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Canadian Society of Civil Engineers.

INCORPORATED 1887.

ADVANCE PROOF *(Subject to revision.)*

TIDE LEVELS AND DATUM PLANES IN EASTERN CANADA.

By W. Bell Dawson, M.A., D.Sc., F.R.S.C., Assoc. M. Inst. C.E., M. Can. Soc. C.E., Engineer in Charge of the Tidal Survey of Canada.

1902.

In connection with the Survey of tides and currents which has now been under the direction of the writer for eight years, or ever since its initial or tentative stage, a quantity of information has accumulated regarding tidal levels, and a number of bench-marks have been established. Most of this information has been published from time to time, in the annual Reports of Progress of this Survey; but it will be of advantage to collate in a condensed form the results obtained, as these now include good determinations of mean sea level, low-water datum planes, and other levels of permanent value.

This Tidal Survey, as a branch of the Department of Marine, has for its primary object the determination of the time-relations of the tide, and the turn of tidal currents, for the information of mariners. The determination of levels is thus quite collateral to the object which the Department has in view, but it is necessary within certain limits; because, at the principal tidal stations, it is essential to have a bench-mark in order to maintain a uniform datum level for the

reduction of the observations. It was also evident that a large amount of important information could be secured by taking more complete levels, and by establishing bench-marks at all tidal stations at which recording instruments were placed, even for a few months. The additional work involved was therefore undertaken from the outset; and as the Survey has to be carried on with a minimum of technical assistance, this has been done by the writer personally. The endeavour has always been made to connect the new levels with any that were already established ; and the work of others thus embodied in the results, is always noted. As these levels are chiefly important for the purposes of harbour construction, city drainage, etc., they will, no doubt, be of interest to this Society.

It may be well at the outset to give some definitions and explanations, regarding the leading planes of reference deducible from tidal observations. Mean Sea Level is the most important of these; as it is presumably a plane which has a truly constant elevation around a coast of any extent, however much the range of the tide itself may vary. The elevations of mean sea level which are here given, are determined from hourly ordinates of the tide, as recorded on a self-registering tide gauge, for periods of not less than one complete year at a time. Its evaluation is one result of the harmonic analysis of the tidal record, which is made for all the principal stations for which tide tables are primarily prepared. This analysis, by which the tidal constants are determined, is made in the Nautical Almanac office, London, by Mr. E. Roberts, F.R.A.S., who is himself a leading authority on this method.

On all marine charts, the soundings are reduced to what is known as the level of " low water at ordinary spring tides," and, accordingly, this is usually known as the Admiralty datum. It is not a plane which has a continuous or constant elevation, however; but its elevation is lower where the range of the tide is greater. In an estuary in which the range of the tide increases, it is necessarily an inclined plane, lower at its head. It is convenient for chart purposes, however; although its level, even locally, is not capable of a strict or scientific definition. (See article on *Tides* by Professor G. H. Darwin, in " Admiralty Manual of Scientific Inquiry.") Where there is a pronounced diurnal inequality in the height of the tide, the practice of the Admiralty is to take the level of the lower of the two low waters in the day, to be on the safe side.

The Harmonic Tide Plane is an endeavour to express this level of low water at ordinary spring tides, in the harmonic notation. It was first defined in the Tide Tables for India, where the method of harmonic analysis was first extensively used for tidal reduction; and it is there termed "Indian spring low-water mark." In this analysis, the various elementary tidal undulations, considered as functions of time, are all referred to Mean Sea Level as their horizontal axis. The Harmonic Tide Plane is defined as being at the vertical distance below Mean Sea Level, which is given by the sum of the semi-amplitudes of the following harmonic components :—

M_2 the principal lunar semi-diurnal component.

S_2 " " solar " " "

K_1 the luni-solar diurnal component.

O_1 the lunar diurnal component, due to the moon's change in declination.

In the level as thus defined, the two leading components which go to make up the diurnal inequality, are included. This must be considered as a compromise, to represent the ordinary practice of taking the diurnal inequality into account, in arriving at the low-water datum. In the formula given in the United States Tide Tables, these same components are used to represent the diurnal inequality, but they are modified by a function of their arguments; the level of the harmonic tide plane being defined by the following sum :—

$$M_2 + S_2 + (K_1 + O_1) \sin \tfrac{1}{2} (M^\circ_2 - K^\circ_1 - O^\circ_1)$$

(See Tide Tables, U.S. Coast Survey, for 1897, page 17, foot note.)

We are able to give two examples of the relation between these planes of reference, for two of our harbours, Quebec and Halifax. At these, the original low-water datum of the Admiralty charts was definitely fixed by reference to a bench-mark, and the Harmonic Tide Plane has now been determined from the observations; and the actual relation between them will be seen from the levels now given for these harbours.

From these explanations, it is evidently very difficult to re-determine the low-water datum when its level is left unrecorded; and at best, the result arrived at is uncertain. It may, therefore, 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, even by mariners and ship owners, as it deserves to be. For if the trouble

is taken to record permanently, by reference to a bench-mark, the level of low water as originally decided upon for the soundings on a chart, it becomes possible to refer any future measurements to the same datum, and thus to ascertain whether exceptional tides fall below it, and so reduce the chart soundings. 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.

