TIDAL CHANGES IN THE STRAIT OF CANSO REGION
1955

TIDES AND WATER LEVELS SECTION
DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA

CANADA

TIDAL CHANGES IN THE STRAIT OF CANSO REGION

TIDAL AND CURRENT SURVEY

June 3rd., 1955

Ottawa

INLAND WATERS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES

FOREWORD

The reported high water levels that have occurred in the Strait of Canso region since completion of the Causeway have led to requests from the Departments of Transport and Public Works that the Canadian Hydrographic Service investigate the tides of this area.

This report is intended to revise and bring up to data a preliminary report issued in March, 1955, which it supersedes. A certain amount of new material has been added and the previously necessary extra-polations eliminated. A field check against possible settling errors has been conducted and difficulties experienced by icing within the tide wells have now been prevented by the installation of immersion type electric heaters.

This report presents factual material concerning the observed changes in the tide during construction of the Canso Causeway. A complete analysis cannot be made until all the 1955 tide records have been obtained and a re-survey of the tidal circulation undertaken; but the results at present available are indicative of the order of magnitude of the changes in the tide and the direction of those changes.

This investigation has been carried out by Mr. N. O. Fothergill under the direction of Mr. C. M. Cross, Chief of the Tidal and Current Survey.

F. C. G. Smith
Dominion Hydrographer.

CONTENTS

ILLUSTRATIONS

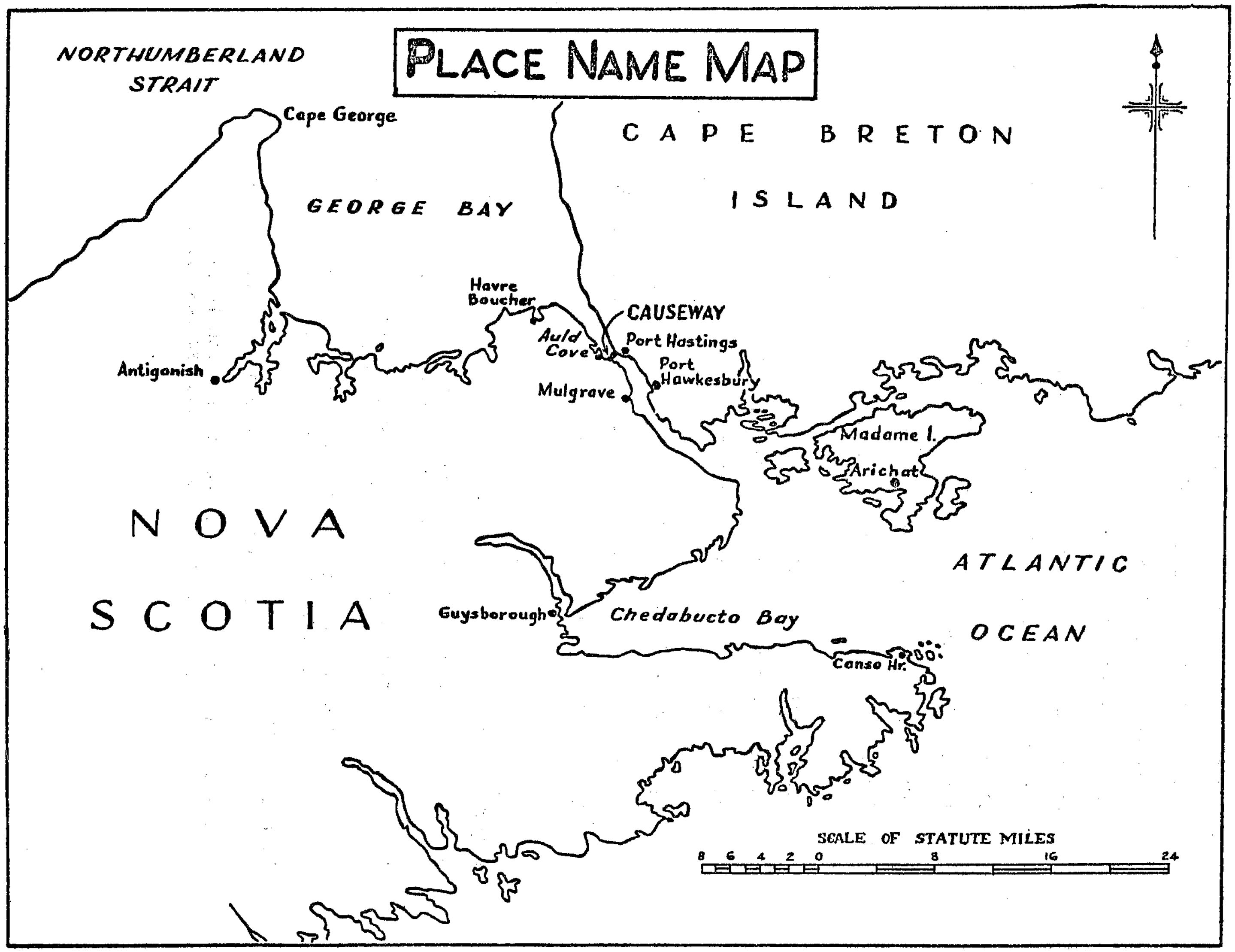

Figure 1 Place name map

TIDAL CHANGES IN THE STRAIT OF CANSO REGION

Construction on the Strait of Canso Causeway began in September of 1952 when the first load of rock fill was dumped into the Strait. By the summer of 1953 the causeway was roughly half way across. The late fall of 1954 marked the close of the gap and from a tidal change point of view the full effects of the causeway became apparent.

The Hydrographic Service established four tide gauges in the summer of 1952: at Auld Cove and Port Hastings on either side of the causeway site, at Havre Boucher in George Bay, and at Arichat in Chedabucto Bay. (See Figure 1). A detailed current survey was conducted throughout the Strait of Canso and its approaches during the summers of 1952 and 1953. As the movement of water to and fro within the Strait profoundly affected the circulation in the outer bays it is planned to re-survey these approaches in the near future and thus complete the project. An important purpose of this project has been to trace the effects of the causeway construction by obtaining a picture of the situation before, during, and after construction.

The tide gauges established at Auld Cove and at Port Hastings have been run continuously since 1952. The other gauges were run during the summer months only. This tidal information is augmented by data from the permanent stations at Halifax and at Charlottetown. The available record is therefore considerable.

TIDAL CONDITIONS BEFORE CAUSEWAY CONSTRUCTION

It is well known that the tide of George Bay, which shows marked diurnal inequality similar to the Charlottetown tide, is quite different from the tide in Chedabucto Bay which is similar to the Atlantic tide at Halifax. The maximum range of the tide in George Bay is only 4.7 feet, whereas in Chedabucto Bay it is 6.4 feet. This difference in the basic tide, together with the fact that the two tides were not in phase, produced a varying hydraulic head between the two ends of the Strait, thus setting up powerful tidal currents. The tide itself within the Strait gradually changed in range, decreasing as it proceeded northwards through the Strait. Thus at Mulgrave the maximum range was 5.5 feet before construction began. Essentially the two distinct tides mixed within the Strait. There was a slight slope to the mean level surface downwards from George Bay to the Atlantic Ocean giving rise to an appreciable net flow southwards through the Strait. In addition, there was a depression of the mean level profile within the Strait due to the presence of strong tidal currents. This depression is estimated to be about 0.15 foot at the causeway site. A similar though much larger effect has been observed in Seymour Narrows, B.C.[1]

TIDAL CONDITIONS AFTER CAUSEWAY CONSTRUCTION

The prime effect of the causeway construction on the tides was to eliminate the mixed tide within the Strait altogether and to bring a slightly enlarged Chedabucto Bay type of tide right up to the south side of the Causeway at Port Hastings. Similarly the George Bay type of tide is now recorded at Auld Cove on the north side of the causeway. Also, the slope in mean level which formerly was spread throughout the Strait is now recorded as a distinct difference in the mean level of the sea on either side of the causeway. The difference in mean level between Auld Cove and Port Hastings has increased by 0.3 foot since construction began.

Since the former strong tidal currents no longer exist, the hydraulic depression of the mean level profile has disappeared. While it is too early yet to say with precision, the apparent effects on mean level of the removal of the depression due to currents and the concentration of the slope in mean level across the causeway has been (1) to increase mean level at Auld Cove by about 0.3 foot, and (2) very little net change in mean level at Port Hastings - probably a very slight drop.

