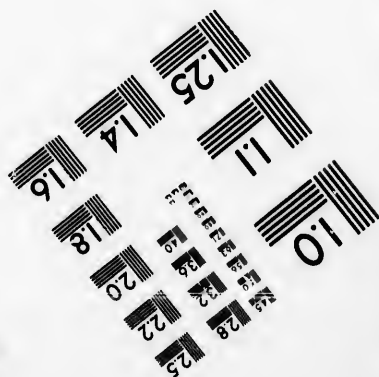
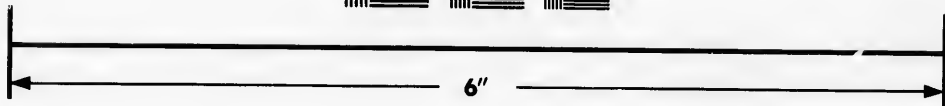
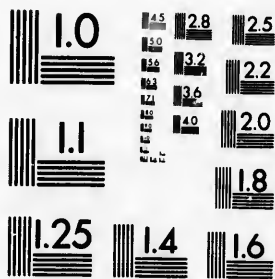


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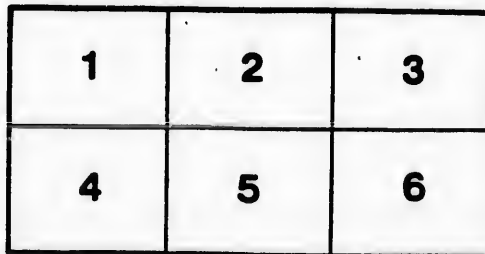
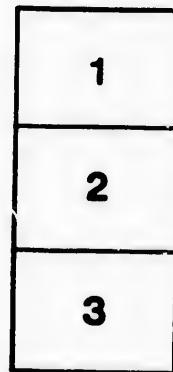
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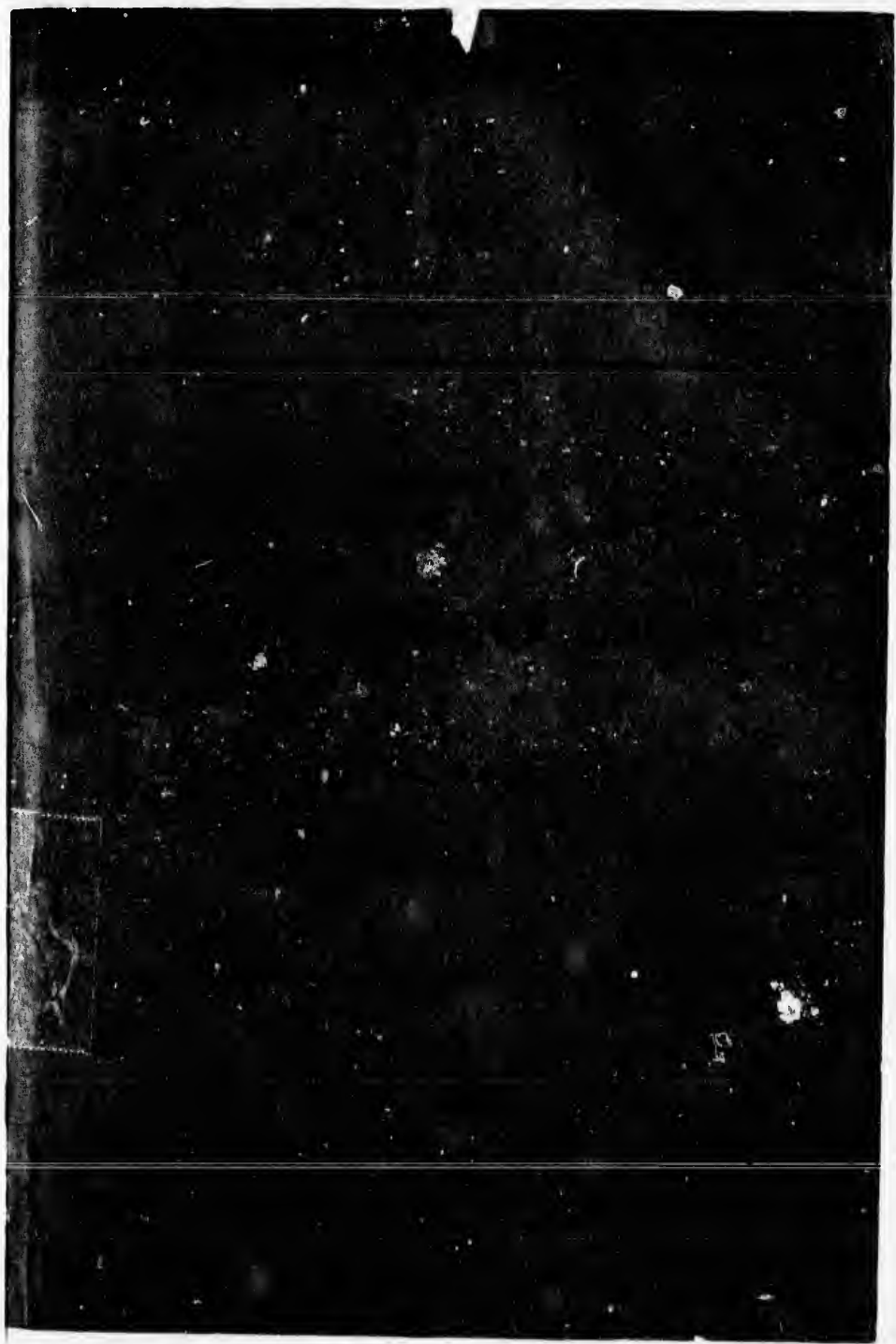
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REPORT
ON
TORONTO HARBOUR, ONTARIO

BY
JAMES B. EADS, C.E.