The only harbours in eastern Canada in which such bench-marks were found to exist, were at Quebec and Halifax. At these, the Admiralty low-water datum was adopted as the plane of reference for the tidal observations, since their commencement in 1894 and 1895. There is also a series of such bench-marks on the St. Lawrence, below Quebec, established in 1885 to 1889, when the latest Admiralty surveys of the St. Lawrence were made by Staff Commander W. F. Maxwell. At St. John, N.B., all such marks were lost in the great fire of 1877. An endeavour has there been made by this Survey to re-establish the elevation of the original low-water datum, as explained further on. It is of unusual importance there, because in New Brunswick, properties and wharf rights are defined by the low water mark; and the variation in its level is pronounced where the range of the tide is so great.

The most important of these planes of reference is undoubtedly Mean Sea Level; and this is the more emphasized because of the difficulty of defining accurately any low water datum. Mean Sea Level is the only satisfactory plane of reference for geodetic levelling; and even from a geological point of view, any subsidence or elevation of the coast can only be ascertained with reference to it. This level can be definitely determined at localities where continuous observations with a self-registering tide gauge have been obtained, and where a bench-mark has been established for reference; as its value can then be worked out at any time, from the tidal record secured. The record when referred to a bench-mark, also affords elevations for extreme tides, mean low water, etc.

The general practice of this survey has accordingly been to establish a local bench-mark wherever tidal observations have been secured, even for a few months in the summer season. In our more

important harbours, good values for Mean Sea Level are now given herein; which are based upon hourly ordinates of the tide during several years of continuous observation.

The elevation of local bench-marks has usually been assumed as 100.00 feet for convenience, and to avoid negative values. When some general system of levelling for Canada comes to be carried out, the value of these will be much enhanced. Meantime, they are of service locally; and in several instances, they have already been of use in dredging operations, city drainage, bridge works, and for other purposes.

In the information which follows, the tide levels are only given in full for the more important harbours; and the relations between the various datum planes in use, which have been ascertained. At other places, the information is limited, for brevity, to a description of the bench-marks themselves, with references to the Reports of Progress of the Tidal Survey, in which the tide levels will be found more fully given.

Quebec.—The low-water datum to which the soundings on the Admiralty chart are reduced, has been recorded by a Bench-mark, which still exists; and the low-water datum itself 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 gauge for Quebec was erected in October, 1893, at the masonry dry dock on the Lévis side; and instrumental levels have been carried over from this Admiralty Bench-mark to the dock by Mr. R. Steckel, of the Department of Public Works. The levels were carried across the river from the Quebec to the Lévis side at Cap Rouge; and a Bench-mark was cut on the dry dock itself on the face of the masonry of the second altar step, on the west side, near the inner end. This Bench-mark is numbered LXXIV. in Mr. Steckel's series. The elevations of the two Bench-marks, referred to his own datum, are as follows:—Admiralty Bench-mark=27.039; Bench-mark No. LXXIV. = 21.616. The elevation of the Bench-mark at the dry dock, above the Admiralty low-water datum, is therefore 22.58 feet ; and this affords a direct means at the dry dock itself of reducing the tide levels to the Admiralty datum.

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, 1900, 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.

The levels of the various marks above referred to, are given in the following list, in which they are all reduced to the original Admiralty low-water datum; and the results of the analysis of the tidal record as regards level, are included also.

Quebec—Tidal Levels and Datum Planes.	Above or below Admiralty Datum. Feet.
Bench-mark at the Marine and Fisheries building in Quebec, which records the Admiralty datum	28.00
Gnomon of the sight gauge at the Dry Dock at Lévis	29.53
Coping of the Dry Dock; average level taken near the dock gate	24.78
Bench-mark No. LXXIV, on the masonry of the Dry Dock, as above described	22.58
Mean Sea Level.—Deduced from the hourly ordinates of the tide during six years of observation, as follows:—	
During one year, January to December, 1894	8.675
" " " " " " 1895	8.529
" " " Feb. 1, 1896 to Jan. 31, 1897	8.511
" " " Feb. 1, 1897 to Feb., 1898	8.648
" " " March 1, 1898, to Feb. 28, 1899	8.563
" " " March I, 1899 to March, 1900	8.575
Mean value for the six years	8.583
Admiralty Datum, or low water at ordinary spring tides. Used as the plane of reference for the tidal observations; and from it also the heights of the tide in the tide tables for Quebec are measured	0.00
Harmonic Tide Plane, or low-water mark at a distance below Mean Sea Level, given by the sum of the harmonic constants $M_2 + S_2 + K_1 + O$. Mean value of this sum for the six years as above=8.764. Elevation resulting, below Admiralty datum	0.18

Zero of the scale of feet cut on the masonry outside the dock gate. Determined from the individual elevations of the feet in the central part of the scale, as cut. Zero below Admiralty datum.. .. .. 7.78

(The depth of water on the sill of the dock at any tide, may, therefore, be found by adding 7.7 feet to the height of high water as given in the tide tables).

Quebec.—Comparison of Datum Levels.

Admiralty low-water datum, at 28.00 feet below the Bench-mark, Marine and Fisheries building, Quebec, as stated on the chart of Quebec harbour.

Datum established by Mr. R. Steckel, in 1880-82, and termed "Approximate Mean Level, Atlantic Ocean." Defined by the following elevations above this datum :—

Elevation of the Admiralty Bench-mark, as above.. .. .. 27.04
" " coping of the Louise Dock.. .. .. 24.02

(See Report by R. Steckel, C.E., on "Water Levels, River St. Lawrence," Department of Public Works, 1890-91.

Harbour Commissioners' datum. Defined as 24.00 feet below the coping of the Louise Dock. Elevation of the Admiralty Bench-mark above this datum = 27.05, as determined by Mr. St. George Boswell, Chief Engineer, Quebec Harbour Commissioners.

