When the difference in the time of the turn, in the Upper and Lower Traverse is allowed for, these observations corroborate those of 1900 very closely ; indeed, considering the way they were taken. This difference as found in 1900, is given below ; and it is to be noted that the result is exact and independent of any small time error ; as by the method of time signals the time was the same at both places, whether it was in accord with the absolute standard or not.

Upper and Lower Traverse.—Difference in time of turn of Current.

At High Water ; from 149 observations. Ebb Stream begins in the Lower Traverse 22 minutes later than in the Upper Traverse.

At Low Water ; from 135 observations ; Flood Stream begins in the Lower Traverse 10 minutes later than in the Upper Traverse.

The current at L'Islet.—The observations taken here, are at the nearest locality to the point at which there is the least depth at low water throughout the whole Lower St. Lawrence between the ocean and Quebec. This is in the Beaujeu channel, seven miles above L'Islet. The observations were taken at the head of the long pier at L'Islet, by noting the time of the swing of a buoy anchored off its end. The turn of the current at the centre of the ship channel was found to be 15 minutes later than at the head of the pier, as nearly as this could be ascertained from shore observations. With this allowance, the turn of the current in the offing of L'Islet is as follows, in relation to the tide at Quebec, as observed simultaneously :—

From the average of 116 observations, the Ebb Stream in the offing of L'Islet, begins 57 minutes before High Water at Quebec.

From the average of 120 observations, the Flood Stream begins 1 hr. 19 min. before Low Water at Quebec.

Resulting relations between the turn of the current and the time of the tide.—When the latest Admiralty surveys of the St. Lawrence were made in 1885 to 1889 by Staff Commander W. F. Maxwell, the turn of the current was ascertained at a number of points with reference to the time of high and low water. The results of these determinations are given on the charts. But unfortunately the time of the tide itself was not known; as there were then no tide tables for the St. Lawrence to refer to, or any data by which it could be ascertained. It was not until the present tidal observations of 1900 were obtained and reduced, that data for the tide itself were secured. These observations therefore make the previous Admiralty determinations practically available to mariners for the first time. The localities for the tidal observations were carefully chosen with this object in view.

The division of the region into two parts in which the tides are referred to Quebec and Father Point respectively, has the further advantage of reducing the variation in the differences during the course of the month, to the least possible amount; which makes the constant differences now published, more closely accurate; because the variation is allowed for, by the method already described, in the calculation of the tide tables for Father Point itself. A further improvement will only be secured when an analysis of the tidal record at Father Point is made, and tide tables calculated independently and directly therefrom. The tidal relations with Father Point as now established, have in either case a permanent value, however.

The relations between current and tide as given on the charts, have been already published in a tabular form in the last Report, and need not be repeated. The final results are given in the table below; which to sum up, is based on the following information:—(1.) On time of the tide throughout the Lower St. Lawrence as ascertained by the the simultaneous observations above referred to. (2.) On the relations between the currents and the tide as given on the Admiralty charts. The turn of the currents at L'Islet and in the Traverse however are based on observations by the Tidal Survey in 1900, as above explained. All results obtained by the use of this table, are in Eastern standard time, for the 75th meridian west of Greenwich.

Tidal Streams in offing of localities given.	Flood Stream begins after or before L.W.	Ebb Steam begins after or before H.W.	Duration of Flood stream.	Duration of Ebb stream.
After or before Low Water or High Water at Quebec:—	h. m.	h. m.	h. m.	h. m.
Quebec Harbour	1 10 after..	1 05 after..	5 00	7 30
St. Laurent	0 31 "	0 54 "	5 00	7 25
Berthier	0 10 "	0 25 "	5 05	7 20
Grosse Isle	0 19 before.	0 08 "	5 10	7 10
L'Islet	1 19 "	0 57 before.	5 30	6 50
After Low Water or High Water at Father Point:—				
In Upper Traverse	3 52 after..	3 13 after..	5 25	7 00
In Lower Traverse	3 57 "	3 35 "	5 45	6 45
Orignaux Point	2 18 "	2 45 "	5 55	6 30
In Brandy Pot Channel	2 04 "	1 46 "	6 05	6 20
Tadousac			6 08	6 15
Green Island			6 00	6 24
Bic Island			5 50	6 34

Gaspé Basin.—The relation of the tide in Gaspé Basin to South-west Point, Anticosti, was found in 1897 from observations during six days, September 10 to 16. The moon being full on September 10, these include the spring tides. The observations were direct readings on a scale of feet, taken by myself; the water in the Basin being very smooth. The readings were at intervals of 5 or 10 minutes, to accord with the secondary undulation which was pronounced; they were taken for an hour or more at high and low water; and afterwards plotted as tide curves. The resulting comparison with the simultaneous record at South-west Point, is as follows in standard time :—

From the six most concordant values, High Water in Gaspé Basin, 58 minutes later than at South-west Point; and Low Water, 43 minutes later.

Range of tide at Gaspé Basin, from 0·77 to 0·83 of the range at South-west Point. Average of eight values obtained, 0·81.

TIDE LEVELS AND BENCH MARKS ON THE LOWER ST. LAWRENCE.

The soundings shown on charts are always reduced to the level of Low Water at ordinary spring tides; and accordingly this level of the water is usually termed the Admiralty datum. In the more recent Admiralty surveys of the Lower St. Lawrence, from Quebec to the Saguenay, care has been taken to fix or establish this datum level, by referring it to a permanent Bench-mark. In this Survey also, the tide levels in our principal harbours as well as at the more important summer stations, are referred to permanent Bench-marks.

It may be excusable to emphasize the primary importance of Bench-marks in maritime matters, as well as for reference in the construction of harbour works; as this does not seem to be as fully appreciated by mariners and ship owners as it deserves to be. This will be best understood by considering the difficulty of re-determining the low water datum when it is not so recorded; and the uncertainty at best, in the result arrived at. But when the level of Low Water, as originally decided upon for the soundings on the chart, is once fixed with reference to a Bench-mark, it is always possible to ascertain whether exceptional tides fall below this datum level, and so reduce the soundings given. Questions relating to the grounding of vessels at low tide can thus be satisfactorily investigated. Any changes in the depths on shoals, or in their position and extent, can be correctly followed. Tidal observations taken at any later date can be reduced to the datum level of the chart itself, and the rise of the tide as given in a tide table will then show the draught available for vessels in addition to the chart soundings.

In placing wharf scales for the tide gauges erected last season, instrumental levels were taken to determine the height of the zero of the scale with relation to the Admiralty Bench-mark and datum. These levels were always taken in two series, the one as a check upon the other, and the accuracy of the result was always within 0·01 of a foot in height.

If there were continuous levels along the St. Lawrence to connect these different Bench-marks, the tide levels could all be referred to one uniform datum. This would be of special interest in so large an estuary, which may fairly be considered as extending to Point de Monts, and thus to have a total length of 230 miles. It would then be possible to follow satisfactorily the actual levels of high and low water in their progress up the estuary, and the effect of storms in raising or lowering them.

The geodetic levels taken by Mr. Steckel, C.E., of the Department of Public Works, when they are worked out, will furnish a basis from which to obtain this result, and the tidal records now secured will then have additional interest from a physical point of view.

For the present we have adopted for the tide levels, an arbitary vertical scale with its zero at 100·00 feet below the Bench-mark in each locality. This method avoids negative values, and this gives in the most convenient manner the true relative heights of all tide levels, including the datum itself.

It is to be noted that the storms which occurred during the season did not lower the low waters below their normal level, as their effect was to raise the water level as

a whole. The lowest low waters recorded are thus unaffected by them, and may be taken as normal in the sense of being due to astronomical conditions only, while on the other hand some of the high waters are exceptionally raised.

Quebec.—The low water datum at Quebec is thus defined by a note on the chart of Quebec harbour :—'The soundings are reduced to the mean level of low water ordinary spring tides, or 28 feet below a Bench-mark cut in the stonework on the east side of the principal gateway to the Marine and Fisheries Department.'

The tide-levels of the recording gauge at the dry dock at Lévis, have been referred from the beginning to the Admiralty datum, as explained in previous reports. At the dry dock there are two scales of feet cut on the masonry, one outside and the other inside of the dock gate, which are intended to show the height of the water above the masonry sill of the dock. The level of the zero of the outside scale was re-determined with care in May last, and was found to be 7·78 feet below the Admiralty datum. The actual level of the sill of the dock is a fraction of an inch higher than this, as explained in Tidal Survey Report of November, 1897.

The levels of the tides at Quebec, from May to October 15, 1900, are given below for comparison with the other tidal stations of that season.