The problem of mean level and its many variations daily, monthly, and yearly, together with the fact that the true changes in mean level due to the causeway construction are small in magnitude, creates many difficulties in separating the true causeway-induced changes from normal variations which have occurred in the past and will occur in the future regardless of the causeway.

The maximum range of the tide at Port Hastings has increased from 5.5 to 6.7 feet. Since mean level has remained practically the same this increase in range has caused the high waters to rise 0.6 foot higher and the low waters to fall 0.6 foot lower than previously. This drop in the low waters and rise in the high waters reduces to zero proceeding from Port Hastings south to Chedabucto Bay (See Figure 6). At Auld Cove on the other hand the maximum range has decreased from 5.2 to about 4.9 to about 4.9 feet, while mean level rose by about 0.3 foot. The result is that high waters are now slightly higher by 0.15 foot, and low waters are now 0.45 foot higher than before construction of the causeway.

INTERPRETATION OF DATA

It should be emphasized that extreme care must be taken in interpreting the significance of monthly values of such quantities as mean higher high water rise, mean level or mean range. It is well known that there is an annual cycle or variation of mean level which directly imposes a similar variation upon mean higher high water rise or mean lower low water rise. Wintertime values of mean level are characteristically high along the Atlantic Coast, whereas they are low in midsummer. A somewhat similar variation occurs with mean range. These variations are primarily due to seasonal weather patterns. They are, however, sufficiently repetitive from year to year that they are considered in the prediction of tides. Caution must be exercised that observed changes in tidal values such as mean level, being normal seasonal variations, are not mistakenly attributed to the effect of the causeway. The normal seasonal variations and the causeway effects are unfortunately of the same order of magnitude, and hence separating the two is difficult if monthly values alone are considered. Satisfactory separation can be achieved if a year's record is considered and due account taken of the 19-year cycle of the tide.

CHANGES IN TIDE LEVELS

Table 1 and Figure 2 show the monthly and yearly values for mean higher high water rise from datum. This reflects some of the effects of the causeway upon the tide at Port Hastings. It is apparent that the increase in the rise of high water at Port Hastings has been small. Table 1 verifies the conclusions reached from the change in maximum ranges, namely that present maximum high waters since the completion of the causeway are approximately 0.6 foot higher than they were prior to construction. As an approximation, the change in mean higher high water multiplied by 1.4 equals the change in maximum high water, under normal conditions. Table 2 and Figure 2 show the values for mean lower low water rise at various locations in the Strait of Canso area, together with values at Halifax and Charlottetown which serve as references as in Table 1. The lowering of mean lower low water at Port Hastings and the raising of mean lower low water at Auld Cove are noteworthy. It should be noted that higher high water and lower low water at Halifax show practically no change throughout the period. Charlottetown appears less steady but it is apparent that the causeway-induced changes, if real, are indeed small.

The values for January, 1955, of mean higher high water rise and mean lower low water rise are high, both in the Strait of Canso area and at Halifax and Charlottetown. This general rise in the water levels is reflected in Table 6 showing extreme high water rise, values at Halifax and Charlottetown are 1.2 and 2.4 feet above predictions. However, a glance at Table 5 shows that these high levels occur frequently at Halifax and Charlottetown and, as will be discussed later, are due to stormy weather conditions.

Table 3 and Figure 3 indicate the changes in mean range which have occurred. The only significant causeway effects are observed at Port Hastings and Auld Cove, where an increase and decrease in range respectively is observed. The values of mean range for January, 1955, at all stations are normal and do not reflect the weather disturbance which affected the mean rises. Table 4 and Figure 4 show the calculated values for maximum range and the deduced changes during the causeway construction.

Figures 4 and 5 are plots of the calculated changes in maximum range and mean level for Port Hastings, Auld Cove, Halifax, and Charlottetown during the construction period of the causeway. The technique of the running mean using 11 months at a time has been employed. They clearly indicate the order of magnitude of the causeway-induced changes.

Figure 6 shows the combined results of the changes in mean level and maximum range in a pictorial form. It effectively summarizes Tables 1 to 4, and Figures 2 to 5.

EFFECT OF WEATHER ON TIDE LEVELS

The rise of the tide with respect to its reference bench mark depends upon the true tidal rise, which is predictable, together with the rise or fall in level due to weather, which is not predictable. During the last 35 years at Halifax and Charlottetown, the recorded tide level frequently rose above the predicted value (See Table 5). Considering the highest levels reached during a particular year, a comparison with predicted values shows that these extreme high waters can be as much as two or three feet above normal. In fact fully half of these yearly extremes exceeded predictions by over two feet. Values of disturbed high waters over three feet are less common, occurrring say about once in ten years. Further, Halifax and Charlottetown are not unusual in this regard for large weather disturbances of the high waters occur elsewhere, for example, the 1953 floods in northwestern Europe where water levels were raised some eight feet above predicted values and which were wholly attributed to an extraordinary weather disturbance.

The effect of weather upon the level of the sea is not well understood. A great deal of work has yet to be done before it will be possible to predict the rise or fall of the sea under given weather conditions. Both winds and barometric pressure can affect the local sea level, for example, a deep low pressure area coupled by strong onshore winds can readily cause a two or three foot rise in the level of the sea. Once initiated, this sea elevation may set up a long period oscillation, or it may migrate as a wave causing high levels at other locations.

Most extreme high waters are extreme because of weather disturbances. This is true at all locations where tide records are taken and undoubtedly true also of the Strait of Canso area. The Port Hastings extreme of 8.1 feet which occurred on January 8, 1955, and that which occurred on March 27, 1955, when a height of 7.9 feet was reached, were both accompanied by stormy weather. An unusually deep low pressure area moved southward of Nova Scotia and stagnated southeast of Newfoundland on January 8th. This storm centre was associated with winds of 25 m.p.h. from the north and northwest. On March 27th, 30 to 45 m.p.h. winds from the southeast were recorded. These two examples illustrate some of the difficulties associated with weather disturbances. Both produced excessively high water levels at Port Hastings, but in the one case the winds were offshore while in the other they were onshore. In both cases, however, the barometric pressure was unusually low.

EXTREME TIDES

The highest level so far recorded at Port Hastings, 8.1 feet in January, 1955, is only about 0.5 foot higher than that of November, 1952, when a level of 7.6 feet was reached. Very little can be concluded from a comparison of a few extreme high waters. The weather factors which give rise to these extremes do not necessarily coincide with optimum tidal conditions for the production of very high waters. In fact it would require many years of data to provide enough examples of extreme tides before and after the causeway construction to reach any definite conclusions about the causeway effects on extreme tides. It can be stated however, that there has been no evidence so far at Port Hastings that the extreme weather tides have been changed any more than the normal tides. At Auld Cove on the other hand a high water level of 8.7 feet occurred on February 7th. Considering that the causeway effects on the normal Auld Cove tide was only a light increase in the high waters, this extreme is surprising. It undoubtedly would have been less had the causeway not existed because of water escaping to the southward. How much less cannot be determined.

THE EFFECT OF WAVES

A further factor should be mentioned. The instantaneous water height due to waves and the ability of waves to cause flooding well above its own height by running up the shore. Tide gauges do not measure waves. A stilling well is employed to dampen out all wave action with the result that the tide gauge measures the average height of the sea over a period of two or three minutes. Thus, a tide level may have a wave of considerable amplitude superimposed on it and not be recorded at the station. The study of waves and wave action along a shore is very complicated but the ability of storm waves to transport water to appreciable heights up a shore cannot be questioned. Has the causeway changed the wave pattern within the Strait of Canso? We have no data to answer this question. All that can be stated is that the maximum level, i.e., high water, about which waves fluctuate has been raised at Port Hastings by 0.6 foot.

Finally, a note on the difficulties experienced at Auld Cove and Port Hastings during the winter of 1954-55. There are many gaps in the available tide record from these stations, particularly in December and January. This was caused by icing problems within the tide wells as well as normal failure due to clock stoppages etc. The deduced tidal values for these months are therefore less reliable but this has been largely overcome by the use of the 11 month running mean technique which strongly inhibits discrepancies.

CONCLUSIONS

This examination of tidal records observed since construction of the causeway began leads to two main conclusions. Firsly, the reported high water levels which occurred in January and March of 1955 were primarily the result of serious weather distrubances. Secondly, the observed changes in the tides of the region due to the causeway are so small that they must be measured in inches only. At Port Hastings, where the maximum effects occur, the increase in the high waters is about 0.6 foot.