Royal Engineers' datum. Adopted as mean tide level in 1864, and used as the datum for their contoured plan of Quebec. Level of this datum = 7.76 feet above Mr. Steckel's datum, as determined by him from their Bench-marks.

Results with Relation to the Admiralty Datum.	Above Admiralty Datum.
Bench-mark, defining the Admiralty datum..	28.00
Royal Engineers' datum, being their determination for Mean Sea Level at Quebec..	8.72
Mean Sea Level, as determined from six years' continuous observation by the Tidal Survey, at the Lévis Dry Dock..	8.58
R. Steckel's datum, 27.04 feet below the Admiralty Bench-mark..	0.96

Quebec Harbour Commissioners' datum :—

From R. Steckel's determination of actual zero of tide scale	0.94
From elevation of Admiralty B.M., by St. G. Boswell.. ..	0.95
At 24.00 feet below coping of Louise Dock..	0.98
Admiralty datum, and Tidal Survey datum..	0.00

Bench-marks along the St. Lawrence, below Quebec.—In the more recent Admiralty surveys of the Lower St. Lawrence, from Quebec to the Saguenay, Bench-marks were established as already noted, to fix or define the level of "Low-water at ordinary spring tides," to which the soundings of the charts are reduced.

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, 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 arbitrary vertical scale with its zero at 100.00 feet below the Bench-mark in each locality. This method avoids negative values, and it gives in the most convenient manner the true relative heights of all tide levels, including the low-water datum of the charts. For brevity, we will omit the details of the tide levels, and give only a list of the Bench-marks which were made use of, at the tidal stations that were in operation during the season of 1900. These tide levels are published in the Tidal Survey Report of December, 1901, pages 15 to 20.

Crane Island.—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.) This is the shallowest point in the river below Quebec.

Grosse Isle.—At Grosse Isle there are two wharves 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.

The greatest known rise of the tide, in February, 1894, is 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 31 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.

During the season of 1900, 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. 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 reply. 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 noted upon it.

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.

There are no Bench-marks established by the Admiralty below Rivière du Loup. The only others further down the estuary are those used at the principal tidal stations for the purpose of maintaining a constant datum level, for the reduction of the tidal observations. These are as follows :—

Father Point.—The Bench-mark established here by this Survey for reference in the tidal observations, is the head of a copper bolt, let in to a level surface of solid rock at 43 feet to the east of the lighthouse. Elevation adopted, 100.00 feet.

South West Point, Anticosti.—A Bench-mark cut on the rock near the tide gauge, for reference during the observations. The tidal record which was obtained there, extends from July, 1893, to January, 1899, with some interruptions.

Now that tidal record has been secured at these stations, it is always possible to work out the elevations of mean sea level, ordinary low water, extreme tides, etc., with reference to the Bench-mark in each locality. They are thus of permanent value wherever tidal record has been obtained; and their value is the greater in proportion to the length of the tidal record itself.

St. John, N.B.—Owing to the great fire of 1877 the Bench-marks and other points of reference were destroyed; and when the tidal observations were begun in 1893, there was no means of ascertaining the datum plane used in the original Admiralty survey of the harbour, or in the later survey of the entrance to the harbour, made in 1887 by the Public Works Department; nor had any permanent marks been established to show the levels of high and low water at spring tides, as determined at the time that the Government wharf and the breakwater at Negro Point were constructed. There was also no city datum in use; as the steep slope of the streets was taken advantage of, to lay out city works by difference of level without reference to any one datum plane.

In these circumstances it was necessary to re-determine the low-water datum; and its level was not easy to arrive at, where the tide has so great a range, amounting to twenty-eight feet; and the level of low water at spring tides varies so much in consequence. This determination has now been made with great care, by means of the

tidal observations themselves; and it has also been deduced from the level of the breakwater at Negro Point.

The original plans of this breakwater, show the levels of low water and high water at spring tides as adopted during its construction. This low-water level is presumably the same as that used in the latest survey of St. John harbour, which was also made by the Engineers of the Department of Public Works at about the same date. This breakwater is of crib-work; and the outer end may have settled to some extent. The original plans show the tide levels then adopted to be as follows :—High water at 5 feet 0 inches, and low water at 30 feet 6 inches below planking on top of crib-work. With the co-operation of Mr. E. T. P. Shewen, resident engineer of Public Works, and Mr. D. L. Hutchinson, the tidal observer, levels taken near the inner end of the breakwater were carried across to the tide gauge, a distance of 8,000 feet, by means of simultaneous observations of the level of the surface of the water at high tide on a calm day. This method should give quite as close a result as can be deduced from the breakwater; as the surface of the planking itself is uneven to the extent of about two inches; as the following levels show. The elevation of the planking of the breakwater at 150 and 250 feet from the shore end, was found to be as follows, the Bench-mark on the Custom House being 100.00 :—

		Feet.
At 150 feet.	Planking, north side	76.89
do	do south side	76.79
At 250 feet.	do. north side	76.70
do	do south side	76.64
Mean elevation at 150 feet, where the settlement is presumably the least		76.84
Low water, as above defined		30.50
Hence, original low-water datum as adopted when the breakwater was built		46.34

A similar determination was made from the level of the Government wharf on the St. John side; the low water-water datum being shown on the original plans as 31 feet, less 6 inches below the level of the timber cap of that wharf. The resulting level of the low-

water datum was 43.57; and this was further checked by comparison with the zero of a tide-board spiked to one of the wharves, and said to be at the same level as the one used while the survey of the harbour was being made. The level of the zero of this tide-board is 43.78, which agrees nearly with the above; but the indications make it more probable that settlement has occurred here and lowered the level, rather than in the case of the breakwater at Negro Point. The datum as obtained from that breakwater, probably gives the original level of low water at spring tides, as nearly as it can now be arrived at from existing structures, for purposes of comparison with the new determinations. The tidal observations themselves show that the actual level of low water at spring tides is below this. The uncertainties attached to determinations of this character are obviated for the future by the establishment of a Bench-mark to which the series of levels now obtained are referred. This Bench-mark is cut on the granite foundation at the south-east corner of the Custom House; and its elevation is assumed as 100.00 feet.