Description.	Elevation. (Feet.)
Bench-mark at the Marine and Fisheries building in Quebec, as above described	100·00
Coping of the dry dock at Lévis; average level near the dock gate	96·78
Bench mark No. LXXIV, on the masonry of the dry dock, west side	94·58
Exceptional High Water, or storm tide, during a gale on September 12	92·30
Highest level of High Water which was undisturbed by storms, during the season from May 1 to October 15, 1900; on July 13	91·10
Admiralty datum, or low water at ordinary spring tides; 28 feet below the Admiralty bench-mark	72·00
Lowest level of Low Water recorded during the season of 1900, on September 9	71·85
Zero of the scale of feet cut on the masonry outside of the dock gate, 7·78 feet below Admiralty datum. Corresponding elevation	64·22

On the Admiralty chart of 'The Traverse,' the soundings are reduced to the level of low water at ordinary spring tides, the level being referred to two Bench-marks, one at Grosse Isle and the other at L'Islet. These Bench-marks are described below. Also the soundings in the West Narrows, Beaujeu Channel, are reduced to the level of low water ordinary springs, at 25 feet 4 inches below the base of the Crane Island light house. (See note on Admiralty Chart No. 318.)

Grosse Isle.—At Grosse Isle there are two wharfs on the side of the island facing the channel of the river. The Admiralty Bench-mark is a ring bolt, let into the rock at high water mark, situated 200 feet west of the West Wharf. The level of low water at ordinary spring tides, to which the soundings on the chart of the Traverse are reduced, is at 21 feet 10 inches below this Bench-mark.

In using this ring bolt as a Bench-mark, the point taken for reference was the top of the eye through which the ring passes.

As the maximum range of the tide on the whole length of the St. Lawrence river occurs at Grosse Isle, the levels for extreme high and low water are given below. The longest tidal record was also obtained here, extending from May 4 to October 15.

Description.	Elevation. (Feet.)
Top of cap at outer end of West Wharf	103·38
Highest known High Water at the spring tides of February, 1894, as marked at the time and pointed out by Captain Langlois, who resides on the island. The more trustworthy marks give the level of this high water as 102·85 or 103·33. Best mean value	103·01
Bench-mark—Top of eye of ring bolt, as above described. Elevation adopted	100·00
Highest level of High Water recorded during the season of 1900, on September 12	99·90
Highest level of High Water undisturbed by storms during the season of 1900	98·95
Admiralty Low Water datum, at 21 feet 10 inches below the ring bolt	78·17
Lowest level of Low Water recorded during the season of 1900, on September 9	77·80
Zero of Wharf Scale of tide gauge, at 23·78 feet below the ring bolt	76·22
Extreme Low Water, said to lay bare the surface of the mud at site of tide gauge near end of wharf. Corresponding elevation	72·90 (?)

The greatest known rise of the tide, in February, 1894, is thus 24·84 feet above Admiralty datum. This is of interest, as the tide here attains its maximum range on the St. Lawrence.

L'Islet.—The Admiralty Bench-mark is a 'broad arrow' cut into the face of a vertical rock, at 30 feet east of the inner end of the pier at L'Islet. The level of low water at ordinary spring tides, to which the soundings on the chart of the Traverse are reduced, is at 34 feet below this Bench-mark.

On the face of the same rock, a little lower down and to the westward, a copper bolt is let in horizontally, and is marked G.B.M. (Government Bench-mark) No. CLIV.

The levels at L'Islet are as follows:—

Description.	Elevation. (Feet.)
Admiralty Bench-mark, as above. Elevation adopted	100·00
Copper bolt above described, cross-line at the centre	98·28
Highest level of High Water recorded during the season of 1900, on September 12	86·10
Highest level of High Water undisturbed by storms during the season of 1900	84·70
Admiralty Low Water datum, at 34 feet 0 inches below their bench-mark	66·00
Lowest level of Low Water recorded during the season of 1900, on September 11	65·60
Zero of Wharf Scale of tide gauge	63·81

During the whole season, from May 12 to October 15, there were seven tides which fell to the level of the Admiralty datum, or went below it. None of these were more than 0·40 of a foot below datum, this being the lowest point reached, as shown above. This indicates the amount by which the chart soundings in the Traverse may be reduced at times. The levels at Grosse Isle give a corresponding result.

Orignaux Point.—The Admiralty Bench-mark at this point, is a 'broad arrow' cut on a small vertical face of rock, facing the east; at a distance of 37½ feet west of

the inner end of the wharf. It is noted on Chart No. 314, entitled 'Orignaux Point to Goose Island,' that the datum to which the soundings are reduced is 27 feet 11.5 inches below this Bench-mark. As our tidal observations showed Low Water at spring tides to be several feet above this, the attention of the Admiralty was drawn to the discrepancy; and they furnished the corrected value of 23 feet 1½ inches, in May last. It is to be noted that this does not affect the accuracy of the chart soundings themselves; but only the level of the Bench-mark to which they are referred for record. The level of Low Water for this chart is also referred to a Bench-mark at St. Jean Port Joli, as there mentioned.

Description.	Elevation. (Feet.)
Top of cap at the head of the wharf at Orignaux Point	105.37
Bench-mark as above. Elevation adopted	100.00
Extreme High Water; said to reach the top of sheet piling protection, about nine feet below top of cap. Corresponding elevation	96.00
Highest level of High Water recorded during the season of 1900, on July 15 and August 11	95.70
Admiralty Low Water datum; at 23 feet 1½ inches below the bench-mark	76.88
Extreme Low Water; said to lay bare the mud at inside angle of wharf behind the head. Corresponding elevation	74.90
Lowest level of Low Water recorded during the season of 1900, on September 10	74.80
Zero of Wharf Scale of tide gauge	69.97

Rivière du Loup.—The Admiralty Bench-mark is a 'broad arrow' cut into a vertical face of rock, facing north; at 100 feet westward of the centre of the flag pole which stands on the highest ground of Rivière du Loup Point, near the wharf.

On Admiralty chart No. 313, entitled 'Saguenay river to Orignaux Point,' the level of low water at ordinary spring tides is at 24 feet 2 inches below this Bench-mark.

Description.	Elevation. (Feet.)
Bench-mark as above. Elevation adopted	100·00
Exceptional level of High Water during the gale of September 12	93·50
Highest level of High Water, undisturbed by storms, during the season of 1900, on July 14	92·25
Admiralty Low Water datum, at 24 feet 2 inches below the bench-mark	75·84
Lowest level of Low Water recorded during the season of 1900, on September 10	73·70
Zero of Wharf Scale of tide gauge	71·43

Father Point.—The Bench-mark established here by this Survey for reference in the tidal observations, is the head of a copper bolt, let into a level surface of solid rock at 43 feet to the east of the lighthouse. A constant datum level is maintained with reference to this Bench-mark, for the reduction of the tidal observations. For comparison, during this season, we need only give at present the levels of the highest and lowest tides observed, between May 1 and October 15.

Description.	Elevation. (Feet.)
Tidal Survey Bench-mark, as above	100·00
Exceptional level of High Water, during the gale of September 12	96·00
Highest level of High Water, undisturbed by storms, during the season of 1900	94·45
Low water datum, as adopted by this Survey, for the tidal observations	78·95
Lowest level of Low Water during the season of 1900, on September 10	78·50
Zero of Sight-gauge scale	77·19

Tadousac.—As there is no Bench-mark here it will be best to give the height of the tide on the wharf scale itself, to compare its range with the other stations.

Description.	Elevation. (Feet.)
Level of High Water during the gale of September 12	22·75
Highest level of High Water, undisturbed by storms, as recorded during the season of 1900, on September 11	21·60
Lowest level of Low Water during the season, on Sept. 10	2·70
Zero of Wharf Scale of tide gauge	0·00

Cape Chatte.—The height of the tide on the Wharf Scale itself, was as follows :—

Description.	Elevation. (Feet.)
Level of High Water during the gale of September 12	14·05
Highest level of High Water, undisturbed by storms, as recorded during the season of 1900, on August 11	13·45
Lowest level of Low Water during the season, on Sept. 10	0·50
Zero of Wharf Scale of tide gauge	0·00

The value for Low Water is approximate ; the gauge being situated at the mouth of Cape Chatte river which is surrounded by bars which begin to show at low tide. The water near low tide does not therefore fall to its true level. The difference between the level at the gauge and the open water was found from several sets of observations from which a series of corrections at the lower levels of the tides, were deduced. The greatest difference at the lowest tides is five inches. A corresponding correction has therefore been made in the height here given to allow for this.

It may be of interest for comparison to give the greatest observed range during the season at these successive stations along the St. Lawrence. It is to be noted, however, that these do not give the progress of the same tidal undulation throughout the estuary. The ranges as shown below, are the differences between the lowest and the highest levels of the tide at each station, taken from the figures already given ; with the omission of tides disturbed by storms.