References:

1. G. W. LaCroix and J. P. Tully - The Anomaly of Mean Sea Level in Seymour Narrows, B.C.
J. Fish. Res. Bd. Canada, 11(6), 1954

Tidal and Current Survey,
Ottawa, June 2, 1955.

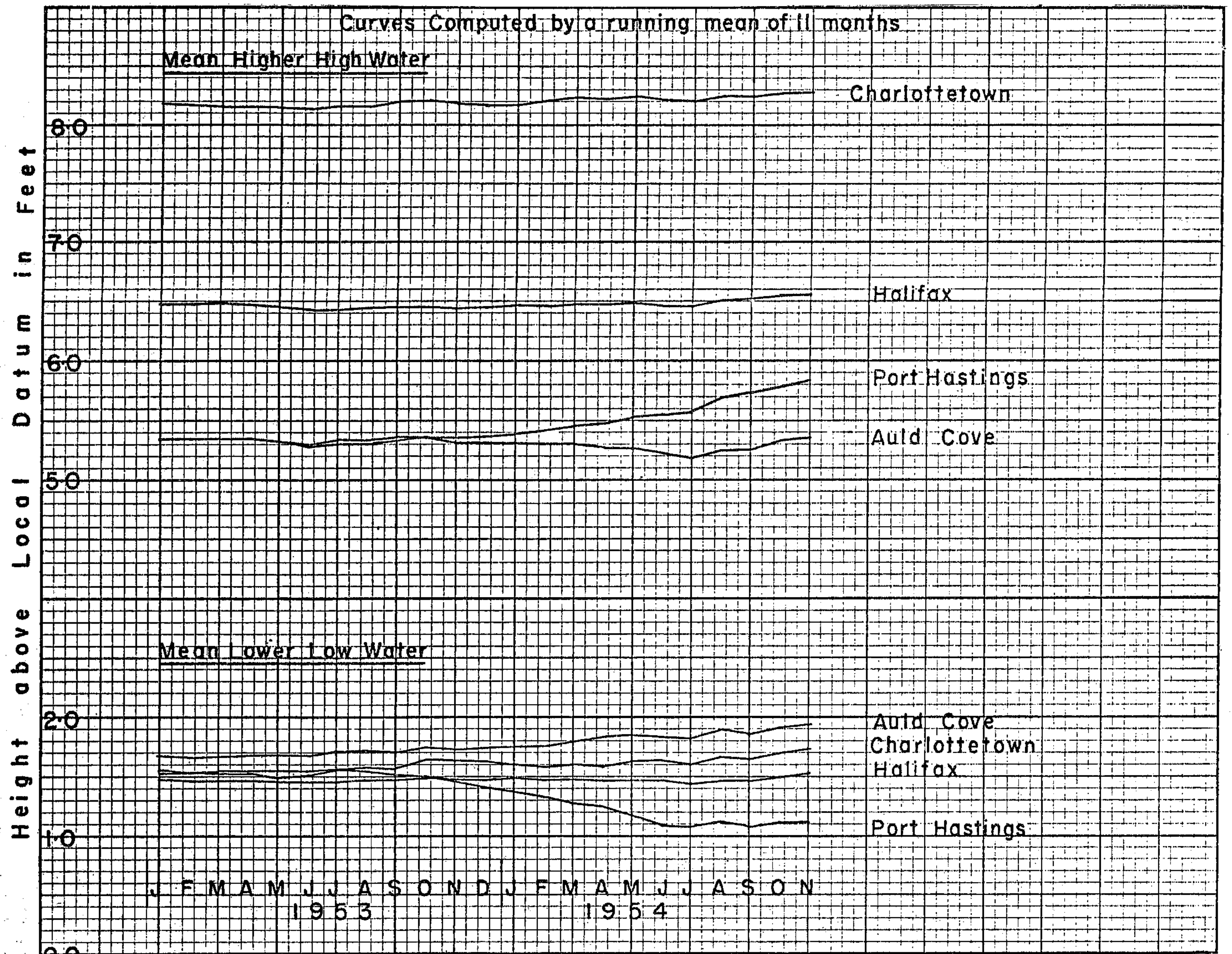

Figure 2 Observed changes in tide levels during construction of the causeway

Table 1

Mean Higher High Water Rise in Feet

		Halifax	Arichat	Port Hastings	Auld Cove	Havre Boucher	Charlottetown
1952	July	6.16				4.79	8.11
	Aug.	6.15	5.92	5.11	5.03	4.72	8.10
	Sept.	6.28	6.06	5.18	5.12	4.70	8.08
	Oct.	6.41	6.01	5.33	5.11	4.91	8.19
	Nov.	6.63	6.36	5.68	5.64	5.21	8.39
	Dec.	6.68		5.53	5.50		8.19
Mean		6.39	6.09	5.37	5.28	4.87	8.18
1953	Jan.	6.65		5.47	5.50		8.21
	Feb.	6.52		5.64	5.75		8.42
	Mar.	6.50		5.14	5.23		7.97
	Apl.	6.50		5.18	5.27		8.19
	May	6.50		5.29	5.39		8.04
	June	6.32	5.94	5.18	5.13		8.24
	July	6.26	5.91	5.18	5.07	4.93	8.06
	Aug.	6.40	6.04	5.26	5.27	4.06	7.90
	Sept.	6.30	5.99	5.18	5.14	4.96	8.17
	Oct.	6.34	6.18	5.34	5.23	5.21	8.13
	Nov.	6.41		5.27	5.35		8.06
	Dec.9	6.72		5.67	5.84		8.54
Mean		6.45	6.01	5.32	5.35	5.04	8.16
1954	Jan.	6.72		5.65	5.59		8.46
	Feb.	6.54		5.46	5.53		8.36
	Mar.	6.51		5.59	5.42		8.32
	Apl.	6.22		5.18	4.82		7.80
	May	6.54		5.29	5.11		8.07
	June	6.49	5.95	5.37	5.09		8.16
	July	6.39	5.97	5.46	5.14	4.90	8.23
	Aug.	6.35	6.09	5.74	5.17	4.92	8.36
	Sept.	6.39	5.95	5.61	4.94	4.87	8.11
	Oct.	6.47		5.86	5.29	5.17	8.29
	Nov.	6.52		5.88	5.21		8.18
	Dec.	6.59		5.97	5.41		8.33
Mean		6.48	5.99	5.59	5.28	4.97	8.22
1955	Jan.	7.13		6.71	6.16		8.79
	Feb.	6.59		5.80	5.44		8.20
	Mar.	6.62		6.00	5.69		8.32
	Apl.	6.51		5.77	5.21		8.06

Table 2

Mean Lower Low Water Rise in Feet

		Halifax	Arichat	Port Hastings	Auld Cove	Havre Boucher	Charlottetown
1952	July	1.21				1.38	1.33
	Aug.	1.26	1.61	1.47	1.55	1.41	1.37
	Sept.	1.43	1.71	1.53	1.62	1.61	1.52
	Oct.	1.47	1.56	1.62	1.63	1.64	1.76
	Nov.	1.63	1.94	1.76	1.73	1.55	1.61
	Dec.	1.64		1.68	1.73		1.46
Mean		1.44	1.71	1.61	1.65	1.52	1.51
1953	Jan.	1.59		1.52	1.70		1.45
	Feb.	1.47		1.60	1.91		1.87
	Mar.	1.63		1.40	1.64		1.66
	Apl.	1.53		1.51	1.76		1.46
	May	1.31		1.42	1.68		1.26
	June	1.28	1.50	1.39	1.44		1.40
	July	1.20	1.48	1.32	1.41	1.43	1.32
	Aug.	1.41	1.71	1.47	1.76	1.75	1.60
	Sept.	1.43	1.69	1.60	1.75	1.77	1.74
	Oct.	1.60	1.83	1.46	1.69	1.79	1.75
	Nov.	1.58		1.96	1.76		1.38
	Dec.	1.58		2.04	2.00		1.71
Mean		1.47	1.64	1.56	1.71	1.69	1.55
1954	Jan.	1.76		1.32	1.88		2.06
	Feb.	1.60		1.16	1.56		1.58
	Mar.	1.61		1.35	2.18		2.16
	Apl.	1.10		0.83	1.44		1.23
	May	1.34		0.99	1.65		1.24
	June	1.33	1.39	0.90	1.59		1.13
	July	1.27	1.48	0.96	1.81	1.56	1.44
	Aug.	1.47	1.68	1.16	2.20	1.77	1.94
	Sept.	1.53	1.52	1.05	1.90	1.65	1.65
	Oct.	1.56		1.25	2.16	1.85	1.67
	Nov.	1.46		0.86	1.66		1.72
	Dec.	1.46		1.22	1.71		1.83
Mean		1.46	1.52	1.09	1.81	1.71	1.64
1955	Jan.	2.05		1.78	2.64		2.40
	Feb.	1.56		0.98	1.72		1.83
	Mar.	1.47		1.01	1.98		1.90
	Apl.	1.55		1.05	1.74		1.74