The comparison of the various old and new datum planes is given in the following list, together with the levels resulting from the analysis of the tidal record. The low-water datum adopted by this Survey, is 55.06 feet below the Bench-mark cut on the Custom House, or at elevation 44.40. This datum is based upon the tidal observations themselves; and it is used as the plane of reference to which the whole series of observations is reduced, and to which also the height of the tide in the tide tables is referred.

St. John, N.B.—Tidal Levels and Datum Planes.	Elevation referred to Bench mark.
	Feet.
Bench-mark on Custom House, as above described.. ..	100.00
Gnomon or zero-point of sight gauge, since June, 1896..	97.94
Highest high water, at the spring tides of October and November, 1896. Probably about the level of the highest astronomical tide possible, apart from storm disturbance..	73.10
Mean Sea Level.—Deduced from the hourly ordinates of the tide during four continuous years of observations. Height above Tidal Survey datum, as follows :—	

During one year, May, 1894 to May, 1895.. ..	13.955
„ „ „ May, 1895 to May, 1896.. ..	13.947
„ „ „ May, 1896 to May, 1897.. ..	13.972
„ „ „ May, 1897 to May, 1898.. ..	14.056
Mean value for the four years..	13.982
Resulting elevation of mean sea level..	58.38
Level of low water at spring tides, as determined from the breakwater at Negro Point, as above explained..	46.34
(This is presumably the low-water level to which the soundings at the entrance of the harbour were reduced in the survey of 1887, as shown on the chart).	
Level of low water at spring tides, as adopted in the original survey of the harbour by the Admiralty. Surveyed under the orders of Captain W. F. W. Owen, R.N., in 1844..	Unknown.
Harmonic Tide Plane, or low-water mark at a distance below mean sea level, given by the sum of the harmonic constants $M_2 + S_2 + K_1 + O$ Mean value of this sum for the four years as above = 12.562. Resulting elevation..	45.82
Public Works datum, adopted by Mr. Shewen in 1896 for construction purposes. Based upon the hourly ordinates during the one month of October, 1895..	45.66
Tidal Survey datum, at 55.60 feet below the Bench-mark. From this datum the height of the tide tables for St. John is measured..	44.40

The plane of reference from which the height of the tide in the tide tables is measured, should, if possible, be placed sufficiently low that few tides in the course of the year may fall below it; as this gives rise to negative values in the tide tables. Where the range of the tide is so great as it is at St. John, and there is consequently so much variation in the level of low water at spring tides, it is difficult to adopt a low water datum which, on the one hand, will exclude these negative values, without, on the other hand, placing it too far below the probable level of low water to which the soundings on the chart of the harbour were originally reduced. If the low-water datum is thus placed too low, it makes it appear that the height of the tide gives a *greater* depth on shoals and bars, than will in

reality be found upon them. The Tidal Survey datum for low water as above defined, is still appreciably above extreme low water. During the course of the year 1895, six tides touched or fell below this datum. Also in the calculated tide tables for 1898 there are six out of the twenty-five spring tides during the course of that year, at which some of the low waters touch or fall below this datum; the lowest tides falling to four-tenths or five-tenths of a foot below it. This datum has therefore as good a position on the whole for a plane of reference for tidal purposes as can be chosen, to avoid the two difficulties above referred to, in a port where the tide has so great a range.

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 sidewalk. Elevation, 133.54. (This Bench-mark was used for reference in determining all the tide levels in the season of 1898).

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

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 gauge.. .. .. 100.66

Zero of Tide Scale of the gauge; 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 beginning 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

Other Bench-marks on the Bay of Fundy.—We will omit as before, the details of the tide levels found from the observations which were taken in 1898, throughout the Bay of Fundy. These are given in the Tidal Survey Report of December, 1898, pages 19 to 22.

Parrsborough.—Bench-mark for the tide gauge at Parrsborough 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 Parrsborough, a cross road turns off to the westward; and the building is on the north side of this cross road, at 200 feet along it from the corner.

Windsor.—Bench-mark 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.

(Windsor cont.)

Elevation adopted for this Bench-mark, 100.00.

Bench-mark 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. Elevation of this Bench-mark above the same plane of reference, 100.03.

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.

Digby.—A Bench-mark was cut on a flight of granite steps in 1898, to fix the levels of the tidal observations; but unfortunately these steps have since been pulled down. Accordingly, last season, a new Bench-mark was cut on the Post Office building, built since; there being no masonry buildings in the town in 1898. The original levels were found from known points on the long Digby pier; and, after checking these with each other to make sure that there had been no settlement in the timberwork, they were carried to the new Bench-mark. This is on the north side of the tower of the Post Office building, at the joint between the granite foundation and the brick-work above. It is marked by a broad arrow, cut at the upper edge of the granite, at two feet west of the basement window in that side of the tower. Elevation of this Bench-mark, 108.98; the cap of the pier at the tide gauge being originally taken as 100.00 for convenience in the tidal measurements.