1882

REPORT UPON THE HARBOUR OF TORONTO.

Hon. Sir H. L. LANGEVIN, C.B., K.C.M.G.,
Minister of Public Works, Canada.

SIR,—I have the honor to submit the following Report upon the Harbour of Toronto.

Before making a personal inspection of the harbour, I expressed the wish that I should be furnished with such information relating to it as would be useful in a study of the questions upon which my advice was desired. In response to this request I have received a compilation of the available records touching the Harbour, entitled: "Memorandum with accompanying plans and documents relating to the past and present state of the Harbour of Toronto," and at the same time I received the following letter:

No. 6532, Subj. 13.

"DEPARTMENT OF PUBLIC WORKS, CANADA,
OTTAWA, 19th April, 1881.

"SIR,—The preparation of the information you desired to have relative to the Harbour of Toronto prior to the examination you are to make having been completed, I now enclose the same in pamphlet form, and am directed by the Honorable the Minister to request you to proceed with such examination at your earliest convenience.

"There are two points which will demand your serious consideration:—

"1st. The western entrance—its proper width and depth, and the means to be adopted to maintain both, as well as to restrain or prevent the growth of the island shoal northwardly and westwardly either by works erected at the entrance or from the island, or both.

"2d. The eastern entrance,—whether it is desirable that it should remain open; if so, the means to be adopted for its maintenance to an ample width and to a depth

equal to that of the western entrance. If it should be closed, the manner in which this should be accomplished and its future maintenance provided for.

"You will be kind enough to report fully on these points, as well as on all others having a bearing on the preservation or improvement of the harbour which may be brought to your notice during your examination, such report to be accompanied by plans and estimates of the cost, and such suggestions as you may be pleased to make.

"Although your attention is called to certain points for investigation, it is the wish of the Minister that your report shall be full and comprehensive and embrace every thing which may have a bearing on the object of your enquiry.

"You will please notify the Chief Engineer when you propose visiting Toronto.

"I have the honor to be, Sir, your obedient servant.

(Signed)

"F. H. ENNIS, Secretary."

The Memorandum and its appendices contain a mass of important information upon the subject in hand, which will be found very useful in forming a correct judgment as to the merits of any system of works which has been or which may be suggested for the benefit of the harbour. But as the careful examination of these facts *in extenso* may be inconvenient when this Report is under consideration, and as they constitute a part of the evidence by which I have been guided, I think it proper to append to this Report a copy of the Memorandum, as it contains in a compact form the gist of the information which is embodied in the entire volume.

During the latter part of last June, I visited the City of Toronto and met the Chief Engineer, Mr. Henry F. Perley, there by appointment. Through his courtesy I was provided with every facility necessary to enable me to make such an inspection of the harbour and its vicinity, as I desired. During my examination I was accompanied by the Chief Engineer, and by Mr. Kivas Tully, Engineer of the Harbour, and from these gentlemen I obtained, verbally, much useful information. Mr. Tully's knowledge of the harbour is the result of many years of close and intelligent observation of its phenomena, while residing in Toronto. During my visit I made as thorough an inspection of the harbour as I desired, and fully informed myself as to the causes which in my opinion have produced its deterioration.

As no instrumental survey of the harbour had been made since 1879, and as an accurate knowledge of the most recent changes in it was important, not only in arriving at a correct solution of the problem, but also in making an accurate estimate of the cost of the works needed for its improvement, I requested that another survey should be made with especial reference to the changes which had occurred in its two entrances, where works of improvement would probably be located. This survey the Chief Engineer caused to be made during last July and August, and I have been furnished with the results. I am therefore in possession of all of the information requisite for an intelligent and thorough study of the subject. This study I have made and I trust that I shall succeed in presenting to the Dominion Government, in as convincing a light as they are presented to my own mind, the several reasons that have induced me to make the recommendations herewith submitted. To aid me in this part of my task I desire to impress on the memory of the reader, each one of the three facts presently named, which appear to me to be the most important phenomena in the consideration of the very novel problem presented by the Harbour of Toronto.

First. There has been for nearly a century a constant growth of the northern end of the peninsula in the direction of the Queen's Wharf.

Second. Although this extension has diminished the *width* and *depth* through the entrance or throat of the harbour, it has not materially altered the *distance* which existed

sixty-three years ago between the deep water immediately inside of the harbour and that near the entrance on the outside of it.

Third. While the crest of the extremity of the peninsula has advanced about 1,700 feet to the west in the last sixty-three years, its submerged face on that side has greatly receded, and the deep water of the lake along its western shore has proportionately moved to the east, thereby resulting in a much steeper slope on this side of the peninsula, to the depth of at least 18 feet, than it had in 1818.

These three facts are so important that the proof of each one in order, is herewith submitted.