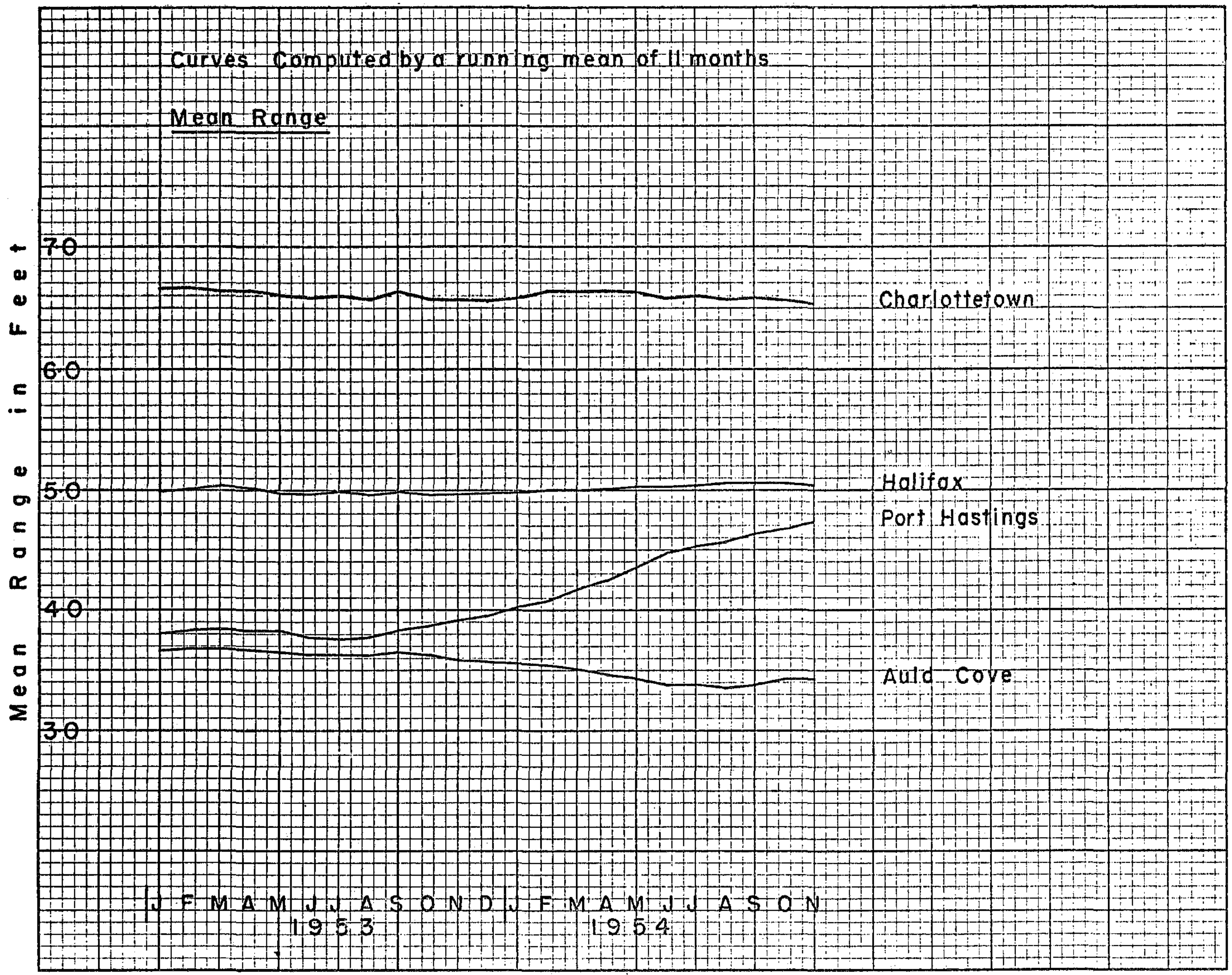

Figure 3 Observed changes in mean range during construction of the causeway

Table 3

Mean Range or Difference H.H.W.-L.L.W. in feet

		Halifax	Arichat	Port Hastings	Auld Cove	Havre Boucher	Charlottetown
1952	July	4.95				3.41	6.78
	Aug.	4.89	4.31	3.64	3.48	3.31	6.73
	Sept.	4.85	4.35	3.65	3.50	3.09	6.56
	Oct.	4.94	4.45	3.71	3.48	3.27	6.43
	Nov.	5.00	4.42	3.92	3.91	3.66	6.78
	Dec.	5.04		3.85	3.77		6.74
Mean		4.95	4.38	3.76	3.63	3.35	6.67
1953	Jan.	5.06		3.95	3.80		6.76
	Feb.	5.05		4.04	3.84		6.56
	Mar.	4.87		3.74	3.59		6.31
	Apl.	4.97		3.67	3.51		6.73
	May	5.19		3.87	3.71		6.79
	June	5.04	4.44	3.79	3.69		6.84
	July	5.06	4.43	3.86	3.66	3.50	6.74
	Aug.	4.99	4.33	3.79	3.51	3.31	6.31
	Sept.	4.87	4.30	3.58	3.39	3.19	6.43
	Oct.	4.74	4.35	3.88	3.54	3.42	6.39
	Nov.	4.83		3.31	3.59		6.68
	Dec.	5.14		3.63	3.84		6.83
Mean		4.98	4.37	3.76	3.64	3.36	6.61
1954	Jan.	4.99		4.33	3.71		6.40
	Feb.	4.94		4.30	3.97		6.78
	Mar.	4.90		4.24	3.24		6.16
	Apl.	5.12		4.35	3.38		6.58
	May	5.20		4.30	3.46		6.83
	June	5.16	4.56	4.47	3.50		7.03
	July	5.12	4.49	4.50	3.33	3.34	6.79
	Aug.	4.88	4.41	4.58	2.97	3.15	6.42
	Sept.	4.86	4.43	4.56	3.04	3.22	6.46
	Oct.	4.91		4.61	3.13	3.32	6.62
	Nov.	5.06		5.02	3.55		6.46
	Dec.	5.13		4.75	3.70		6.50
Mean		5.02	4.47	4.50	3.42	3.26	6.58
1955	Jan.	5.08		4.93	3.52		6.39
	Feb.	5.03		4.82	3.72		6.37
	Mar.	5.15		4.99	3.71		6.42
	Apl.	4.96		4.72	3.47		6.32