	Feet.
Cape Chatte—Greatest observed range ; season of 1900	12·95
Father Point " "	15·95
Tadousac " "	18·90
Rivière du Loup " "	18·55
Orignaux Point " "	20·90
L'Islet " "	19·10
Grosse Isle " "	21·15
Quebec " "	19·25

As there are usually several high and low tides at nearly the same level during the season, a more rigorous comparison would only alter these values by a small fraction. The apparent irregularity at the three upper stations next to Quebec is due to the division of the river into two channels above Orignaux Point, and to the greater depth of the north channel which extends nearly to Grosse Isle. This explains also the relatively earlier arrival of the tide at Grosse Isle, as shown in the tidal differences.

TIDE LEVELS AT THE HEAD OF THE BAY OF FUNDY.

In order to compare the extreme tide levels at the head of the Bay of Fundy, it is first of all necessary to have a continuous datum plane for reference; as observations have been obtained around the head of Cumberland Basin, near Amherst, at Aulac, and at Sackville. In this district also, there occur the most extensive 'dyked marshes' in Nova Scotia, which cover many square miles; and the level of extreme tides is of the first importance for their protection.

An excellent datum for reference has been determined in this region by the Engineers of the Chignecto Marine Transport Railway, which still lies uncompleted. The line of this railway extends from the Fort Lawrence dock on Cumberland Basin, across the isthmus of Chignecto to Baie Verte, and its datum brings into relation the tide levels in the Bay of Fundy and the Gulf of St. Lawrence. The comparative levels resulting from the observations of these Engineers have already been published in the Tidal Survey Report of December, 1898, pages 29 to 32. To extend this datum around the head of Cumberland Basin from Amherst to Sackville, it was hoped that the Intercolonial railway levels could be made use of. These railway levels were originally taken with care, but unfortunately no permanent marks were placed to record them; and the original structures have all been altered since, or the grade on them has been raised. The only available method of re-determining the original datum, was to make use of the 'grade points' at the ends of cuttings. With this object, levels were run for about a mile along the Intercolonial from the Marine Railway, in October 1898; but after the most careful reduction and averaging, the result was still uncertain within the limits of fifteen inches, which was too wide a margin to be of any value.

It was accordingly decided this season, to run instrumental levels especially for the purpose, from the Bench-marks which still exist on the Chignecto Marine Railway, around the head of Cumberland Basin to Sackville. The only time that could be had for this, amid the press of the work proper to the season which had a prior claim, proved to be very windy; which in so flat a country greatly increased the difficulty. The Bench-marks referred to are on masonry culverts, but the stone is of a soft description and has now become so much weathered that they are difficult to find, even with a good description which was noted on the ground in 1898. A new Bench-mark was therefore cut on the engine-house at the Fort Lawrence dock, which was connected in elevation with the existing Bench-marks, and thus affords a good permanent mark as a record of the valuable tide levels of the Marine Railway.

The distance from this to Sackville is nine miles. This distance was subdivided into two lengths at Aulac, and on each sub-division the levels were run in the two directions to secure a check upon them. The limiting total errors on the subdivisions, were 0·03 and 0·02 of a foot from the mean values, and as these balanced one against the other the outstanding error on the whole distance was 0·01 of a foot, from the mean. The Bench-marks established by these levels are given below, with reference to the well-established datum of the Marine Railway.

The elevations of the Bench marks on the Marine Railway were found from a personal examination of the original profiles on which they are marked. They are within half a mile of each other; and the difference of elevation on the profile is 3·44 feet. But in September 1898, the true difference of level was found to be 3·41 feet; and in September 1901, from levels run three times from the one to the other, the difference at present is 3·39 feet. The discrepancy, now amounting to 0·05 of a foot, is apparently due to the cracking and settlement of the masonry of the culverts on which they are cut. Values are accordingly adopted for them which average this discrepancy; and

the averaged value thus obtained is used in establishing the new Bench-mark, and as a starting point for the extended levels around Cumberland Basin.

Bench-marks around Cumberland Basin, as established in 1901.—New Bench-mark on north end of engine house at Fort Lawrence dock, Chignecto Marine Railway. Cut on the string-course of yellow sandstone, at the foot of one of the brick pilasters. Elevation above the Marine Railway datum, 101·42.

Original Bench-mark at the west end of a masonry box culvert on the Marine 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 Marine Railway datum as shown on the original profile, 97·42. Elevation adopted, to average the discrepancy as explained above, 97·45.

Original 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, where the Marine Railway crosses it, 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 as shown on the original profile, 100·86. Elevation adopted, to average the discrepancy as explained above, 100·84.

On the masonry abutments of the Missiquash River railway bridge. East bridge seat, under the centre of the track ; elevation 99·16.

Ditto :—West bridge-seat ; elevation 99·28.

Bench-mark at Aulac. Head of a railway spike, in the top of an old cedar telegraph pole, cut short ; in swamp behind west end of platform, Aulac railway station; at 65 feet from west side of station building, and 35 feet from the front of station platform. Elevation, 91·65.

On the masonry abutments of the Tantramar River railway bridge. East bridge-seat at the centre of the track ; elevation, 102·45.

Ditto :—West bridge-seat, elevation, 102·38.

Bench-marks at Sackville. Broad arrow cut on the masonry foundation at the south end of a white wooden house occupied by William Hicks. The house is north of the Sackville railway station, and is at 160 feet from the corner of the station road. Elevation of bench-mark, 99·86.

In Sackville station yard. Head of a railway spike in the top of an old cedar telegraph pole cut short ; which is beside fence on south side of station yard, at 190 feet east of railway station building, and nearly opposite east end of station platform. Elevation, 93·89.

Extreme levels of High Water and Low Water at the head of the Bay of Fundy.—As observed in Cumberland Basin at the Fort Lawrence dock at the south end of the Chignecto Marine Railway, and at Sackville ; and now reduced to the uniform datum of the Marine Railway for comparison.

The level of extreme High Water is of the first importance with reference to the dyked marshes, and last spring this was further emphasized by wash-outs on the Intercolonial railway, occasioned by the dykes being overflowed. It is chiefly important to know the highest level which it is possible for the tide to reach, when not affected by storm disturbance ; as this will recur periodically under conditions which admit of its prediction. Last autumn and this spring such tides have occurred. The highest levels reached were marked at Sackville, and also at the end of the Marine Railway on Cumberland Basin, when this locality was visited by me early in June. The wash of the recent high tides was then still visible, and the points reached by the water were shown to me by Mr. F. S. Hanford, who is in charge of the unfinished works of the Marine Railway, and resides there. These points were marked, and their elevation determined when the extended levels were taken in September.

A continuous series of observations of the heights of high and low water was made by the Engineers of the Marine Railway at Fort Lawrence dock, at the mouth of the Missiquash river, which extended from August to December, the year being probably 1893. These have already been published in the Tidal Survey Report of December, 1898, and are given as a diagram in Plate III therewith. The extreme values of high and low water then observed are now given again for comparison; and it is to be noted that these extreme tides always occur in the autumn, which is included in the period

of these observations. In the following summary, such other observations as have been secured by this Survey are also noted, to make an embodiment of all the information extant. The extremes here given may be taken as limiting values for natural or astronomical tides, when unaffected by storm disturbance.

Levels of extreme High and Low Tides in Cumberland Basin, Head of Bay of Fundy.	Elevation above Marine Railway datum.
	Feet.
Saxby tide of October 5, 1869, which flooded the country during a heavy storm. Elevation reached. (The datum of the Chignecto Marine Railway is taken as 100 feet below this level.)	100·00
Highest High Water observed at Fort Lawrence dock by the Engineers of the Marine Railway, during five months, August to December, probably in 1893. Occurred October 25	96·00
Exceptional High Water of October 8, 1896, which overflowed the dykes at many places between Amherst and Sackville, and along the Petitcodiac River. Elevation at Fort Lawrence dock	96·13
Exceptional High Water of November 7, 1900, day tide. During a period of light east wind which does not affect height. As marked at the time by Captain Chase at the wharf at Sackville, on the Tantramar River near its mouth	96·68
The High Water of October 9, 1900, also rose within two inches of this. Corresponding elevation	96·52
High waters of April 20 and May 18, 1901; about equal in height. Midnight tides; which in May overflowed the dykes in places, causing a wash-out on the Intercolonial railway. Wind northerly and north-easterly at these dates, which does not affect height.	
(1.) At Fort Lawrence dock. Two independent points in this vicinity, marked by myself. Elevations of the tide at these points, 96·15 and 95·85, Mean	96·00
(2.) At the wharf at Sackville, on the Tantramar River near its mouth. Two points marked at the time by Captain Chase. Elevations, 96·00 and 95·96, Mean	95·98
Extreme High Water at Aulac, as indicated in September, 1901, by wash at Aulac River batardeau, at the crossing of the Intercolonial railway	95·33
From the continuous observations during four and a half months, at Fort Lawrence dock: Mean level of High Water throughout the month	89·00
From the continuous observations during four and a half months, at Fort Lawrence dock: MEAN SEA LEVEL. (See Report of Dec., 1898, p.30.)	70·76
From the continuous observations during four and a half months, at Fort Lawrence dock: Mean level of Low Water throughout the month	52·59
Reference level, taken as extreme Low Water, to which the Marine Railway soundings are reduced	47·20
Lowest Low Water observed at Fort Lawrence dock by the Engineers of the Marine Railway, during the five months, August to December. Occurred October 25 and November 24	47·00