In proof of the *first*, we learn that in 1788, Mr. J. Collins, Deputy Surveyor-General, reported the navigable channel for vessels to be 1,500 feet wide and from 18 to 20 feet deep. The waters of the lake at the time were as he says very high. The survey of Bouchette, 5 years later, shows only 15 feet as the maximum depth and a channel 480 yards wide. Much of this difference in the maximum depth and width and that reported by Collins, was doubtless due to the different level to which Bouchette referred his measurements.

In the very interesting and instructive competitive report of Mr. Sandford Fleming, C. E., (page 64 of the appendix to Memorandum) we find the following statement:

"On comparing the charts of Bouchette, Bayfield, and Bonnycastle, with my own from a recent survey [in 1850] showing the state of the peninsula at the present time, we obtain results as follows:

"First—That the channel between ten (10) feet water lines was, in

- " 1796, about 480 yards wide,
- " 1828, about 310 yards wide,
- " 1835, about 260 yards wide,
- " 1850, about 120 yards wide."

This comparison is entitled to much confidence, for the reason that it was evidently made by a careful and intelligent engineer, who had within reach at Toronto at that time, the necessary data to determine the difference in the levels to which these several surveys were referred, and without which information so very accurate comparison of these surveys could have been made.

From these comparisons, and from his estimates, Mr. Fleming arrived at the conclusion, that the northward growth of the peninsula reduced the width of the channel at the rate of from seven to ten yards annually, and that this required a deposit of about 11,000 cubic yards each year. The annual growth during the years embraced by his comparison is shown to be remarkably constant and regular.

On the 11th of April of this year, as appears by the chart of comparative surveys from 1875 to 1879, inclusive, the width between the Queen's wharf and the ten-foot contour line on the peninsula was only about 225 feet, and much of this width is no doubt, due to dredging.

The *second fact* is shown by a comparison of Mr. Fleming's survey of 1850, with the most recent one made this year. The 15 feet inside and outside contour-lines on the latest survey, measured across the end of the peninsula where they approached each other most nearly, are about 2,400 feet apart.

In comparing the latest contours with the 15-foot contours of Mr. Fleming, it should be observed that there are two 15-foot soundings on his chart in the bight of the outer curve which are not embraced by it. If the curve were drawn through the outer one of these, which it might be with equal propriety, the line would be

moved out about 420 feet. The distance would then be about 2,200 feet between the two 15-foot contours on Mr. Fleming's chart, if measured over the line of least distance between the same contours on the survey of 1881. This line crosses the end of the peninsula about 1,350 feet from the end of the Queen's wharf. On a line nearer to the Queen's wharf the distance between them on Mr. Fleming's chart is only about 1,800 feet. The lesser distances between these contours on Mr. Fleming's survey are owing to the higher datum plane from which the depths were measured. He says (p. 63, Memorandum and Appendix) that his report was "chiefly founded on a very laborious and expensive survey between August, 1849, and the spring of 1850." With regard to the datum level, he says:

"These soundings amount to between two and three thousand, and are reduced to an approximate mean level of Lake Ontario, ascertained in conjunction with Captain Lefrey from a series of lake levels taken by his direction during several years."

This level is, I believe, about one foot and a half higher than the present datum established by the late Captain Hugh Richardson in 1850. The hydrographic diagram of Mr. Kivas Tully shows the mean level of the lake during twenty-five years ending in 1879 to have been 18.20 inches above the present datum plane.

No material difference is observable between the last survey and that made by Mr. Fleming thirty years ago in the width of the shoal between the 15 foot contours at the locality named, when the discrepancies I have alluded to are duly considered. That this distance has not appreciably altered in the last six years admits of no question, when the survey of 1875 is compared with that of 1881.

In still further proof, it is proper to quote the following from the report of Mr. William Kingsford, engineer in charge, dated July 7th, 1875, who seems to have been a close observer of the changes in the harbor and its entrances. He says (page 110, Memorandum and Appendix): "The eastern spit of land which protects the harbor is formed of sand, much of which is frequently in motion. It has been asserted that, carried away from the original place of deposit, it finds its way into the harbour. The examination of last year proves that such is not the case. There is no less depth of water to-day in the inner harbour than is shown on the map of the first survey made by Bouchette in 1785.

The proof of the *third fact* referred to, will appear by making the following comparison of Bayfield's survey with the survey of 1881. Draw a line upon each from the light-house to the centre of the Queen's Wharf, and from points on this line measure, perpendicularly to it, the distances to the 2, 4, 10, 15, and 18-foot soundings shown on Bayfield's chart near the central part of the western face of the peninsula; and compare those depths with the depths at the same places on the chart of 1881.

First. At a point on the line 4,500 feet from the light-house we find it is about 1,900 feet to the most southerly one of the two-foot soundings. At this place on the survey of 1881, the depth is now 13 feet greater.

Second. At a point on the line 5,600 feet from the light-house it is 1,500 feet to the next two-foot sounding on the Bayfield chart. At this place the depth is now 6 feet greater.*

Third. At a point on the line on the Bayfield survey 4,000 feet from the light-house it is 1,450 feet to the southern four-foot sounding. The depth here is now 27 feet greater.

* Note.—This latter two-foot sounding and others on the same shoal are shown more distinctly on an engraved chart of Bayfield's survey published "with corrections" in 1863. They are scarcely discernible on the photo-lithograph published with the memorandum.

Fourth. At a point on the line 4,300 feet from the light-house it is 1,200 feet to the other four-foot sounding. The depth at this place is now $1\frac{1}{2}$ feet greater.