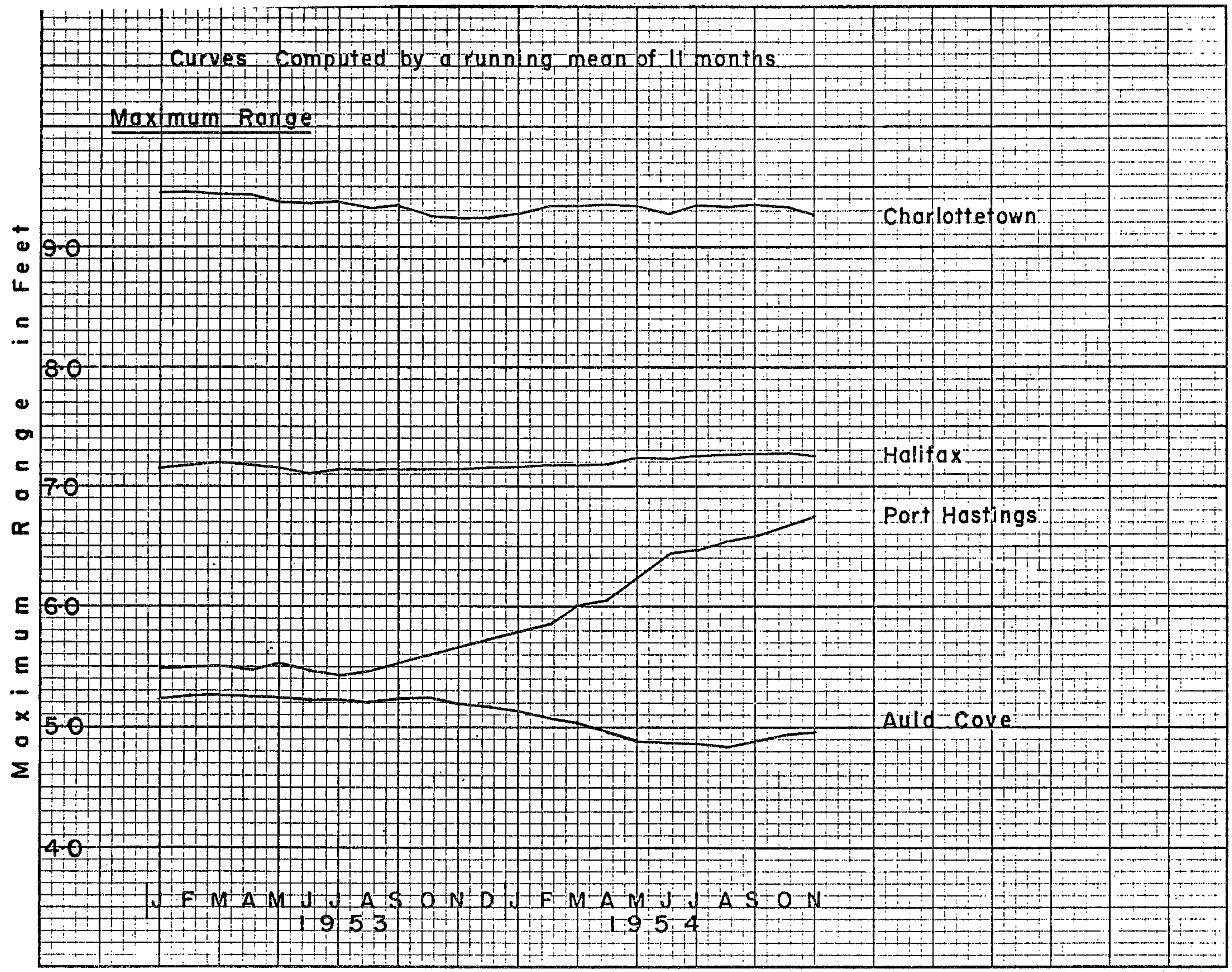

Figure 4 Observed changes in maximum range during construction of the causeway

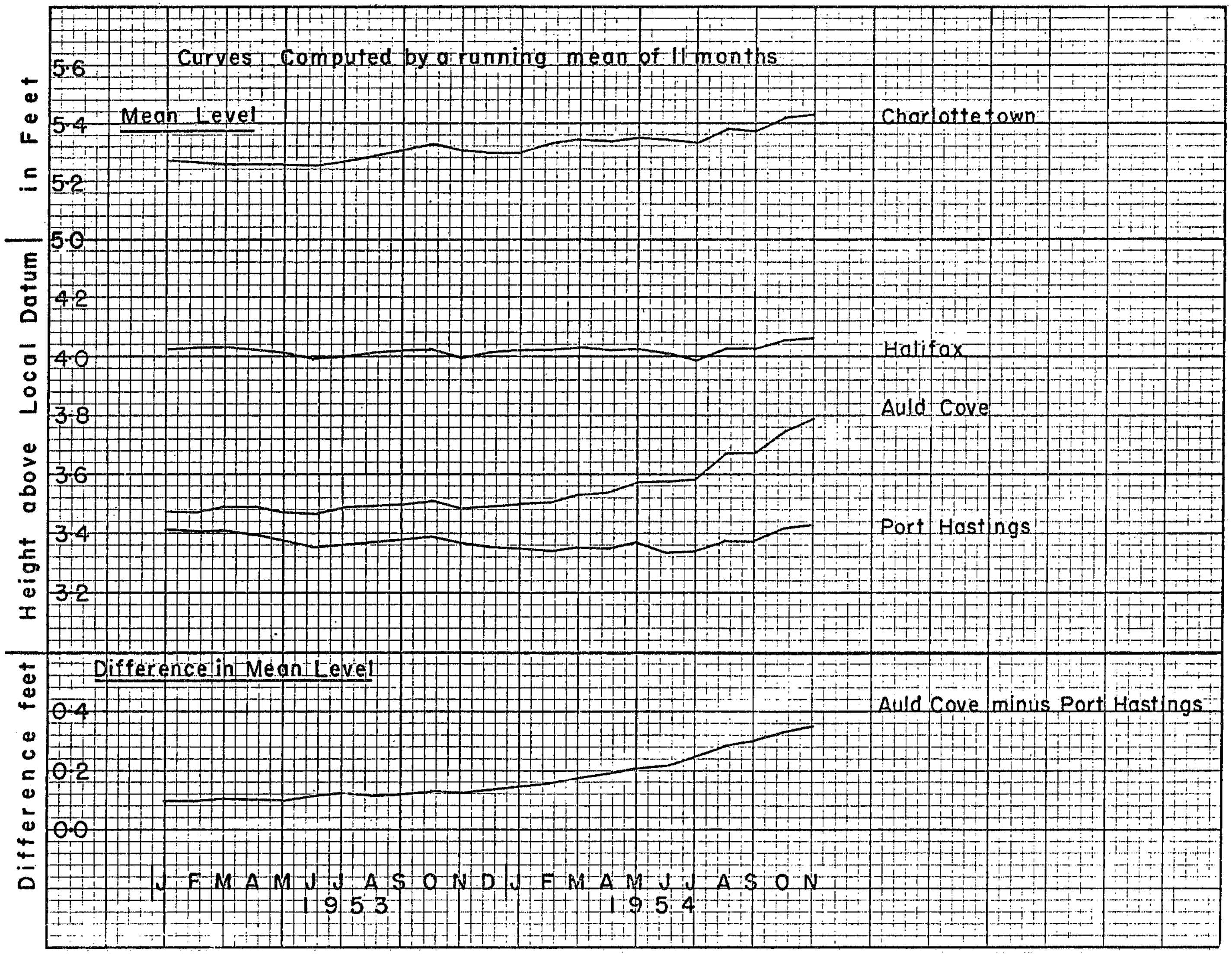

Figure 5 Observed changes in mean level during construction of the causeway

Table 4

Calculated Maximum Range in Feet

		Arichat	Port Hastings	Port Hastings Running Mean 11 months	Auld Cove	Auld Cove Running Mean 11 months	Havre Bouch
1952	July						4.77
	Aug.	6.34	5.35		4.91		4.67
	Sept.	6.43	5.40		5.08		4.48
	Oct.	6.50	5.42		5.12		4.81
	Nov.	6.36	5.64		5.47		5.12
	Dec.		5.51		5.32		
Mean		6.41	5.46		5.18		4.77
1953	Jan.		5.61	5.48	5.32	5.22	
	Feb.		5.74	5.50	5.57	5.25	
	Mar.		5.54	5.50	5.39	5.26	
	Apl.		5.32	5.49	4.95	5.25	
	May		5.38	5.51	5.19	5.23	
	June	6.35	5.42	5.46	5.13	5.21	
	July	6.29	5.48	5.41	5.16	5.21	4.94
	Aug.	6.24	5.46	5.46	5.27	5.20	4.97
	Sept.	6.36	5.30	5.53	4.98	5.22	4.69
	Oct.	6.61	5.90	5.61	5.24	5.22	5.06
	Nov.		4.93	5.67	5.10	5.19	
	Dec.		5.08	5.72	5.34	5.16	
Mean		6.37	5.43		5.22		4.92
1954	Jan.		6.24	5.79	5.49	5.13	
	Feb.		6.28	5.87	5.56	5.07	
	Mar.		6.23	6.00	4.99	5.02	
	Apl.		6.09	6.07	4.87	4.95	
	May		5.93	6.24	4.81	4.89	
	June	6.34	6.26	6.42	4.73	4.88	
	July	6.30	6.30	6.46	4.66	4.87	4.68
	Aug.	6.48	6.73	6.53	4.40	4.84	4.66
	Sept.	6.56	6.75	6.59	4.47	4.88	4.73
	Oct.		6.73	6.67	4.48	4.93	4.75
	Nov.		7.13	6.75	5.22	4.96	
	Dec.		6.65		5.43		
Mean		6.42	6.44		4.93		4.71
1955	Jan.		7.00		5.17		
	Feb.		6.89		5.47		
	Mar.		6.99		5.42		
	Apl.		6.84		5.14		