Yarmouth.—The tide levels here, which have been revised and extended last season, are given further on; as well as their relation to the Yarmouth Town datum.

Clarke Harbour.—This harbour is in the immediate vicinity of Cape Sable, the extreme southern end of Nova Scotia. From this point, the tides begin to assume the character which they have in the Bay of Fundy. A Bench-mark was established here in 1902. It is the top of an iron bolt drilled into the rock at 14½ feet from the north-east corner of Swim's warehouse, which is the most northerly of a set of buildings that extend to the Government wharf at Swim's Point. Zero of tide scale, 21.98 feet below this Bench-mark.

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 as well as 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 in that harbour.

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, etc.; 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 Comissioners 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," which is the datum plane used for the levels on this railway. 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, because of its being 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 at Moncton by the writer. 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 have arrived 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 railway datum plane.

The next question was to ascertain 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 on the ground was made by the writer. 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; 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 march, 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 with the correction as determined from the construction profile. 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 Marine Railway, which are given further on.

A further endeavour was made to obtain a cross connection between the levels of the European and North American Railway, and those of the Marine 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 Marine 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 Marine Railway. To make up the gap, instrumental levels were run by the writer in 1898. 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 Marine 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 elevations 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, or the comparison of the tide levels.

The difficulty met with in obtaining a reliable result from these railway levels, serves 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. The levelling at the time is often well and carefully done by competent engineers; and could it be made use of subsequently, it would be of the greatest service. This Society may deem it advisable to take steps to prevent the further loss of such valuable work in future.

Tide levels at the head of the Bay of Fundy and in the Gulf of St. Lawrence, from the levels of the Chignecto Marine Railway.—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. These levels 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. in the Report of Progress of the Tidal Survey of December, 1898, with a table of elevations of high and low water and the spring and neap ranges of the tide. 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 as indicated by a 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 horizontal 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.

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 Marine 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.

	Feet.
29th Aug. to 26th Sept.—Elevation of Mean Sea Level.. ..	70.26
27th Sept. to 25th Oct.— " " " " "	70.80
26th Oct. to 23rd Nov.— " " " " "	71.12
24th Nov. to 22nd Dec.— " " " " "	71.01
Mean Elevation..	70.80

At Tidnish, Baie Verte, Gulf of St. Lawrence : Mean Sea Level from observations on 78 days, on which both high water and low water were obtained, between 11th August and 16th November.

Mean elevation..	71.02

There are two Bench-marks on masonry culverts in the vicinity of the Intercolonial Railway, which record the Marine 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 Marine 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.

These Bench-marks 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 has been used in establishing a new Bench-mark, and as a starting point for extended levels around Cumberland Basin.

It was necessary thus to extend the plane of reference of the Marine Railway for some miles, in order to compare the tide levels at the head of the Bay of Fundy; as observations have now been obtained near Amherst, at Aulac, and at Sackville. This was undertaken in the autumn of 1901. The distance from Fort Lawrence dock 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, as well as a description of the original Bench-marks themselves, and the revised elevations which have been adopted for them.

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.

With regard to extreme High Water, 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. The extreme values of high and low water observed by the Engineers of the Marine Railway are here given 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. Simultaneous observations show that the unusually high tide of Oct. 8th, 1896, 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.

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 continuous observations during four lunar months, at Fort Lawrence dock...

Mean level of High Water throughout the month.	89.23
MEAN SEA LEVEL. (See details above given).. ..	70.80
Mean level of Low Water throughout the month.	52.38

Reference level, taken as extreme Low Water, to which the Marine Railway soundings were 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

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.

Description of the Dykes.	Elevation above Marine Railway datum.
Cumberland Basin, Bay of Fundy.	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 100 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 Trantramar River, at crossing of Intercolonial Railway	97.56
Dykes on Tantramar River, opposite Jacksville, 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 the spring of 1901, at Fort Lawrence Dock and Sackville; as it comes out within ¼ inch of the same elevation at these two extremes of the line of levels which was run.

Values for the extreme range of the tide in the Bay of Fundy, and the relation between the range in the two arms of the Bay, in Cumberland Basin and in Minas Basin, are given in the Tidal

Survey Report of December, 1901. These are based upon the best determinations obtained to date; but they may be omitted here as not within our present scope.

GULF OF ST. LAWRENCE.—NORTHUMBERLAND STRAIT AND CABOT STRAIT.

The following Bench-marks have been established for reference at summer tidal stations, where observations have been secured for a period of three to five months, in the summer seasons of different years.

Carleton Point, Chaleurs Bay.—Top of pile in the angle between south side of wharf and front of freight shed. Zero of gauge 15.01 feet below top of this pile.

Neguac, Miramichi Bay.—Bench-mark cut on the south-east corner of the lighthouse at Lower Neguac. Zero of gauge 9.37 feet below this Bench-mark.

Cape Tormentine.—Bolt in rock at head of the railway wharf, about 200 feet south of the track. Zero of gauge at 12.80 feet, and zero of wharf scale at 10.80 feet, below this Bench-mark.

Summerside, P.E.I.—A Bench-mark has lately been established here, by Commander Tooker, R.N., to define a low-water datum for the recent surveys made under his direction. It is a "broad arrow" of sheet copper placed on a pile on the east side of the Government wharf, nearly abreast of the lighthouse. The low-water datum is at 7.60 feet below this Bench-mark.