Fifth. At a point 4,750 feet from the light-house it is 2,000 feet to the ten-foot sounding on Bayfield's chart. At this place the depth is now 9 feet greater. The ten-foot contour here has receded 400 feet.

Sixth. At a point on the line 5,000 feet from the light-house it is 2,000 feet to the fifteen-foot sounding of Captain Bayfield. At the same place the present depth is 4 feet greater. The fifteen-foot contour has receded here about 200 feet.

Seventh. At a point on the line 5,200 feet from the light-house it is 2,050 feet to the eighteen-foot sounding on Bayfield's chart. The present depth here is about 2 feet greater.

These comparisons are sufficient to show that the five-foot contour line about the middle of the western face of the peninsula is at very nearly the same place now that it was sixty-three years ago, while the contours between five feet and eighteen feet have greatly receded.

A further comparison of Captain Bayfield's survey with that of 1881, will prove by similar measurements that the dry crest of the northern end of the peninsula has not only advanced to the north, but has likewise advanced to the westward about 1,700 feet from the end of the sand spit shown on Capt. Bayfield's chart, by which the western face of the peninsula above the five-foot contour line has been much steepened by a movement precisely the converse of that which has steepened it below that depth. The sand which constituted the bottom beyond the present five-foot contour line in 1818 out to the depth of eighteen feet, has evidently been transported by the action of the waves up to the northward and on to that part of the western face of the peninsula which is now above the present five-foot contour. This process has greatly steepened the western face of the peninsula without really advancing it lakeward.

If comparisons be made further southward on the face of the Peninsula, the change wrought by wave action in this direction will be still more marked. For instance at a point on the line from the Queen's Wharf to the light-house, 2,600 feet from the latter, the Bayfield chart shows a depth of but 3 feet on the outer face of the shoal at the distance of 2,600 feet. The depth here must now be about nineteen feet, as the spot is about 100 feet outside of the outermost sounding on the chart of 1881, where a depth of 18.5 feet is recorded. The depth of three feet is now 1,600 feet eastward on the survey of 1881. If we assume that the plane to which Captain Bayfield reduced his soundings was eighteen inches higher than the present datum, it would still show that the three-foot contour at this locality is 1,550 feet further landward than it was in 1818.

From this and other comparisons which may be made between these two surveys it will appear that while the top or dry part of the peninsula at its northern end has apparently swung out towards the lake about 1,700 feet westwardly, the submerged portion of it at the southern end of this face, has, to the depth of eighteen feet, swung in towards the light-house about the same distance eastwardly. The common centre about which these changes seem to have vibrated from east to west, is located near the central portion of the western face of the peninsula. The centre about which the vertical movement has occurred by which the entire face of the peninsula has been steepened, seems to have been at the depth of about five feet, and at a point also near the central part of the western face of the peninsula. In this movement the eighteen-foot contour at the northern end has not materially changed its location, while the zero margin of the lake at the other end, immediately west of the light-house has been almost if not quite as stable.

The prolongation of the isthmus northwardly and the alteration of its western face, are unquestionably due to wave action, and as a proper understanding of the phenomena produced by waves is absolutely necessary to enable the reader to form an intelligent judgment of the merits of the conclusions arrived at, in regard to the causes of the changes which have occurred at the harbor of Toronto, and of the probable results of the remedial works herein proposed, I will be pardoned for explaining the manner in which the waves affect the sand and other materials composing the bottom of seas, lakes, etc.

A simple illustration of the action of waves on the surface of *very deep water* can be made by tightly stretching a long cord between two points and then striking it near one end. The wave produced by the blow travels rapidly back and forth along the cord from end to end, but the material of which the cord is made simply rises and falls without advancing with the wave. So it is with the *water* where the lake is deep. The wave may pass ever so rapidly, but it cannot of itself set up any continuous horizontal motion in the water. A bird or a buoy afloat upon it would simply rise and fall as the waves passed under it. At the same time it would have a slight motion to and fro in the direction the waves are travelling but unless impelled by the wind or a current in the lake, it would remain in the same locality. The case is quite different, however, when the wave reaches water so shoal that the bottom resists the sinking of its crest. When this resistance is felt, the water which at that moment constitutes the wave, has, as a result of this resistance and of its own momentum, a horizontal motion imparted to it. This horizontal impulse becomes still greater as the depth lessens. Hence, although the velocity of the wave itself is diminished as it reaches shallower depths, the water through which it passes has a constantly increasing velocity imparted to it in the direction of the shore, and in the case of big waves it becomes so swift that it is driven with great force out upon the beach.

This translatory motion gives to the waves the power to take up from the sea bottom, or to set in motion, the sands, shells and other materials of which it is composed, and to transport them shoreward with more or less force. The quantities thus transported depend upon the size of the waves, the formation of the shore upon which they exert their force, and the size, gravity and abundance of the material acted upon.