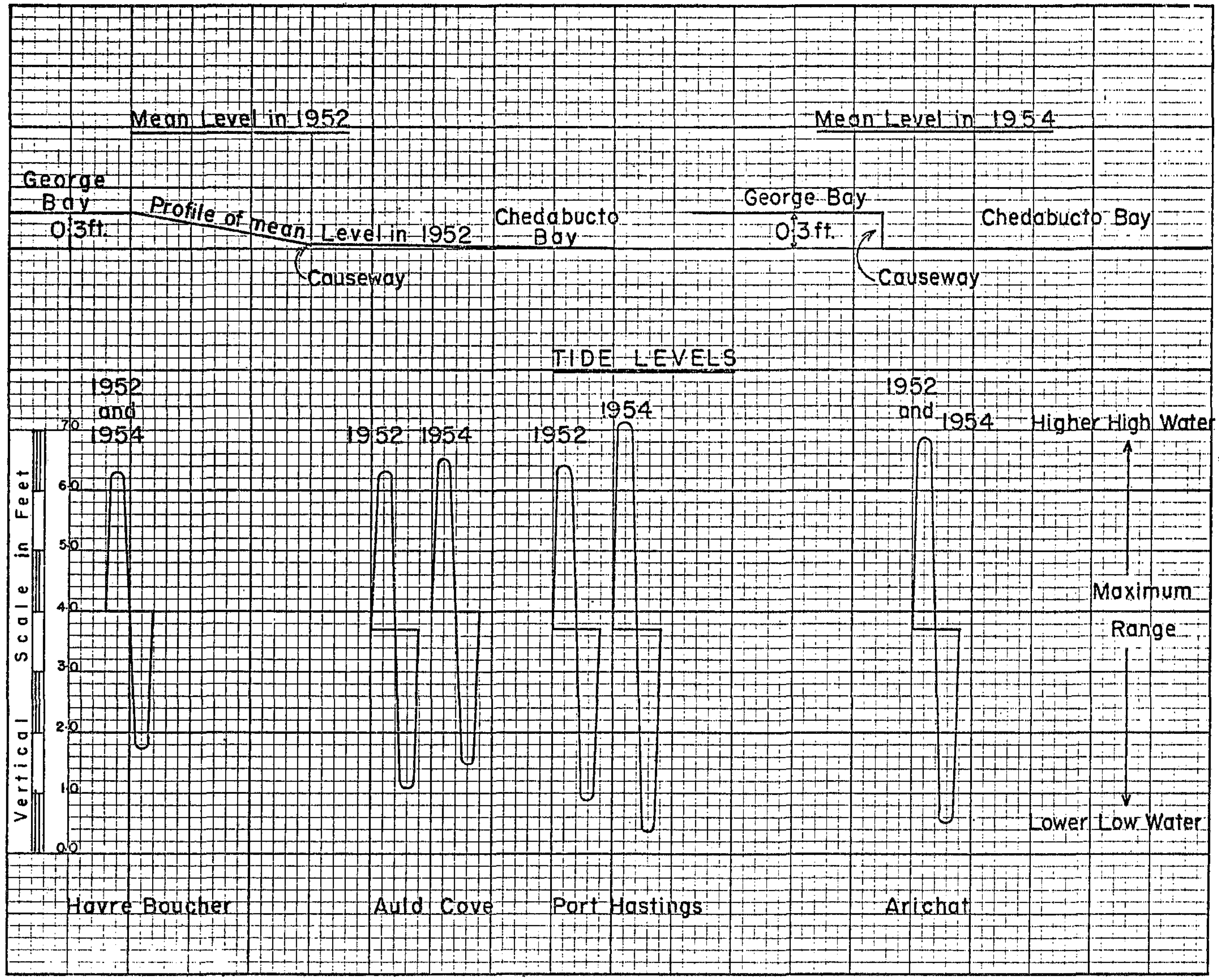

Figure 6 Diagram showing the changes in tide levels during construction of the causeway

Table 5

Yearly High Water Extremes in Feet

	Halifax		Charlottetown			
Year	Observed	Above Predictions	Observed	Above Predictions	Port Hastings	Auld Cove
1920	8.3	1.8	9.6	1.4		
1921	7.9	1.3	9.4	0.8		
1922	8.0	1.5	9.2	0.4		
1923	8.5	2.0	10.4	2.9		
1924	8.3	1.6	10.2	1.6		
1925	8.1	3.1	9.8	2.2		
1926	9.0	2.5	10.4	2.1		
1927	8.5	1.8	10.6	2.5		
1928	8.3	1.9	10.0	1.8		
1929	8.3	2.0	9.7	2.3		
1930	8.5	2.2	9.7	1.6		
1931	9.0	2.5	10.4	2.4		
1932	8.0	2.0	9.6	0.8		
1933	9.3	3.0	10.4	2.0		
1934	8.8	2.7	9.9	1.6		
1935	8.2	2.2	10.2	2.4		
1936	8.5	2.0	11.6	3.3		
1937	8.6	1.5	10.4	2.4		
1938	7.8	1.3	10.9	2.9		
1939	8.5	1.8	10.0	1.6		
1940	9.1	3.3	10.4	1.8		
1941	8.2	2.0	10.3	1.5		
1942	8.8	2.2	9.9	2.3		
1943	8.5	1.6	11.4	2.9		
1944	8.4	1.6	10.6	2.4		
1945	8.9	2.1	10.7	3.0		
1946	8.4	1.4	10.6	2.3		
1947	8.8	2.7	10.6	3.0		
1948	8.7	2.0	10.3	2.6		
1949	8.0	0.6	10.9	2.4		
1950	8.3	1.1	10.3	2.2		
1951	8.1	0.8	10.8	2.7		
1952	9.3	2.4	10.7	2.1	7.6	7.7
1953	8.2	0.9	10.2	1.8	6.9	7.0
1954	7.9	0.9	11.0	2.8	7.2	7.9

Halifax Breakdown		Charlottetown Breakdown	
Number	Height range above Predictions	Number	Height range above Predictions
4	0 - 0.9 feet	3	0 - 0.9 feet
13	1.0 - 1.9 "	9	1.0 - 1.9 "
15	2.0 - 2.9 "	20	2.0 - 2.9 "
3	3.0 and over	3	3.0 and over

Table 6

Extreme High Water Rise in Feet

		Halifax	Above Halifax Predictions	Arichat	Port Hastings	Auld Cove	Havre Boucher	Charlottetown	Above Charlottetown Predictions
1952	July	6.9	0.2				6.8	9.0	0.2
	Aug.	7.0	0.2	7.2	6.2	6.0	5.4	9.5	0.5
	Sept.	7.1	0.1	7.1	6.4	6.3	5.8	9.6	0.9
	Oct.	8.0	0.9	7.1	6.5	6.1	6.4	9.2	0.9
	Nov.	8.2	1.2	7.6	7.6	7.7	7.3	10.0	1.9
	Dec.	7.4	1.2		6.5	6.7		9.1	1.1
1953	Jan.	7.9	0.7		6.7	7.0		9.6	0.7
	Feb.	8.3	1.1		6.9	6.8		9.6	0.6
	Mar.	8.2	0.8		6.3	6.5		9.8	0.6
	Apl.	8.2	0.9		6.6	6.6		10.0	1.3
	May	7.4	0.3		6.1	6.2		9.3	1.3
	June	6.9	0.1	6.7	6.0	6.0		9.1	0.9
	July	7.1	0.3	6.9	6.1	6.1	5.8	9.2	0.8
	Aug.	7.4	0.2	7.2	6.2	6.4	6.3	9.3	0.2
	Sept.	7.2	-0.1	6.8	5.9	5.8	5.6	9.7	1.8
	Oct.	8.0	0.7	7.5	6.7	7.0	7.1	10.0	1.0
	Nov.	7.3	-0.1		6.2	6.2		9.6	0.7
	Dec.	7.8	1.0		6.4	6.8		10.3	1.8
1954	Jan.	8.0	2.2		7.1	7.9		11.0	2.8
	Feb.	7.9	0.9		6.7	7.3		10.3	2.5
	Mar.	7.8	1.5		6.3	7.0		9.5	1.0
	Apl.	7.5	0.6		6.5	6.7		9.6	0.9
	May	7.6	0.6		6.4	6.1		9.3	0.5
	June	7.4	0.4	7.1	6.6	6.1		9.2	0.6
	July	6.9	0.5	6.7	6.2	5.9	5.7	8.8	0.7
	Aug.	7.3	0.5	7.0	6.7	6.3	6.2	9.5	1.1
	Sept.	7.9	1.4	6.7	6.6	5.7	5.6	9.0	0.0
	Oct.	7.7	0.2		7.0	6.4	6.2	9.4	0.7
	Nov.	7.2	-0.1		7.1	7.3		9.8	1.1
	Dec.	7.5	0.1		7.2			10.5	1.5
1955	Jan.	8.2	1.2		8.1	8.0		10.2	2.4
	Feb.	7.5	0.7		6.9	8.7		10.1	1.5
	Mar.	8.4	1.8		7.9	6.7		10.1	1.6
	Apl.	7.7	0.4		7.0	6.1		9.5	1.4