For greater permanence, instrumental levels have been carried from this, to one of the few masonry buildings in the town. The point chosen as a Bench-mark is at the north-east corner of Holman's Block; the joint between the stone foundation and the brickwork, at the top of the course which forms the doorstep level all along the street front of the building. Elevation adopted for this Bench-mark, 100.00. Elevation of the broad arrow, as above, 87.30. Elevation of the low-water datum, defined as 7.60 feet below the broad arrow, 79.70.

(For the complete series of tide levels at Summerside, see Tidal Survey Report of Nov., 1902).

Charlottetown.—There is no City datum; although an approximate level for low-water was obtained from a short series of tidal observations when the drainage system was put in; and more recently,

the tide levels established by this Survey in 1896 have been made use of. There is no Bench-mark to record and fix the low-water datum of the charts. The Bench-marks established by this Survey have enabled a uniform datum to be used for the tidal observations of 1896 and 1901. By the instrumental levels taken last season, all the information extant with regard to extreme high and low tides, has been referred to these Bench-marks, which thus serve to fix perpermanently all the important tide levels; and the datum adopted in 1901 for the Hillsborough bridge now under construction, has also been connected with them. They are as follows :—

Original Bench-mark of 1896. On Peake's building at the south-west corner of Queen and Water streets. The northern end of the sandstone window sill next to the corner, on the front of the building facing on Queen street. Elevation, 100.00.

New Bench-mark, 1901. On a brick block at the south-west corner of Queen and King streets. The top of the sandstone plinth at the corner, on the side facing King street; the level being the same as the joint between the sandstone foundation and the brickwork on the King street side of the block. Marked by an inverted broad arrow on the stone above the plinth, and the letters "B.M." Elevation, 103.18.

(The elevation of this Bench-mark above the Hillborough bridge datum is 108.49 feet).

	Feet.
Exceptional High Waters during gales; being night tides on October 11-12 and on December 5, 1900, the latter being the higher of the two. Average level of three points marked at the time by the Harbour Master and by Mr. G. Handrahan..	95.30
Top of cap of wharf beside the tide gauge, at the south-west corner of Connolly's wharf..	94.09
Highest High Water recorded by the gauge in the season of 1896. Occurred November 6; level raised by a storm. ..	93.90
Highest High Water recorded by the gauge during the season of 1901, from May 30 to November 15. Occurred on October 1..	93.95
Low Water Datum, based upon the average elevation of the lower of the two low waters in the day, at spring tides, during the two seasons of 1896 and 1901..	84.80
Lowest Low Water recorded by the gauge in the season of	

(Charlottetown, cont.)

1896; a number of those in the early part of the season being lost on account of chokage when the tide was low. Occurred October 9.. .. .. 84.35

Lowest Low Water recorded by the gauge during the season of 1901, between the dates already given. Occurred October 29.. .. .. 84.00

Exceptional Low Water, as observed by the Engineers of the Hillsborough bridge; 1901, May 20.. .. .. 83.03

Zero of the scale of the gauge in 1896.. .. .. 81.80

" " " in 1901, set one foot higher than in 1896.. .. .. 82.80

Level of the inlet of the tide column in 1901.. .. .. 78.03

Pictou, N.S.—The Bench-mark to which the levels are referred, is the surface of the stone door sill at its south end, in the door way of the Custom House building which faces the Harbour.

	Feet.
Elevation adopted for the Bench-mark as above..	100.00
Extreme High Water, which occurred during the "August gale," on August 9, 1873. The highest tide known, but not definitely recorded..	.....
Exceptional High Water ; a night tide in December, 1889, as marked by the Harbour Master at the time. It occurred during a gale from the north and north-west..	90.86
Exceptional High Water of December 5, 1900; as marked at the time by Mr. Peter Fraser..	89.72
Highest tide recorded by the tide gauge during the season of 1896, from June 3, to November 27. Occurred during a storm on November 6..	88.35
Highest tide recorded by the gauge during the season of 1897, from June 21, to November 30. Occurred during a storm on November 27..	88.40
Several tides in these seasons reached elevation..	87.65
Highest tide recorded by the gauge during the season of 1901, from May 20, to November 15. Occurred on October 1..	87.85
(A storm tide on November 10, was 0.05 foot higher).	
Low Water Datum, based upon the average elevation of the lower of the two low waters in the day, at spring tides, during the three seasons of 1896, 1897 and 1901..	81.40

(This elevation of 81.40 should be the same as the Low-water datum of the Chart of Pictou harbour, as nearly as can be ascertained by observations of these three seasons).

Lowest Low Waters recorded by the gauge in each of the three seasons, between the dates already given:—

Season of 1896, on June 26..	80.25
Season of 1897, on November 27..	80.15
Season of 1901, on May 20..	80.02
Zero of the scale of the tide gauge in 1896..	80.16
„ „ „ in 1901, set six inches lower than in 1896..	79.66

The weather conditions at the dates of the above exceptional high waters in Northumberland Strait, are given in the Tidal Survey Report, of November, 1902; and in it a comparison is also given of extreme tide levels, to show the relation of the ranges in Cabot and Northumberland Straits.

Souris, P.E.I.—Circular hole cut in red sandstone and marked "B.M.," about 90 yards west of shore end of Knight's wharf. Zero of the gauge at 6.00 feet below this mark.

Port aux Basques, Newfoundland.—This is the nearest harbour to Cape Ray, at the south-west angle of Newfoundland. The point here used as a Bench-mark, is the top of an iron eye-bolt, let into the rock, six feet west of the north-west corner of E. Pike's fish store; at the head of the Government wharf.