The direction of these translatory currents is determined by the shape of the sea bottom. If the shore be precipitous, very little or no such current will be created; but where the bottom is sloping to the sea, the waves will be constantly directed shorewards, no matter how obliquely they may approach it. Hence waves on such shores are continually piling up reefs and beaches, and through some of these every river must struggle to reach the sea, unless it enters it between bold headlands, and is incapable of transporting enough detritus to form a delta at its mouth; or unless some sea current exist sufficiently strong to sweep away the sedimentary matter brought down by it. Of course the height of the wave determines the depth at which the resistance of the bottom is felt, and at which the horizontal motion of the water is first induced. This depth will therefore be the extreme limit at which the material of the bottom can be set in motion by the wave. A study of the surveys which have been made on the western shore of the isthmus at Toronto satisfies me that the waves which roll in upon it are not large enough to move the sand when the water is over 18 feet deep. I can discover no evidence that the bottom has been disturbed at a greater depth there during sixty-three years; and the area within which the waves are formed that break upon it forbids the belief that they are large enough to affect the bottom at a greater depth. The magnitude of a wave does not depend so much upon the force of the wind as upon the "fetch" or distance through which it can travel without interruption, and the depth of the water on which it moves.

Waves travel much more rapidly in deep than in shallow water. This is the cause of the phenomenon called "breakers." As each wave approaches still

shallower water, its speed becomes still more retarded, hence the wave behind is always moving more rapidly than the one in advance. As it gains upon its predecessor it gets the benefit of the deeper water of that wave. The result of this is that at regularly recurring intervals or rhythmic periods, one of the waves completely overtakes the one in front of it, by which it secures for itself a still greater depth and maintains the velocity due to that depth. This enables it to travel so rapidly over the one it has surmounted, that it outstrips it in the race and consequently falls over in front of it, or, as it is termed, "breaks."

The wave has more ability to carry the sand up on to the beach than it has to bring it down again notwithstanding the slope of the shore. This is because the ratio of frictional resistance of the shore increases as the depth of the water passing over it is diminished, and also because the material carried up on to the beach, is almost wholly suspended in the water. The interval of time required for the shoreward current to come to rest and for the return current to be started, is sufficient to permit the sand to fall to the shore, from which the less rapid current seaward is unable to move it.

A very important part of the study of our problem is involved in the inquiry as to whether the portion of the isthmus now constituting an island is undergoing any serious alteration in its size. Is it being added to? or is it diminishing? We know that its form has been altered to the serious injury of the channel, by the extension of the peninsula northward. It is a matter of great importance to know whether the material which has been added to the end of the peninsula in the last 63 years has been brought from Humber Bay, Scarborough Heights or elsewhere, or whether it has been transported from the southwestern portion of the peninsula itself.

If it has been brought from the eastern shore of the Lake, from Humber Bay or Niagara, we must look for an annual contribution of the same kind indefinitely, from such foreign source, and this fact would thrust into any plan for the improvement of the western entrance, a very embarrassing element. This material would accumulate about the entrance to our works, to such an extent as to need annual dredging and probably an extension of the necessary piers from time to time. With such a prospect I should not hesitate to advise that the western entrance be abandoned and that the remedial treatment, although much more expensive, be at once applied to the eastern gap. It is, however, only necessary to make an approximate estimate of the amount of material which has been removed from the western face of the peninsula, near Gibraltar Point, northward and within a distance of about 2,000 feet westward from its present margin, to know that the immense quantity of sand which covered the lake bottom over this area in 1818, and which has now been removed by wave action, was quite sufficient to have transferred the crest of the peninsula 1,700 feet westward in the shallow depths then existing, and to have added to its length all of the material which it has received during the last 63 years, without any contributions from foreign sources.

I have made some approximate estimates of the quantity of sand which has been removed from this area during the last sixty-three years. On the large chart accompanying this report, which is a copy of the survey made by Mr. F. M. Hamel in 1881, will be found a line drawn from the light-house to the Queen's wharf, with four lines at right angles to it. These are designated as "A. B." "C. D." "E. F." and "G. H." In comparing the sections, as nearly as possible with those similarly located on Bayfield's chart, I find that south of line "A. B." in the last 63 years there have been removed about six million cubic feet. Between lines "A. B." and "C. D." sixteen million two hundred and fifty feet. Between "C. D." and "E. F." eighteen million, seven hundred and fifty feet. Between "E. F." and "G. H." five million one hundred thousand feet, and north of line "G. H." one million, four hundred thousand cubic feet, making in all, forty-seven million, five hundred thousand cubic feet; or, one million, seven hundred and sixty thousand cubic yards.

This is at the rate of about twenty-eight thousand cubic yards per annum; an amount amply sufficient to account for the northward growth of the Peninsula and likewise for the westward advance of the crest of it. The data are not sufficient to enable me to determine what amount of it has been deposited to the eastward of the line between the Queen's wharf and the light-house, but it is evident from the foregoing that no addition from any foreign source has been made to the northern and western face of the Peninsula since Bayfield's survey. The changes which have occurred on the western face of it, give substantial assurance of the permanency of the western entrance to the harbour, if it be located in accordance with the recommendations hereinafter made.

No grain of sand rests upon any part of the shores of the peninsula, or in the channel, that was not brought to its present resting place by a current of water which left it there because it was not able to move it farther. The slope of the shore is therefore the result of an equilibrium between the force of the currents which sweep over it, and of the opposing force of gravity in the sand. The slope which the shore assumes under these different forces is termed in technical parlance, its "angle of repose." Owing to the greater mobility of the sand when saturated, this angle is flatter or lower on the submerged part of the shore than on the dry reefs or beaches. When a broad channel is exposed to storms and is swept by violent waves in different directions, the bottom becomes still flatter. Hence the angle of repose assumed, is so low that any natural channel through such deposits on the sea coast, must possess great width if it have any considerable depth in its central part. This will be better seen when it is remembered that it is about 1,200 feet from the shore line on the western face of the peninsula out to 16 feet of water, although this shore is under the influence of wave action which is quite favorable for the maintenance of a steep angle of repose. A natural channel therefore, if formed of the same materials, which I assume to be almost wholly of sand, would, if it were possible to have its opposite shores swept by similar waves, require to be 2,400 feet wide to maintain a central depth of 16 feet. In a narrow and sheltered channel the sand would maintain an angle of from four to six horizontal, to one vertical, or about eleven degrees. The perimeter of the cross section of a channel swept only by currents moving in direction parallel to its axis, conforms very nearly to the arc of a circle.