Range of the Tide in the Bay of Fundy.—It is evident from the above figures, that although the range of the tide in the Bay of Fundy is remarkably great, it has been much exaggerated. The greatest ranges in the whole extent of the bay, occur in Cobequid Bay at the head of Minas Basin and in Cumberland Basin. The extreme end of Cobequid Bay, however, is cut off at low water by sand bars. The water is thus ponded in, and does not fall to the true level of low water; but remains at a level which is eighteen feet above this, according to the chart. Accordingly, the highest range that can be measured at any one point, is at Noel Bay. The range at spring tides and the rise at neap tides in these localities, as given in the Admiraly 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.

The observations in Cumberland Basin are more detailed, and they now include the levels of extreme High Waters in recent years, as above given. From all the material thus available, we obtain the following results :—

From the lowest level of Low Water which occurred during the four months of continuous observation, to the level of the highest tide ever known, which flooded the country in October, 1869, during a severe storm; the extreme difference of level is fifty-three feet.

Maximum range at spring tides apart from storm disturbance; from the lowest observed Low Water, to the highest undisturbed High Water, in different years, 49·68 feet.

From the continuous observations from August to December, above referred to. It is probable that this series of observations includes the day tides only; but at this season these are higher than the night tides. These tides are therefore the highest in the course of the year; and the moon's perigee and apogee then corresponded closely with full and change. Average range of the tides during four consecutive months :—

Range of Spring Tides, near the time of the moon's perigee..	47·58 feet
" " moon's apogee...	37·20 "
Range of Neap tides; general average in the above period..	31·00 "

(For the proportional range in Noel Bay, see note on page 26.)

Level of the Top of the Dykes.—These dykes are built to reclaim the extensive 'marshes' or hay lands between Amherst and Sackville, on Cumberland Basin, Bay of Fundy. The elevation given in each case is the average level of several points on the dyke. The relation of the dyke level to extreme High Water will be seen on comparing these levels with the table already given.

Description of the Dykes.	Elevation above Marine Railway datum.
	Feet.
Dyke on east side of Missiquash River, at its mouth	97·26
" west side of Missiquash River, at crossing of Intercolonial Railway	97·14
" east side of Aulac River, at Aulac Station, Intercolonial Railway	97·13
Crest of batardeau on which Intercolonial Railway crosses Aulac River.	97·33
Dyke on west side of Aulac River, at same locality	97·11
" north side of Aulac River, about 1,000 yards from Intercolonial Railway track	97·35
" north side of Tantramar River, half a mile east of railway bridge	97·64
" at same locality, protecting railway track (about nine inches higher than other dykes)	(98·38)
Dykes in same vicinity, general level to horizon	97·82
Dyke on north side Tantramar River, at crossing of Intercolonial Railway	97·56
Dykes on Tantramar River, opposite Sackville, general level to horizon.	97·44
General average level of top of dykes (omitting the special dyke along railway)	97·38

We may note with regard to these dykes the great uniformity in level throughout the stretch of nine miles in extent. This can only have been arrived at from the level of the water itself when standing at high tide. The level as now determined will be valuable for future reference, and also in establishing the relation of the dyke level to extreme High Water.

As a check on the accuracy of the levels themselves as now taken, we may note the close correspondence of the elevation of the exceptional high water of last spring, at Fort Lawrence Dock and Sackville; as it comes out within ¼ inch of the same elevation at these two extremes of the line which was run.

OBSERVATIONS OF TIDES AND CURRENTS IN THE SUMMER SEASON OF 1901.

Summer stations in Northumberland Strait and Cabot Strait.—It has already been ascertained, that the tides in Northumberland Strait can best be calculated from the principal tidal station on St. Paul Island; and that for the Strait itself, Pictou is the best harbour of reference. The method adopted is therefore first to compute tide tables for Pictou by means of two series of variable differences from St. Paul Island, the series for high and low water being distinct from each other; and the variation being in accordance with the moon's declination, in the period of the draconitic or declination month. (See Report of Tidal Survey, Dec. 1898, page 9.) From the Pictou tide tables, those for Charlottetown are next calulated by means of a constant difference of time; and tidal differences from Pictou are also given for other ports throughout the Strait.

The data for the main calculation for Pictou were obtained in 1896 and 1897, when the moon's declination had its maximum range. A further analysis of the differences in terms of the degree of declination was made, to allow for the diminished range in succeeding years; but the result was not sufficiently definite to be trustworthy. The present year was eminently suited however to obtain the supplementary observations required for the purpose; as the range of the moon's declination is now at its minimum, having arrived at exactly the opposite extreme since 1896. Better comparative data between Charlottetown and Pictou will also be secured by this season's observations.

The observations at Pictou were begun as early in the season as possible, the first record being secured on May 20. The gauge at Charlottetown was erected a few days later; and observations at Summerside, in Bedeque Bay, were begun on June 12. These last are intended to secure accurate tidal data for that port; as tide tables have already been published locally by the newspapers there, which are far from accurate. To meet the need, a preliminary result from one month of observations has been worked out immediately, in time to issue with the tide tables for 1902.

To show also the immediate advantage often resulting from tidal observations, it may be mentioned that the Engineers of the Hillsborough bridge now under construction, were taking special observations on a tide scale to ascertain the extreme range of the tide. When they found that the complete tide curves were being secured by this Survey on a self-registering gauge, these special readings were discontinued, and the desired values were supplied during the season by this Survey. The saving thus affected to the advantage of the bridge work, would amount to a large proportion of the outlay made by this Survey for the tidal observations secured at Charlottetown this season.

The object of the tidal observations in Cabot Strait was to obtain comparisons with St. Paul Island in case of any accident to that station, which is always possible because of its extremely exposed position. With this object, registering gauges were placed in Sydney harbour and at Port aux Basques, at the corner of Newfoundland near Cape Ray. It was found, however, that the character of the tide at Sydney was so exceptional, that it was not comparable with St. Paul Island; and accordingly, after one complete month of record had been secured there, the gauge was removed to Neil's Harbour; a point on the Atlantic side of Cape Breton Island, as near as practicable to its northern extremity.

The record secured in Sydney harbour will be valuable in determining a tidal difference for that port; and thus, also, in affording a check upon the tidal differences along the Atlantic coast of Nova Scotia eastward from Halifax. The City datum at Sydney was carried onward by instrumental levels, as far as the site of the gauge; which was placed at the Intercolonial Railway wharf, at Battery Point in the South Arm; and this will furnish the value of low water and mean sea level with reference to the City datum itself.

The two gauges at Neil's Harbour and Port aux Basques have afforded a comparison during several months which is simultaneous with the record at St. Paul Island. Port aux Basques is fairly well sheltered, but Neil's Harbour is only a harbour in name, as it has practically no protection from the open Atlantic; and much trouble was experienced in consequence from wave motion, notwithstanding the precautions taken to prevent this from complicating the recorded tide curves. It is proposed, however, to construct a breakwater there during the coming season, which will make it a more suitable locality for

future observations, should these be indicated as desirable by this season's work. The distances of these localities each way from St. Paul Island are 35 miles westward and 68 miles eastward; the clear width of Cabot Strait itself being 75 miles.

A well established relation with one or other side of Cabot Strait will thus practically afford additional security to this principal station. These relations will also serve better to define the character of the main tidal undulation which here enters the Gulf area from the ocean. This in itself is of much importance, as it is this undulation which gives rise to all the tides throughout the Gulf area, as well as on the St. Lawrence, as far up as tidal influence is felt. This influence extends to a distance of 760 miles from its original entrance through Cabot Strait from the ocean.