Table 7

Extreme Low Water Rise in Feet

		Halifax	Below Halifax Predictions	Arichat	Port Hastings	Auld Cove	Havre Boucher	Charlottetown	Below Charlottetown Predictions
1952	July	-0.3	0.7				-0.2	-0.8	0.8
	Aug.	0.0	0.3	0.3	0.3	0.4	0.1	-0.4	0.7
	Sept.	0.1	0.4	0.4	0.5	0.6	1.0	0.3	0.8
	Oct.	0.2	0.6	0.0	0.0	0.0	0.1	-0.4	0.7
	Nov.	0.5	0.6	1.2	0.8	0.6	0.5	0.3	0.0
	Dec.	0.4	0.6		0.8	0.7		-0.6	1.4
1953	Jan.	-0.4	1.0		-0.1	0.2		-0.6	1.0
	Feb.	0.1	0.6		0.2	0.2		-0.4	1.5
	Mar.	0.5	0.0		0.4	0.6		0.1	0.2
	Apl.	0.4	0.1		0.6	0.9		-0.4	0.3
	May	0.4	0.4		0.1	0.3		0.0	1.1
	June	0.5	0.3	0.7	0.8	0.8		0.0	0.3
	July	0.3	0.1	0.9	0.6	0.6	0.6	0.1	0.6
	Aug.	0.5	0.0	0.7	0.5	0.9	1.1	0.4	0.5
	Sept.	0.1	0.7	0.2	0.5	0.0	0.4	-0.4	0.9
	Oct.	0.5	0.3	0.5	0.4	0.6	0.5	-0.1	1.2
	Nov.	0.6	0.2		0.7	0.8		-0.3	0.3
	Dec.	0.3	1.1		0.8	1.1		0.0	0.4
1954	Jan.	0.3	0.7		0.2	1.0		0.5	0.3
	Feb.	0.8	0.4		-0.3	0.4		0.2	0.7
	Mar.	0.5	0.1		-0.2	0.9		0.1	0.4
	Apl.	-0.1	0.6		-0.8	0.4		-0.8	0.7
	May	0.4	0.0		0.1	0.8		-0.6	0.2
	June	0.4	0.0	0.7	0.1	0.3		-0.7	0.4
	July	0.4	0.1	0.5	0.0	0.6	0.2	-0.4	0.5
	Aug.	0.6	0.1	0.6	0.2	1.2	0.9	0.8	0.5
	Sept.	0.3	0.5	0.0	-0.6	0.3	0.8	0.1	0.5
	Oct.	0.5	0.1		-0.1	0.5	0.2	-0.4	0.4
	Nov.	-0.3	0.8		-0.6	0.1		-0.5	0.7
	Dec.	0.1	0.6		0.4	-0.6		-0.4	1.0
1955	Jan.	0.7	0.4		1.3	1.6		1.0	0.4
	Feb.	0.6	0.6		0.0	0.6		0.1	1.1
	Mar.	0.2	0.9		0.0	0.0		-0.6	2.1
	Apl.	0.5	0.0		0.1	0.4		-0.5	0.3

TIDAL CHANGES IN THE STRAIT OF CANSO REGION

(Appendix to Report of June 3rd, 1955)

Tides and Water Levels,
Inland Waters Branch,
Department of Energy,
Mines and Resources.

Ottawa

May 3, 1957

FOREWORD

This report, by W. I. Farquharson, has been prepared as an appendix to the report of the same title, dated June 3rd, 1955. It takes into account some of the storms which have occurred since that date and includes conclusions as to the tidal changes determined by a series of harmonic analysis of the tides at Auld Cove and Port Hastings at regular intervals from 1952 to 1955.

N. G. Gray,
Dominion Hydrographer.

APPENDIX TO

TIDAL CHANGES IN THE STRAIT OF CANSO REGION

VARIATIONS IN SEA LEVEL

The periodic variations in sea level are due to the tides which cause the sea to oscillate above and below its mean level. The magnitudes of their oscillations vary solely with astronomical conditions. The observed tides are the resultant of two oscillations, one with a period of half a lunar day and the other with a period of a lunar day. The relative magnitudes and phases of the semi-diurnal and diurnal oscillations differ from place to place, and actually differ very appreciably in George Bay and Chedabucto Bay.

The non-periodic variations in sea level can be divided into short and long term variations, the former being associated with the occurrence of strong winds and large variations in barometric pressure, the latter with year to year differences in meteorological conditions, climatic changes and movements of the earth's crust.

The Strait of Canso connects the Gulf of St. Lawrence to the Atlantic seaboard and prior to the construction of the causeway, the tides, where it is sited, represented an approximate mean between those inside and those outside the gulf. The effects of storms upon sea level at Port Hastings and Auld Cove, before they were separated by the causeway, were very similar.

Long term changes in sea level inside the gulf are not necessarily the same as those on the Atlantic seaboard. In fact at Halifax there has been a fairly progressive rise, at a rate of about one foot per century, during the last 50 years, whereas at Charlottetown sea level remained fairly steady until about 1940, since then it has been rising at a greater rate than at Halifax. Prior to the construction of the causeway there was a flow from that end of the strait where the level was the higher to the lower level and there was no appreciable difference in sea level at Port Hastings and Auld Cove.

The causeway now seals off the former connection between the two bodies of water and tends to make the periodic and non-periodic variations at Auld Cove conform with those in the gulf and to make those at Port Hastings conform with those of the Atlantic Coast.

CHANGES IN THE TIDES AT THE SITE OF THE CAUSEWAY

The tides at Auld Cove and Port Hastings were harmonically analysed for the months of August, in the years 1952 to 1955. These analyses show that the major changes occurred between 1953 and August 1954.

Table A-1 shows the ranges of the semi-diurnal and diurnal tides at Auld Cove and Port Hastings, both before and after construction of the causeway.

	AULD COVE		PORT HASTINGS	
	MEAN RANGE OF TIDE		MEAN RANGE OF TIDE	
DATE August	Semidiurnal range	Diurnal range	Semidiurnal range	Diurnal range
1952	2.52 ft	0.96 ft	2.82 ft	0.82 ft
1955	1.95 ft	1.42 ft	4.04 ft	0.46 ft

TABLE A-1

Thus prior to construction the differences in the tides at the two places were very slight, those at Port Hastings being a little more like those occurring on the Atlantic coast. Since completion the tides at Auld Cove are typical of those occurring in George Bay and the tides at Port Hastings typical of those in Chedabucto Bay. At Auld Cove, where the diurnal tide is relatively large, there is an appreciable inequality in the heights of successive tides, but the inequality in the tides at Port Hastings is not significant.

The average levels, relative to mean sea level, reached by the resultant of the semi-diurnal and diurnal oscillations at the two points, before and since construction are shown in Tables A-2 and A-3. There has also been a change in the times at which high and low water occur at the two places and the tables also give a comparison between the average intervals between the moon's meridian passage and the occurrences of high and low water.

As far as the possible occurrence of very high levels is concerned, the tidal changes at Port Hastings are the important ones, for all the high water levels have been raised by 0.5 to 0.75 ft.

CHANGES IN MEAN SEA LEVEL AT THE SITE OF THE CAUSEWAY

These changes are important as the tides oscillate about mean sea level, and, if that is raised, then all the tidal levels will be raised by a corresponding amount.

Running means of sea level have been computed for the period from the end of 1952 at Auld Cove and Port Hastings, for Charlottetown as representative of the level in the Gulf of St. Lawrence and for Halifax as representative of the level on the Atlantic seaboard. Geodetic datum at Auld Cove and Port Hastings has been determined by levelling from Halifax, but there is no levelling between Halifax and Charlottetown so that any difference in sea level at these two places has not been determined directly.