The ability of a river to carry the detritus with which its water is charged, is due to the velocity of the current. When it reaches the sea the current subsides, and the sediment, before held in suspension, is deposited. The sea waves leach out by continual agitation the argillaceous and other lighter portions of these deposits, while the sand, gravel and heavier materials are left to dam back the river and form the foundations upon which it in turn builds up its bank still further out. Their low slopes defy the fury of the waves, and if any littoral (or shore) current prevails in the sea where the river is thus extending its banks, this current carries the river deposits to the leeward, builds up that bank more rapidly than the other and compels the discharge finally to flow in almost direct opposition to the prevailing sea current. In this way a river will extend its banks out many miles into the sea, its direction being determined by the littoral current or by the prevailing winds. The Mississippi has thus extended its length about sixty miles out into the Gulf of Mexico beyond the present shore lines of the gulf, and its course has been almost directly *against* the direction of the prevailing winds. As the river extends itself into the sea, its banks on the mainland are continually being raised by the annual overflows. These deposit the heavier materials carried by the current close to the river, while the lighter portion, which takes longer to settle, is carried back to the swamp lands. In this way many silt-bearing streams, the Mississippi, the Rhine, and the Po, for instance, have, as they approach the sea, build up their banks many feet higher than the lands on each side of the river.

The direction which rivers take when their channels are built out in the sea, is frequently such as to almost completely enclose extensive bays. After such process

has been carried out to a greater or less distance in the sea, the height of the river on the main land becomes so great that a breach finally occurs in the seaward bank during some extraordinary flood, and the river then takes the shorter way through it to the sea. In such case the channel which it had constructed below the breach is abandoned. Being no longer a conduit for the fluvial current, it is filled up by the action of the waves, and at the same time the height of its banks is reduced to the sea level or below it, and what the river constructed finally becomes the foundation of a peninsula, on which every evidence of the fluvial channel above the surface of the sea, is completely obliterated. The Vistula, Adour, and Senegal, are among the numerous examples of rivers forming such new outlets to the sea, many miles above their former mouths. The long, narrow peninsulas which separate the Frisches Haff and the Curisches Haff in Eastern Prussia from the Baltic, no doubt had their origin in the extensions of the Vistula and Pregel into that sea.

A peninsula thus formed, having its axis parallel to the prevailing winds, receives constant additions by wave action upon its extremity, which continues to extend it, generally, though not always against the wind. If a constant current of the sea sweep along its side in the direction of the end of the peninsula, the accretions thrown up by the waves in storms on the side of it, are gradually transported along in calmer weather, toward its extremity. The side is thus kept steeper and prevented from widening, while the sands thus removed fall to the bottom again in the more sluggish current or eddy, which exists at the end of the peninsula. Here an extensive shoal forms during the calmer weather, to be afterwards thrown up on it by the force of the waves. The sandy breakwaters which enclose the long series of extensive sounds on the coast of Virginia, the Carolinas and Florida, are examples of this kind of peninsula formation. The same process is carried on in tideless seas, though not in such vast extent. The Baltic, Mediterranean, Black Sea and the Great Lakes present many examples of such phenomena.

The sea currents almost invariably carry more or less sand along the shores, and thus furnish the material for the waves to extend the peninsulas. If the source of supply of this material be from any cause exhausted, the growth of the peninsula becomes checked. In such case the long, low slope at the end of the peninsula, under the influence of the waves, may not only be thrown up against it and be greatly steepened, but the end of the peninsula may be made by such influences to change its direction under the oblique force of the waves, in the manner of the Toronto peninsula. An example of a peninsula built out from a headland many miles across a large bay, and stopped in its growth when only half way across, may be seen in the Gulf of Danzig in the Baltic.

The longitudinal growth of a peninsula is checked when it approaches a headland of the main shore, by the pulsations which occur in the basin or harbour enclosed by it. Where tidal action exists the basin is filled and emptied twice a day * through the channel between the end of the peninsula and the mainland, and the further encroachment of the peninsula upon this channel is arrested by the currents which sweep through it upon every ebb and flow of the tide. The higher the tide rises, and the bigger the basin which is filled and emptied, the greater will be the magnitude of the channel thus maintained. When the peninsula has reduced the width of the channel to the size absolutely required for the entrance and exit of the tidal water, the channel becomes permanent.

As the magnitude of a channel thus formed is wholly dependent upon the quantity of water which flows through it, it is evident that the quantity must be diminished if a breach occurs in the peninsula, as a portion of the water which would otherwise serve to maintain the channel and stop the growth of the peninsula is lost through the breach.

NOTE.—The Gulf of Mexico is an exception to this rule: the tide there rises but once a day.