The amount of tidal record secured this season for the purposes explained, at these localities, was as follows:—

St. Paul Island, permanent station, Cabot Strait	Continuous record.			
Pictou, N.S., in Northumberland Strait	May	20	to Nov.	15
Charlottetown, P.E.I. "	"	30	"	15
Summerside, P.E.I. "	June	12	"	15
Sydney, Cape Breton (one month only)	July	4	to Aug.	6
Neil's Harbour, C.B., Cabot Strait	Aug.	9	" Oct.	30
Port aux Basques, Nfld. "	July	9	"	30

These stations were all equipped with self-registering tide gauges, with modifications to secure a scale adapted to the ranges of tide in these localities, and special details in their construction to meet local requirements which need not here be more fully described. Greater trouble also occurred from minor difficulties and accidents than in previous seasons; which necessitated much additional travel in the supervision of the stations. This also made it more difficult to find time for the extended levels in the Amherst region, and the inspection of the four principal tidal stations, which formed part of this season's programme.

Time.—At Pictou, Charlottetown and Summerside, correct time for the observations was obtained by means of the railway signals sent daily along the lines. On the Prince Edward Island railway however, it has been the custom to use time signals merely to insure uniformity throughout the Island in running the trains. Arrangements were therefore made to have this signal agree truly with standard time, as this was essential for accuracy in the tidal observations. Special time signals were secured when necessary; and time comparisons made as a check when the stations were visited.

At Sydney, the railway time signals could be depended upon; but at Neil's Harbour and Port aux Basques, special arrangements had to be made. The observer at Neil's Harbour was provided with a well-regulated watch belonging to the Survey, which was kept true by a telegraph signal every week from North Sydney. The observer at Port aux Basques was furnished with a chronometer carefully rated in advance; and the rate was further checked at the beginning and end of the season, by exchange of time with the St. John observatory.

Levels.—At Charlottetown and Pictou, Bench-marks were placed on permanent buildings and connected in level with those used during the observations of 1896, which establishes continuity in the datum for both series of observations. The Bench-mark at Charlottetown was also connected by the Engineers of the Hillsborough bridge, with their datum. At Summerside, the Admiralty Bench-mark recently established, was used; and as it is only fastened to timber piling, instrumental levels were carried to a block of buildings in the town, built of masonry and brickwork, on which a Bench-mark was established for greater security in future reference.

At Sydney, a new Bench-mark was cut on the Court-house, the nearest permanent building to the gauge site, at about half a mile distant. This Bench-mark was connected by instrumental levels with the scale of the tide gauge in the one direction, and the City datum in the other. At Neil's Harbour there was nothing of a permanent character which could be made use of, for reference levels. At Port aux Basques, a ring bolt let into the rock, at the head of the Government wharf, was made use of as a Bench-mark.

Careful attention was also given to ascertain the levels of extreme high water in previous years at the more important localities; good values for extreme low water being obtained during this season itself. When these levels are fully worked out, much information of permanent value will result.

Observations of Currents.—Observations of the more important currents were secured in the regions in which the tidal observations were taken. In Northumberland Strait the current was observed on the north side of Pictou Island during three months, by noting the turn of a spar buoy anchored ¼ mile from shore in four fathoms of water. This will give the time of the turn of this current in the open Strait with relation to the tide at Pictou, the port of reference.

The turn of the current in First Narrows, Vancouver, was observed during 6½ months by the lightkeeper at Prospect Point; which will serve to make known the time of slack water by referring to the tide tables now issued. A preliminary result from one month's observations, was worked out in time for publication in the tide tables for 1902.

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

W. BELL DAWSON,
In charge of Tidal Survey.

Note on the relation of the Range of the Tide in the Two Arms of the Bay of Fundy; at Noel Bay in Minas Basin, and in Cumberland Basin.

Observations have just been received through the courtesy of the Hydrographer to the Admiralty, taken at Noel Bay for 21 days in June, 1859; and from a careful comparison of these with the observations at Cumberland Basin, for an equal period in which the moon's phases and distance were in close correspondence, it appears that the range of the tide at Noel Bay, is from 12 to 19 per cent greater than in Cumberland Basin. An average value of 15 per cent is probably as good a result as can be obtained from so short a period of observation in different years.

W. B. D.

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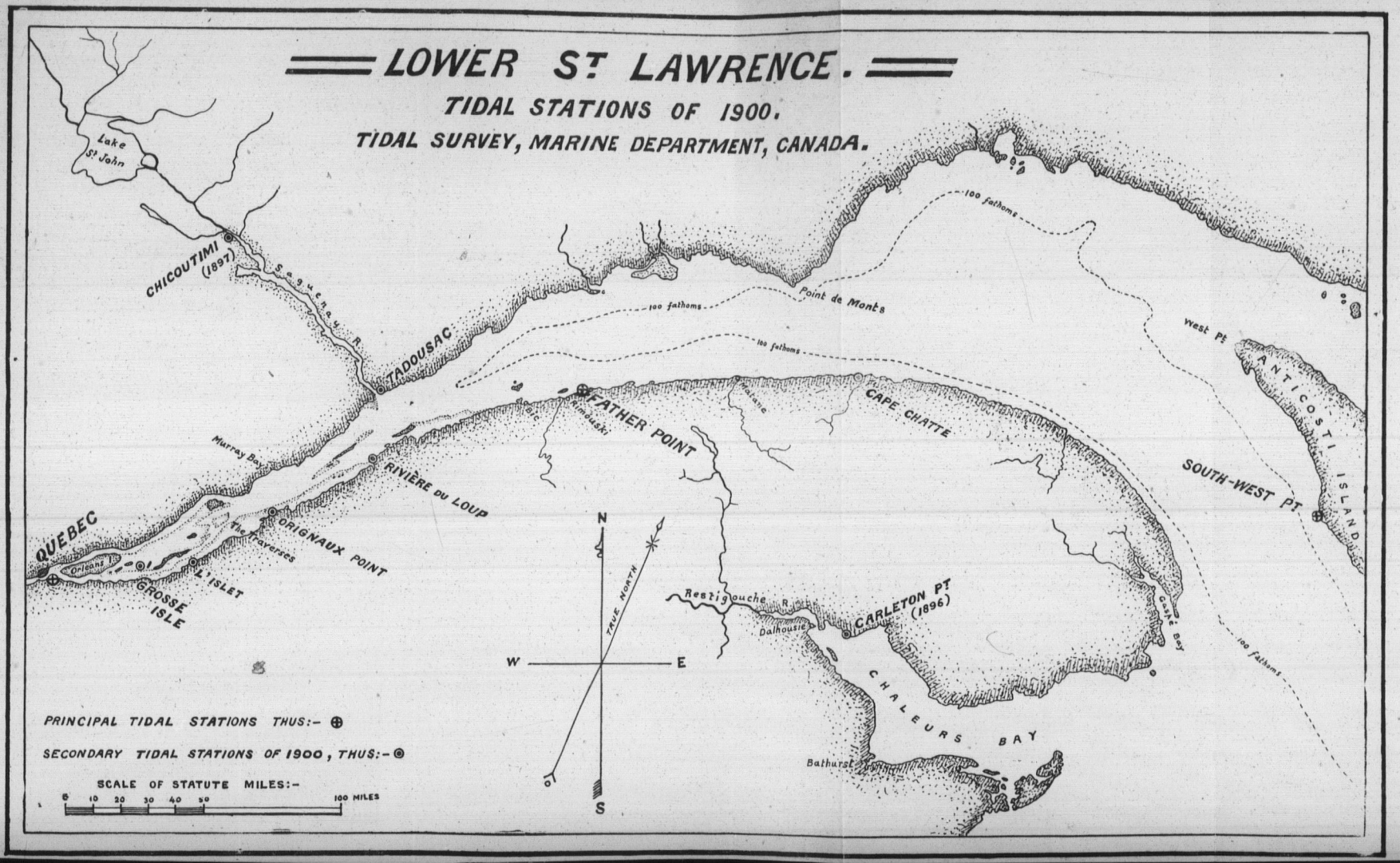
LOWER St LAWRENCE.
TIDAL STATIONS OF 1900.
TIDAL SURVEY, MARINE DEPARTMENT, CANADA.
Lake St John
CHICOUTIMI (1897)
Saguenay R.
TADOUSAC
100 fathoms
Point de Monts
West Pt
ANTICOSTI ISLAND
FATHER POINT
Rimouski
CAPE CHATTE
SOUTH-WEST PT
Murray Bay
RIVIÈRE DU LOUP
ORIGNAUX POINT
The Traverses
QUEBEC
Orleans I.
GROSSE ISLE
L'ISLET
N
S
W
E
TRUE NORTH
Restigouche R.
CARLETON Pt (1896)
Dalhousie
Gaspé Bay
CHALEURS BAY
Bathurst
PRINCIPAL TIDAL STATIONS THUS:- ⊕
SECONDARY TIDAL STATIONS OF 1900, THUS:- ⊙
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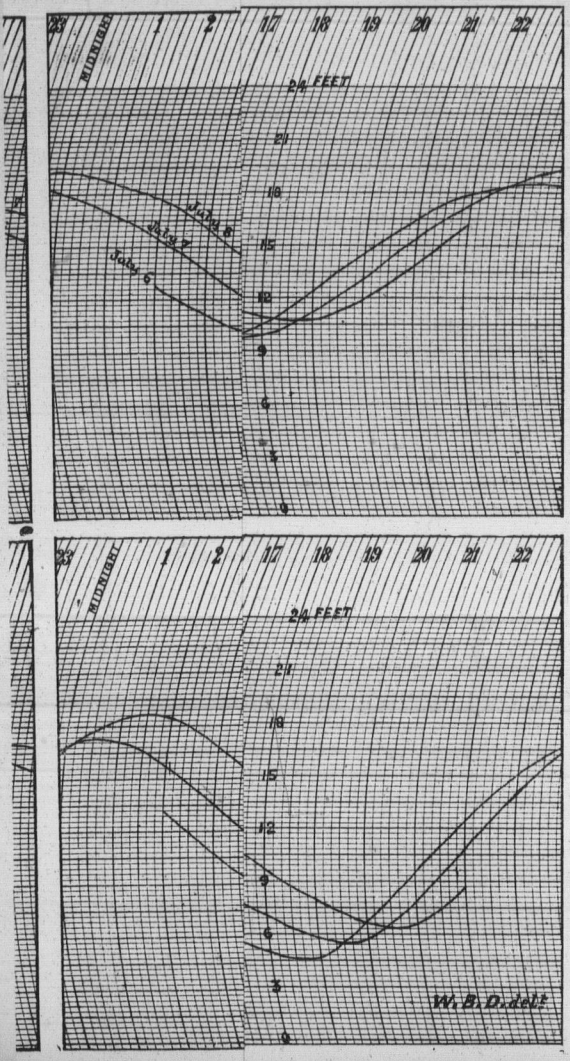
PLATE II.