As was to be expected mean sea level, relative to Geodetic datum, was the same at Auld Cove and Port Hastings prior to the construction of the causeway. At both places any small depression in sea level caused by the strong streams formerly flowing through the strait will have been eliminated. With the completion of the barrier fairly abrupt changes might be expected at both places, bringing the level at Auld Cove into conformity with that inside the gulf and the level at Port Hastings into conformity with that on the Atlantic seaboard. Thereafter the only changes to be expected are the long-term variations of sea level occurring in and outside the gulf. Both Auld Cove and Port Hastings are situated at the heads of what are now bays and in both cases sea level and the fluctuations in sea level must be to some extent affected by purely local conditions. It is therefore improbable that sea level at Charlottetown and Auld Cove are exactly identical, or that sea level at Port Hastings and Halifax are identical.

Table A-4 shows the changes which have occurred at six monthly intervals at all four places relative to the running mean values of sea level in January 1953.

The figures indicate a rise of 0.065 feet at Port Hastings, relative to Halifax, which, with the elimination of the small depression due to the strong streams formerly flowing through the strait, brings the level of the sea at Port Hastings more or less into alignment with that at Halifax. The rise of 0.290 feet at Auld Cove, relative to Port Hastings, must represent the approximate difference of sea level inside and outside the Gulf at the time when the causeway was completed. This amount is not, however, a constant, for throughout the entire period of construction the level of the sea at Charlottetown was rising relative to that at Halifax. This is a continuation of a trend, for sea level to rise at a greater rate inside the Gulf than without, which has existed for a number of years.

RESULTANT OF TIDAL AND MEAN SEA LEVEL CHANGES

In order to obtain the full effect of the causeway upon the tidal levels it is necessary to combine the changes in the tides with those of mean sea level. Table A-5 gives the tidal levels in 1952 and in 1955, in each case they are referred to Geodetic Datum.

Thus so far as the high water levels are concerned, at Auld Cove the decrease in the range of the tide has been more than cancelled out by the rise in mean sea level, so that now those high water levels are slightly higher than prior to construction of the causeway. At Port Hastings there has been both an increase in the range of the semi-diurnal tide and a small rise in mean sea level, and the high water levels are now a half to one foot higher than formerly.

METEOROLOGICAL EFFECTS UPON SEA LEVEL

The coincidence of large storm effects with the highest tides is fairly uncommon and as the gauges at Auld Cove and Port Hastings were first installed in July 1952, there are insufficient data upon which to base firm conclusions as to the change in these effects introduced by the causeway. However, prior to its construction the effects of any particular storm were nearly similar at Auld Cove and Port Hastings. For example, a storm on 29th November, 1952, raised sea level for a period of about 14 hours, and in consequence the high water at Auld Cove, predicted to rise to Geodetic Datum +2.8 feet, actually reached +4.9. The high water at Port Hastings, which was predicted to rise to Geodetic Datum +3.0 feet, reached +5.2 feet. Since the causeway was completed, the effects on either side are still often roughly similar, this was the case with the storm of January 8th, 1955, when the predicted high water level at Auld Cove was raised from +3.2 to +5.1 feet and that at Port Hastings from +3.8 to +5.4 feet. On the other hand there have been occasions, since the construction of the causeway, when the effects on either side have been quite different. The most marked instance of this resulted from the storm of December 29th - 30th, 1954. On the north side of the causeway the sea was raised quite abruptly from its normal level, for a period of about ten hours, to a maximum of 3.5 feet. Throughout most of this period the level of the sea on the south side was depressed, the maximum depression of about fifteen inches coinciding with the maximum elevation on the other side. Another instance of a steep rise on the north side of the causeway occurred on 7th - 8th February, 1955,

YEAR 1952	MEAN LUNITIDAL INTERVALS AND HEIGHTS								LARGE TIDES	
	H.H.W.		L.H.W.		L.L.W.		H.L.W.		H.H.W	L.L.W.
	INT	HT	INT	HT	INT	HT	INT	HT	HT	HT
AULD COVE	2048	+1.7	0847	+0.9	0242	-1.5	1426	-1.1	+2.5	-2.2
PORT HASTINGS	2046	+1.8	0843	+1.1	0123	-1.6	1426	-1.3	+2.6	-2.3

TABLE A-2

YEAR 1955	MEAN LUNITIDAL INTERVALS AND HEIGHTS								LARGE TIDES	
	H.H.W.		L.H.W.		L.L.W.		H.L.W.		H.H.W.	L.L.W.
	INT	HT	INT	HT	INT	HT	INT	HT	HT	HT
AULD COVE	2124	+1.5	1003	+0.6	0342	-1.5	1507	-0.5	+2.2	-2.2
PORT HASTINGS	2013	+2.2	0752	+1.9	0148	-2.1	1402	-2.1	+3.2	-3.0

TABLE A-3

YEAR	1953		1954		1955	
MONTH	January	July	January	July	January	July
	ft	ft	ft	ft	ft	ft
HALIFAX	0	0	0	0	+0.045	+0.010
PORT HASTINGS	0	-0.020	-0.050	-0.050	+0.075	+0.075
AULD COVE	0	+0.005	+0.025	-0.125	+0.365	+0.365
CHARLOTTETOWN	0	+0.005	+0.035	+0.075	+0.165	+0.145

TABLE A-4

	HEIGHTS IN FEET RELATIVE TO GEODETIC DATUM											
	MEAN TIDES								LARGE TIDES			
	H.H.W.		L.H.W.		L.L.W.		H.L.W.		H.H.W.		L.L.W.	
	1952	1955	1952	1955	1952	1955	1952	1955	1952	1955	1952	1955
AULD COVE	+2.3	+2.5	-1.5	+1.6	-0.9	-0.5	-0.5	+0.5	+3.1	+3.2	-1.6	-1.4
PORT HASTINGS	+2.4	+2.9	+1.7	+2.6	-1.0	-1.4	-0.7	-1.4	+3.2	+3.9	-1.7	-2.3

TABLE A-5

when the sea was raised to three feet above its normal level for a comparatively short period. Unfortunately on this occasion there are no records from Port Hastings to show what happened on the other side of the causeway.

With the evidence available, it appears that the causeway has changed the effects of storms to a greater extent on its northern than on its southern side. This may be due to a build-up of the storm effects, propagated into the gradually restricted cross-section of George Bay, against the barrier formed by the causeway. In this particular area storms may on occasions cause fairly rapid oscillations in sea level, comparable on a small scale to the storm surges which develop in the North Sea. If the peak of such a surge happens to coincide with high water of a large tide, then very high levels will be reached. On the occasion of the storm of December 29th, 1954, the peak of the surge arrived at low tide, while that of February 7th, 1955, coincided with a high water of a rather greater than average tide.

SUMMARY OF CHANGES IN LEVEL AT SITE OF CAUSEWAY

While the changes in the tide on either side of the causeway are quite definite, there are still insufficient data for any firm conclusions to be reached with regard to the changes in the effects of storms.

At Port Hastings higher levels are now reached than was formerly the case, solely due to the changes in the tides. There is no evidence of any marked increase in the storm effects on this side of the causeway, which may raise the level of sea by as much as 2.5 feet. Should such a rise coincide with high water of a large tide, then a level of Geodetic Datum +3.9 + (2.5), or +6.4 feet would be reached. Unfortunately the tide gauge has occasionally broken down under storm conditions, but the highest levels actually recorded since the causeway was completed were due to the following combination of tide and storm effects:-

8 Jan. 1955	Tide G.D. +3.7, Storm +1.7 Resultant G.D. +5.4
29 Jan. 1955	Tide G.D. +1.5, Storm +1.5 Resultant G.D. +5.3
30 Dec. 1956	Tide G.D. +3.0, Storm +2.3 Resultant G.D. +5.3
15 Feb. 1957	Tide G.D. +3.8, Storm +1.8 Resultant G.D. +5.6

At Auld Cove there is a probability that the causeway has raised the levels reached under an adverse combination of tidal and storm conditions, mainly because the storm effects appear to have been magnified. With the coincidence of the peak of a storm surge and high water of a large tide, a level of Geodetic Datum +3.2+(3.5) or +6.7 feet might be reached. The most adverse combination actually recorded has been due to the following tidal and storm contributions:-

7th February 1955	Tide G.D. +2.8, Storm +3.0 Resultant G.D. +5.8

Damage by the sea during storms is not usually directly attributable to the actual level reached by the sea, but to the fact that when the sea is at a high level the destructive force of the waves is experienced at levels normally beyond their reach.