I think it altogether likely that the Toronto peninsula had its origin in an extension of the River Don westwardly from the southwestern point of Ashbridge's marsh. It is not necessary to sustain such hypothesis, that its ancient channel should have extended through any considerable length of the peninsula. The root of the peninsula being thus formed throughout a distance of a few hundred feet, would be a sufficient nucleus upon which the waves and the current of the lake would concentrate a great part of the sand lying within a few miles of it in water less than eighteen feet deep. To do this the easterly gales doubtless contributed a large portion of the detritus from the ancient Scarborough Heights. The prevalence of the southwesterly gales will explain the cause of the change of direction which the peninsula has taken at Gibraltar Point without the Don having ever extended its channel through that part of the peninsula. To the wave action resulting from easterly storms must be attributed the constant growth of the eastern end of the island. This growth will be seen by a comparison of the last survey with those of older date.

It is not, however, necessary to penetrate the mystery which enfolds the creation of the peninsula. Its continual advancement to the northward conclusively demonstrates the fact that the filling and emptying of Toronto Harbour under the influence of the winds, the rise and fall of the lake and the discharge of the Don, have not been sufficient to arrest the growth of the peninsula in this direction, and the breach at Privat's Hotel which occurred about thirty years ago has made the currents through the main channel since then, still more impotent to check its northward advance.

It is exceedingly difficult to declare with any certainty what is the greatest magnitude of channel that can be maintained permanently through the main entrance to the harbour without dredging, even if the eastern gap were closed. The annual rise and fall of the lake is a very low process as well as a very irregular one and produces but little current through this channel. The rise and fall of the water in the harbour under the action of the winds and storms is the chief source to which we must look for the necessary force of current to maintain the channel.

With a tidal basin regularly filled and emptied every day, and a permanent cross-section of channel as a resultant to guide him, the engineer can calculate with great accuracy the increased depth which he can secure by the construction of parallel works to reduce its natural width; but at Toronto the facts prove that the dimensions of the main channel are not permanent, nor are they wholly the results of the currents passing through, it but of the incomplete inclosure of the harbour by the peninsula. In other words, the western channel was originally an open roadstead. The peninsula has been, and is now, gradually converting it into a channel of permanent dimensions. If this natural process proceeds, it will reduce its dimensions to those which the tidal action or pulsations of the basin enclosed by it, absolutely require for the exit and entrance of the lake water. It will then preserve that size with comparative permanence. Such channel, uninfluenced by artificial causes, would be shallow and wide, owing to the low angle of repose which the sands that form its bed naturally assume. If this process were completed, the engineer would know by the natural cross-section of channel permanently established, what additional depth could be secured and maintained through the works he would build to contract it; because the tidal action will insure the maintenance of a cross-sectional area sufficient for its accommodation, and, if he contracts that area in width, the tidal force will recover a portion of it by increasing the depth through the works, until such area of cross-section is made large enough to establish a new condition of equilibrium or permanence, between the force of the current and the resisting forces of friction of the bed and the gravity of the materials of which it is formed. Nothing short of some unusual convulsion of nature could close up the channel between the lake and a basin so large as the Toronto Harbour, if but one channel existed. If instead of one there were many into the harbour, they would each be shallower, and

in such case, a long continuance of a low lake level, would make them all unusually shallow, and render them liable to be shut up by wave action which would thus convert the harbour into a lake.

We have, however, in the comparatively stable condition of the inferior channel through the breach a reliable basis for the belief that a channel of sufficient width and depth for the commercial wants of Toronto can be permanently maintained without dredging, simply by the currents resulting from the oscillations of the water in the harbour, if but one channel be permitted. The channel through this gap has now a central depth of about four and a half feet and a surface width of about nineteen hundred feet, when the level of the lake is at zero of the gauge. This is equivalent to a cross-sectional area of nearly four thousand feet or of a channel two hundred feet wide and twenty feet of central depth. This channel has been maintained wholly by the currents that pass through it. If the main entrance were completely closed it is safe to assert that it would have been much deeper and proportionately wider.

It is supposed that the channel through the breach has been maintained by a current sweeping through it, and through the western entrance, at the same time and in the same direction, that is to say, in through one and out at the other, and not by currents induced by the pulsations of the harbour, it is to be answered that such a current would not have the velocity of those currents which result from maximum differences of level between the surface of the harbour and that of the lake. A wind blowing continuously from the southeast would have the effect of creating a current through the gap which would flow out of the western entrance, but the same wind would raise the level in Humber Bay at the same time and thus check, if it did not completely arrest such current. The strongest currents which would flow through the gap, without establishing a counter under-current would probably be induced by winds from the south or southwest. These would elevate the surface in Humber Bay to a greater degree than at the gap. Their effect upon the water on the south shore of the peninsula would be to create a current, toward Scarborough Heights, without materially affecting the level of the surface at the gap. Storms from the east undoubtedly have the effect of creating considerable current through the gap into the harbour. I am of opinion, however, that currents thus created through the gap cannot have the velocity and scouring power which the under-currents hereafter referred to would possess.

The currents which are induced by a rapid rise or fall of the lake, will have their velocities determined by the slope of surface through the channel, (or fall per mile,) and by the amount of frictional resistance of the bed of the channel. It is evident that when an alteration occurs between the surface levels of the lake and the harbour, the steepness of the slope through the channel will be increased in proportion as its length is diminished. The slope of the surface creates the current and the friction retards it; hence it is of prime importance that the channel be kept as short as possible. When the currents are the result of winds prevailing for several days in a direction to fill or empty the harbour an under-current must always exist through the channel in an opposite direction to that which is seen on its surface, provided all other openings from the lake into the harbour be closed.