(For the tide levels referred to this Bench-mark, see Tidal Survey Report of November, 1902.)

At the two permanent tidal stations which command the two entrances to the Gulf of St. Lawrence, the following Bench-marks were established and have been used for reference throughout the series of observations, since their commencement in 1893 and 1894. Accurate values for mean sea level, extreme tides, etc., can thus be derived from the tidal record.

St. Paul Island, Cabot Strait.—Surface of the plate of the dipleidoscope, on top of the iron column supporting it; elevation, 100.06. (Originally 100.00, but raised by frost in successive years to this elevation.) Bench-mark cut on the face of the cliff at the tide gauge in 1893; elevation, 39.92. Copper bolt drilled into a level bench of

rock, between the tide gauge and the sea; elevation, 37.55. Low-water datum, from which the height of the tide in the tide tables is measured, 19.56.

Forteau Bay, Belle Isle Strait.—Surface of the plate of the dipleidscope, on top of the iron column supporting it; elevation, 100.02. (Originally 100.00, but since raised by frost). Centre of bronze bolt drilled into a vertical face of rock in a reef, at about half tide level; at 78 feet south of the south-east corner of the crib work on which the tide gauge stands; elevation, 84.05. Low-water datum to which the whole series of tidal observations is reduced, 81.00.

Sydney, N.S.—The City datum was utilized for the tidal observations. To do this, it was necessary to carry the city levels half a mile further, to the site of the gauge, which was placed at the Intercolonial Railway wharf at Battery Point. A Bench-mark was cut on the Court House, on the corner of Charlotte and Desbarres streets, which is the nearest masonry building to the sight of the gauge. It is cut on the stonework on the south side of the basement doorway, under the main entrance; on the west side of the building.

	Feet.
New Bench-mark cut on the Court House, as above described. Elevation above the Sydney city datum..	57.20
Cap of the wharf at the tide gauge, Battery Point..	10.43
Highest High Water recorded by the gauge during the observations, continued for one month, from July 4 to August 6, 1901, occurred on July 17..	5.35
Lowest Low Water recorded, in the same period; occurred on July 16..	0.10
The Sydney City datum. (Intended for Low Water)..	0.00
Zero of the scale of the tide-gauge; below datum..	-1.51

Halifax, N.S.—Repeated endeavours have been made to ascertain the relation at Halifax, between the Admiralty datum, the Royal Engineers' datum, and the City datum, none of which accord with each other.

The most important of these from a marine point of view, is the Admiralty Low-water datum, to which the soundings on the chart of Halifax harbour are referred. This datum is fixed by reference to a Bench-mark in the Dockyard, and it is defined by the following note on the chart of Halifax harbour:—"The soundings are re-

duced to the level of Low Water Ordinary Spring Tides, viz.: 16.08 feet below a Bench Mark, cut near the South east angle of the Sail loft at the Dockyard." The tidal observations from the self-registering gauge have also shown that the datum as thus defined, is closely in accord with mean low-water at spring tides. This datum may, therefore, be accepted as correct and well established.

The tide-gauge is situated at the Marine and Fisheries wharf, a property adjoining the Dockyard; and the Admiralty datum as above defined, has been used for reference throughout the series of observations, since 1895. The levels were then carried over to the gauge from the above Bench-mark, and they have been repeatedly checked by myself in subsequent years; and any changes in elevation at the gauge, due to settlement or other causes, have been carefully allowed for. The Tidal Survey levels are thus consistent throughout, and in accord with the Chart datum.

The best relation between the other two datum planes, was established by Mr. E. H. Keating, when City Engineer at Halifax, from comparisons between twenty-one Bench-marks, which define the City datum and the Royal Engineers' datum respectively. From his original notes, the difference between them, as indicated by these Bench-marks, ranges from 1.61 to 1.96 feet, when two exceptional values are discarded which he has marked. The actual average of the nineteen remaining differences is 1.81 feet; and the mean value which Mr. Keating has finally adopted, places the Halifax City datum at 1.85 feet below the Royal Engineers' datum. This value for the difference has been generally adopted.

This relation being established, it is clear that if the elevation of the Bench-mark in the Dockyard with reference to either of these datum planes, could be correctly ascertained, the desired relations would result. A further endeavour was accordingly made this season, to connect the Halifax city levels with the Bench-mark in the Dockyard. But the City Bench-marks in that vicinity were found to have both " original " and " corrected " elevations; besides showing a want of agreement with each other; and no method of working out the comparisons could be devised to give a satisfactory result. Discrepancies ranging from four inches to a foot remained outstanding which could not be accounted for, as there was no means of knowing which of them had the greater balance of probability in their favour.

The elevation of the Bench-mark in the Dockyard is given as

11.05 feet above the Royal Engineers' datum on their own plans; and it is also so noted on the chart of Halifax harbour. The tidal observations made it improbable that this could be correct, however; because the Royal Engineers' datum is presumably intended for Mean Sea Level; and this level as now ascertained from four years of continuous observation, is found to differ by 1.55 feet from this value; an error which is inadmissibly large where the range of the tide is only seven feet. In confirmation of this intention it may also be noted that at Quebec their datum corresponds closely with Mean Sea Level; as will be seen by reference to the elevations already given for Quebec.

The attention of the Colonel Commanding the Royal Engineers was called to this discrepancy, as it appeared probable that the error was in the elevation of this individual Bench-mark. On investigation, this proved to be the case, and its true elevation is 12.61 feet, as found by connecting it with four other reliable Bench-marks, also established by the Royal Engineers.