23
MIDNIGHT
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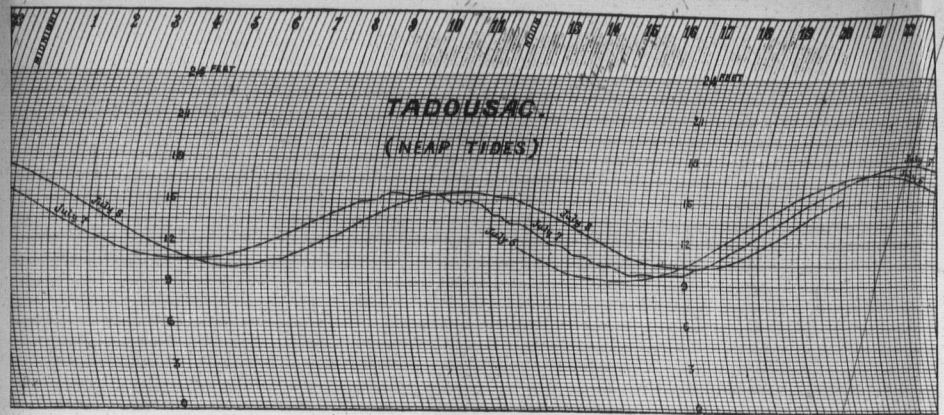
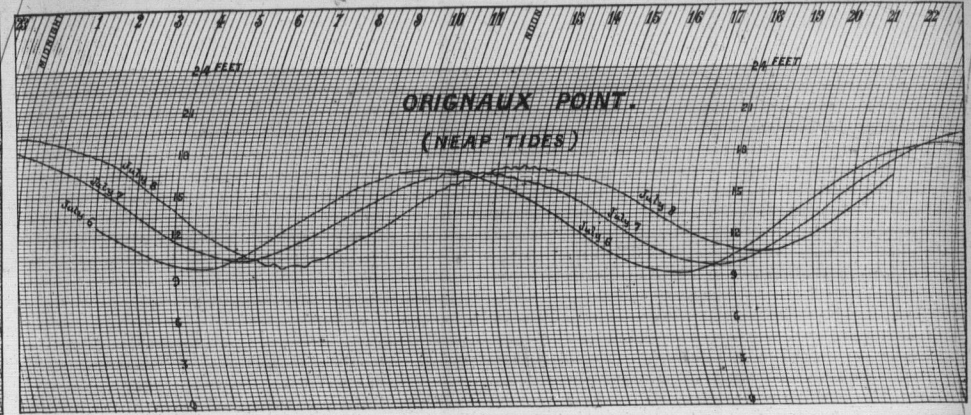
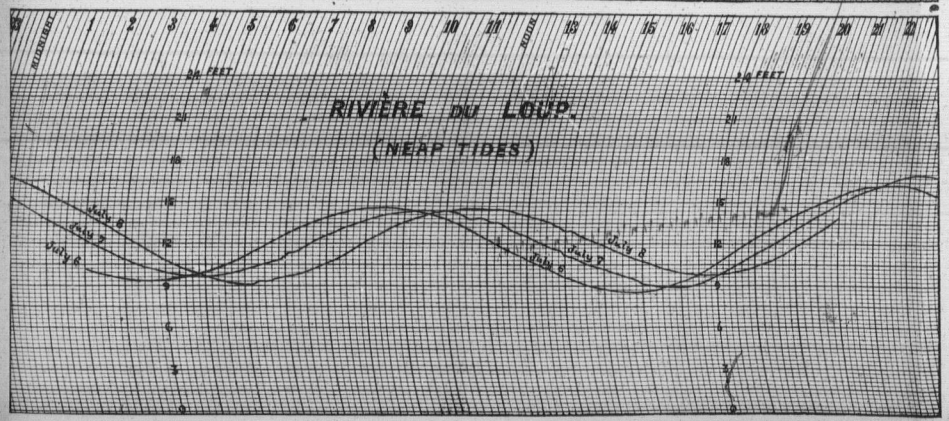
July 8
July 7
July 6
W. B. D. del.t

TIDES OF THE LOWER ST. LAWRENCE.—TIME, EASTERN STANDARD THROUGHOUT.

PLATE II.







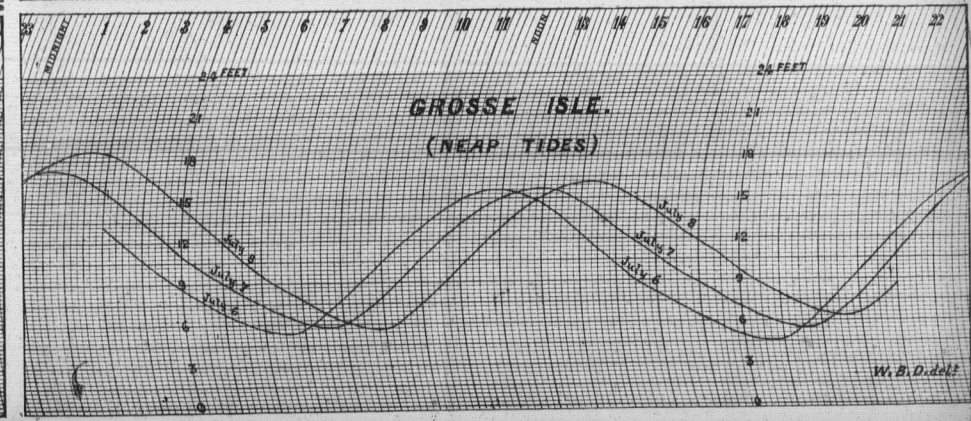
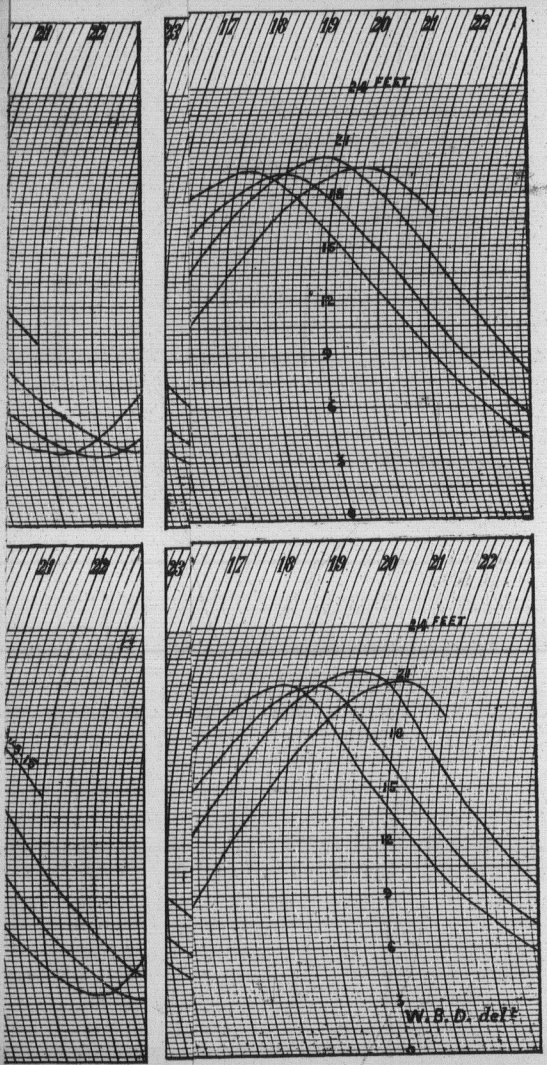


PLATE III.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22
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18
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24 FEET
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21
22
23
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24 FEET
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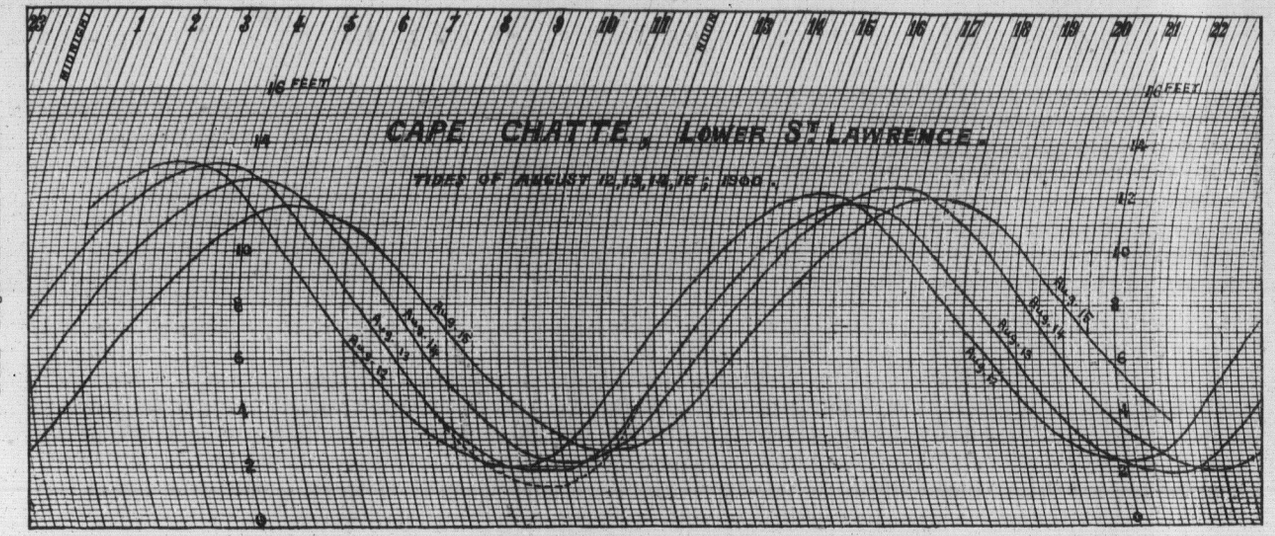
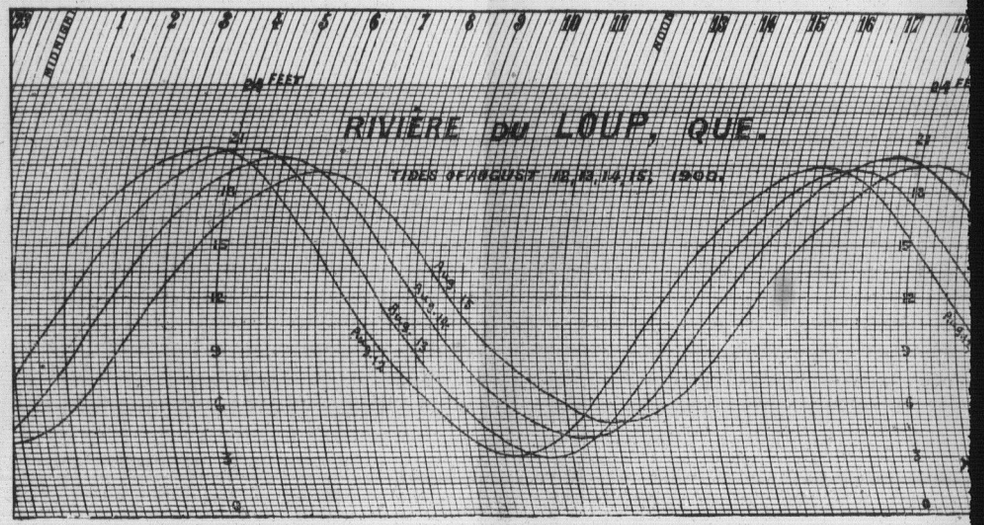
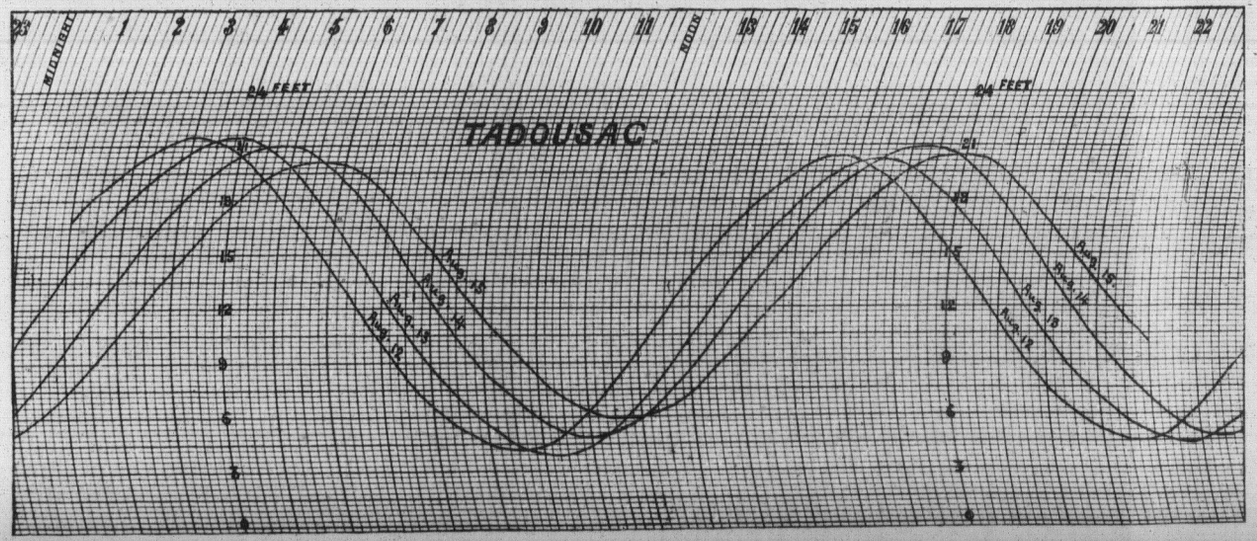
W. B. D. del.t

TIDES OF THE LOWER ST. LAWRENCE RIVER.—TIME, EASTERN STANDARD THROUGHOUT.

NOTE.—Larger scale than the others.