This result may be considered as very satisfactory, as the elevation of the Royal Engineers' datum, as defined by their other Bench-marks, is thus brought into correspondence with Mean Sea Level; as shown in the following summaries in which the results of these determinations are given. It is also confirmatory of the accuracy of the Admiralty low-water datum, because our elevation for Mean Sea Level is referred to the Admiralty datum as defined on the chart, and the independent determination from the Royal Engineers' Bench-marks, is now found to coincide with this. The relations between the three datum planes at Halifax, are thus satisfactorily ascertained. They are given with reference to one datum plane, in the following list:—

Halifax, N. S.—Tide Levels and Datum Planes.	Above or below Admiralty Datum.
	Feet.
Bench-mark in the Dockyard, as above described, which records the Admiralty datum	16.08
Coping of the Halifax Dry Dock	10.97
Highest High Water during the tidal observations from 1895 to 1902. Occurred during a gale on 25th Nov., 1901. Elevation reached	9.35

(Halifax, cont.)

Mean Sea Level.—Deduced from the hourly ordinates of the tide, during four complete years of observation, as follows:—

During one year, Oct., 1895 to Oct., 1896	3.391	
,, ,, ,, January to December, 1897	3.515	
,, ,, ,, ,, ,, ,, 1898	3.512	
,, ,, ,, ,, ,, ,, 1899	3.492	
Mean value for the four years	3.478	3.48

Harmonic Tide Plane, or low-water mark at a distance, below Mean Sea Level, given by the sum of the harmonic constants $M_2 + S_2 + K_1 + O$. Mean value of this sum for the four years 1851-1852 and 1860-1861 = 2.955. Value for the year 1895-96=3.093 feet below Mean Sea Level, which in that year was 3.391. Average elevation resulting 0.41

Low Water as observed. Average level of lower Low-water at each spring tide during 1897 .. .. 0.20

Admiralty Datum, or Low-water, at ordinary spring tides, at 16.08 feet below the Bench-mark. Used as the plane of reference throughout the tidal observations since their commencement in 1895 .. .. 0.00

Level of the plane of reference used for the early tidal observations of 1851-1852 and 1860-1861. Average for the four years = 4.377 feet below Mean Sea Level; or 1.421 feet below the Harmonic Tide Plane. Mean elevation resulting, below Admiralty datum 0.96

(The height of the tide in the early tide tables was referred to this plane of reference).

Sill of the Halifax Dry Dock. Level of the granite sill of the dock, below Admiralty datum 23.49

(The depth of water on the sill of the dock at any tide, may therefore be found by adding 23.4 feet to the height of high water as given in the tide tables).

Other Datum Levels in Relation to the Admiralty Datum.	Above Admiralty Datum. Feet.
Bench-mark in the Dockyard, which defines the Admiralty Low-water Datum	16.08
Saxby tide of October 5, 1869. Elevation at Halifax, as determined in April, 1876, by Mr. E. H. Keating, City Engineer: 7.90 feet above the City datum	9.52
Mean Sea Level, as determined by the Tidal Survey from four years of continuous observation. (See detail given above)	3.48
Royal Engineers' datum, at 12.61 feet below the Bench-mark in the Dockyard, this being the corrected value as determined by the Royal Engineers in 1902	3.47
Halifax City datum, at 1.85 feet below the Royal Engineers' datum, as determined by Mr. E. H Keating, C.E.	1.62
Admiralty datum, and Tidal Survey datum	0.00

Yarmouth.—The best point for a permanent Bench-mark which could be found in the vicinity of the tide-gauge, was the brick chimney of the Kemptville Lumber Company, 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. The point used as a Bench-mark is the joint between the stone foundation and the brickwork, at the north-west corner.

Levels have been taken since, on two occasions, to obtain the relation between the Tidal Survey levels and the Town datum in Yarmouth; and in this endeavour the Town Engineer, Mr. E. S. Matheson, has given his co-operation. In the best comparisons that can be obtained, there is still an uncertainty of over two inches in the result however; as will be seen from the elevations referred to the Yarmouth town datum, given below. The elevations of some additional points are now given; and the slight variation in the elevation of the tide scale is also indicated. The rail level at the railway crossing at the foot of Forrest street was originally taken as 100.00, but this was found to have changed more than an inch between 1898 and 1901, and was therefore thrown out as unreliable. The levels on hydrants are here taken on top of the spindle.

(Yarmouth, cont.)

	Feet.
Bench-mark on chimney, as above described..	108.53
On hydrant at the corner of Cliff and Main streets..	137.31
Elevation above Yarmouth town datum = 141.88.	
On hydrant at the foot of Horton street, near Water street.	103.87
On hydrant at the foot of Brown street, corner of Water street..	103.32
Top of stone post at south-east corner of L.E. Baker's office; at head of the Yarmouth S.S. Company's wharf..	94.81
Elevation above Yarmouth town datum = 99.54.	
Highest high water observed in the season of 1898, July 4, p.m.	90.45
Lowest low-water observed in that season, July 5, a.m.. ..	74.15
Zero of Tide Scale, as originally set in 1898..	72.36
" " after being replaced more than once by a new scale. Elevation in September, 1901..	72.37

The above levels were taken in 1901 and 1902; and as in the case of all the Tidal Survey levels published, they are reliable within 0.01 of a foot. The zero of the tide scale in 1901 was checked by two series of measurements made by two different methods; and the alteration in elevation since 1898 may be disregarded where the range of tide is sixteen feet.