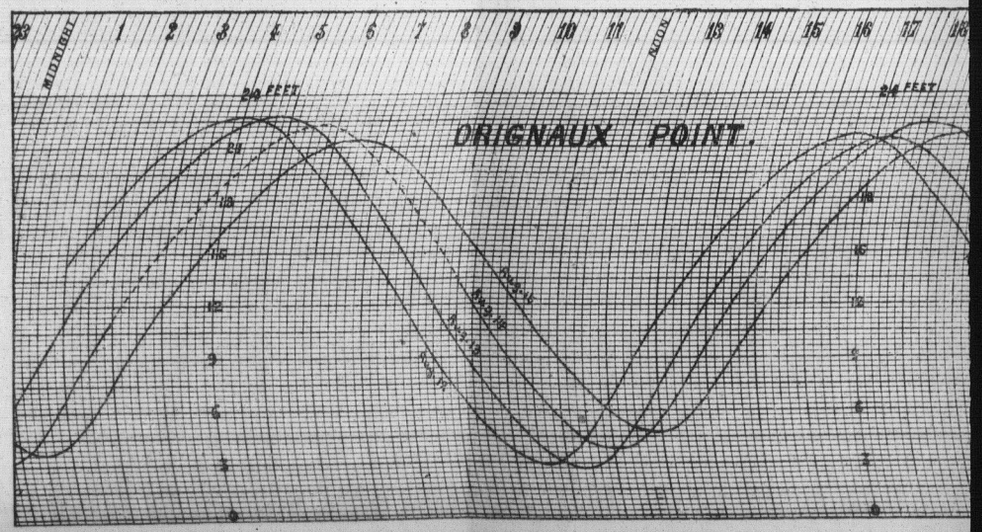
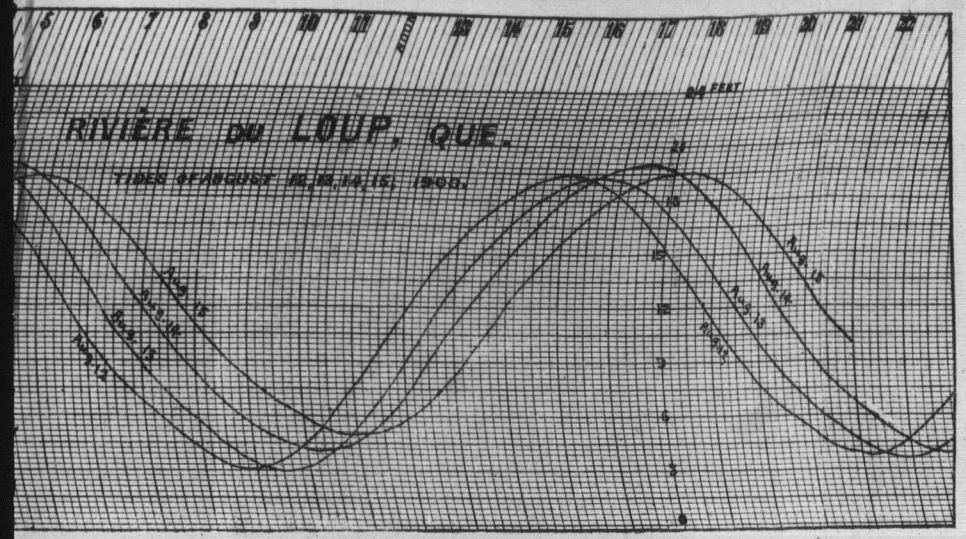
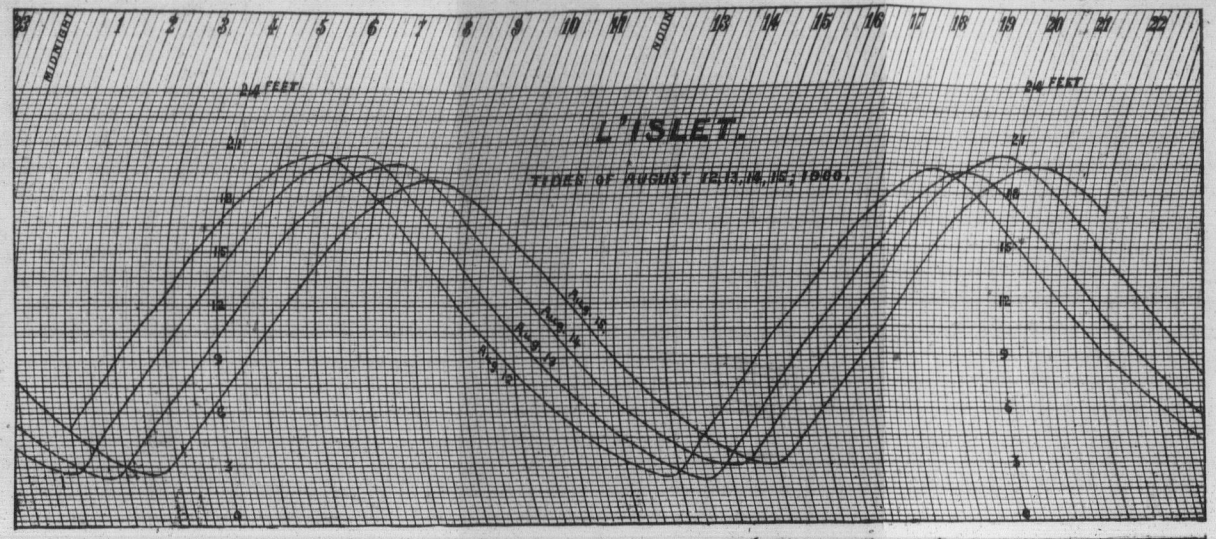


PLATE III.


RIVIÈRE DU LOUP, QUE.
TIDES OF AUGUST 12, 13, 14, 15, 1908.
24 FEET
HOURS
MIDNIGHT
Aug. 12
Aug. 13
Aug. 14
Aug. 15
Aug. 16


L'ISLET.
TIDES OF AUGUST 12, 13, 14, 15, 1908.
24 FEET
HOURS
MIDNIGHT
Aug. 12
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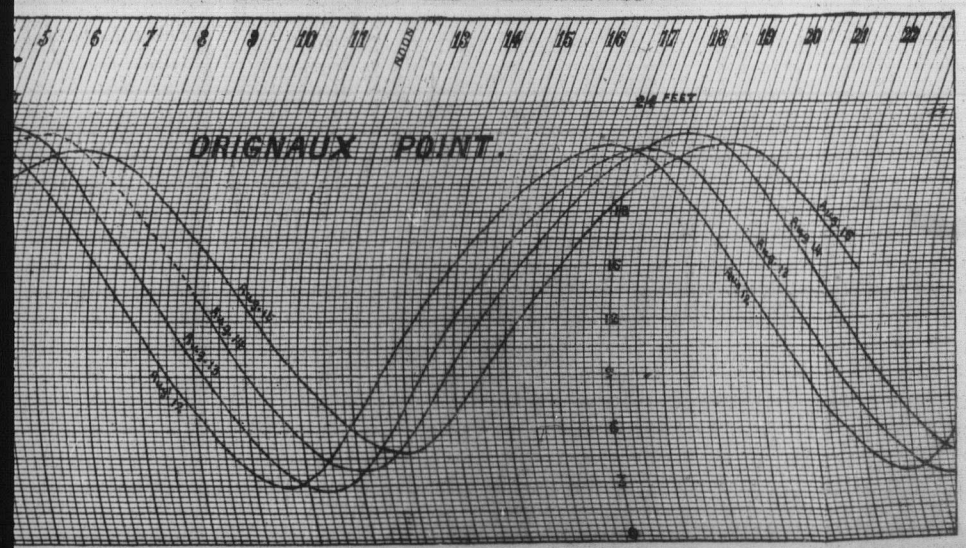
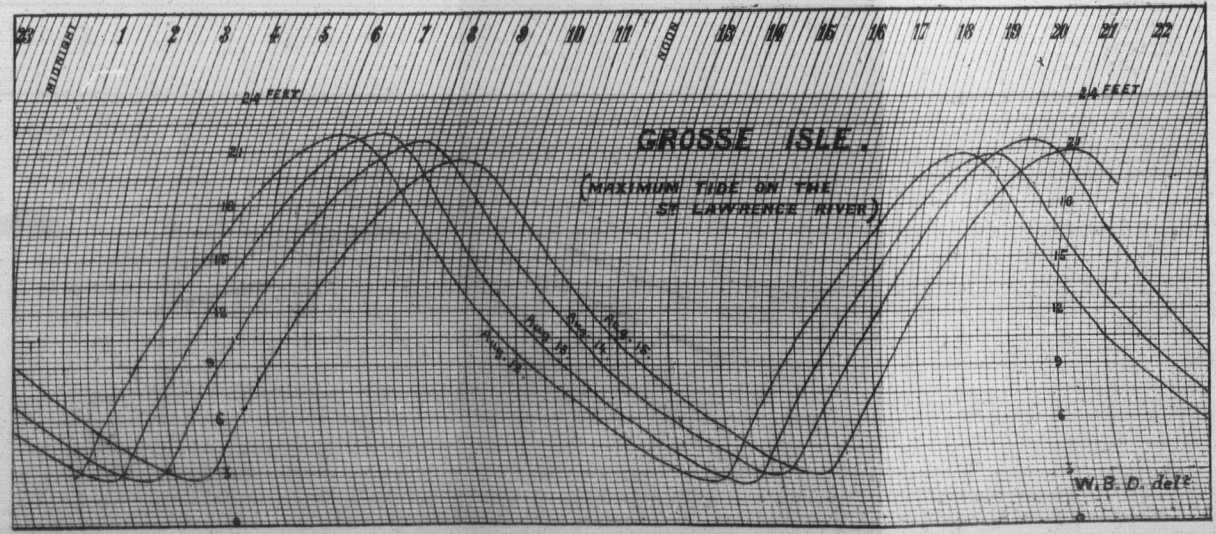
Aug. 15
Aug. 16


DRIGNAUX POINT.
24 FEET
HOURS
Aug. 12
Aug. 13
Aug. 14
Aug. 15
Aug. 16


GROSSE ISLE.
(MAXIMUM TIDE ON THE ST LAWRENCE RIVER)
24 FEET
HOURS
MIDNIGHT
Aug. 12
Aug. 13
Aug. 14
Aug. 15
Aug. 16
W.B.D. delt