It is impossible for an east wind to sweep over the harbour for an entire day without creating an outward surface current through the proposed channel, supposing the breach at Privat's Hotel and all communication with Ashbridge's bay to have been closed. This current will continue to exist so long as the friction of the air sets the surface water in the harbour and channel in motion, and it is impossible that the water should continue for any considerable length of time to flow out of the harbour in the direction of the wind, without lowering its surface level. A counter current of equal intensity will then be created below the surface current in the channel. This under-current will be the result of hydrostatic pressure induced by the greater height of surface outside of the harbour.

I should hesitate to advise the construction of a channel of greater dimensions than three hundred feet in width and a central depth of eighteen feet below the present datum plane, although I am not prepared to say that one of greater size cannot be maintained without dredging after it be once completed.

A channel of the dimensions named can be constructed either at the breach on the peninsula, or at western entrance to the harbour, with nearly equal assurance of its permanence. The question therefore, as to which locality shall be selected for the channel, should be determined mainly by the relative advantages which each would possess for navigation, and the relative cost of each. These are both decidedly in favor of the western location.

So far as to the safety and ease with which vessels could enter either one of these channels during bad weather, there can be no doubt that the preference is most decidedly in favor of the western entrance. Owing to its peculiar position, this entrance is completely protected from storms from every quarter except the southwest. To connect the deep water on the two sides of the peninsula by the shortest route, requires the location of a channel nearly parallel to the direction of these storms; therefore vessels arriving in such weather, would be able to sail directly into the channel and proceed at once to the harbour.

I have laid down upon the general chart of the harbour, (No. 1), the lines upon which the works that would be required for the improvement of the eastern gap should be located, if such improvements were deemed more desirable than that of the western entrance. These are shown in dotted lines, and will be readily found on the map. Where these lines are double, the works would need to be equally as strong and costly as the breakwater required on the south side of the western entrance. In addition to the works at the gap, its improvement would necessitate the complete closure of the western entrance by a dyke from the Queen's wharf to the end of the peninsula, as shown also with dotted lines.

On comparing the length of these several lines of works with those hereinafter recommended, (the location of which is shown in solid lines on the map,) it will be seen that the improvement of the eastern gap would require 4,840 linear feet of heavy work, including 400 feet of the Queen's wharf dyke, and 6,220 linear feet of light work; while the western entrance will require only 2,745 linear feet of heavy work; and only 7,403 linear feet of light work.

In this comparison it is assumed that 800 feet of the landward end of the breakwater, and 1,040 feet of the Queen's wharf dyke, will be of light work. Therefore 2,095 feet less of heavy work, and 1,123 feet more of light work, will be required to improve the western entrance.

The amount of dredging required to make the eastern channel, would likewise be greater than that needed at the western entrance. With such an enormous difference in the extent of the works and because of the other decided advantages in favor of the western entrance, I have deemed it unnecessary to prepare detail plans for the improvement of the eastern gap. They would only be useful in determining accurately the difference in the cost of each entrance. Whereas, if the eastern one cost no more, I should be unwilling to give it the preference.

If the channel were located at the gap it would need to be about 700 feet longer than the western channel, and the currents through it would therefore be less rapid than through the western one under the same conditions of wind and tide. Hence they would not maintain a channel of as great a width and depth as the western one. I should not, however, expect to find much difference in them from the injurious effect of wave action at their lake entrances, because either one selected for improvement must first be dredged to the maximum depth required, and as this would be a depth at which there would be little or no disturbance of the bottom at the end of the

channel by wave action, there need be but little fear that either channel would require dredging as a result of wave action alone. The lake currents, however, carry more or less sand in suspension, and if this be carried into a channel of greater dimensions than the tidal action or pulsations of the harbour demand, they will be deposited in it and will gradually diminish its size to that which can be permanently maintained by the maximum currents through the channel.

To attempt to utilize the present western channel would involve the removal of a large amount of stone by blasting to obtain a sufficient depth, and would moreover require the channel to be crooked, in as much as the western end of it would necessarily have to be curved to the south west to reach the deep water of the lake. Thus located it would require to be very considerably longer than a straight cut across the peninsula. This greater length, and its curvature would be very objectionable. The greater length would increase the friction of the currents flowing through the channel and therefore diminish their velocity. The curvature would diminish their velocity still more, by checking the momentum of the water.

I am confident that a channel 300 feet wide between parallel works, at the western end of the harbour, with a central depth of 18 feet below the present zero or datum plane, can, when once established by dredging, be afterwards maintained by the natural currents through it, if it be located across the northern end of the peninsula between the lines, shown in the accompanying chart (No. 1), provided all other communication between the lake and the harbour be completely closed.

I have the honor to submit the following

RECOMMENDATIONS.

1. The closure of the Eastern Gap with a dyke of sheet piling, protected on the sea side against undermining, with brush and stone.
2. The construction of a breakwater and the necessary parallel works to protect and maintain a channel 300 feet wide and 18 feet deep across the northern end of the peninsula, to connect the deep water of the harbour with the deep water of the lake.
3. The excavation of the necessary depth and width of channel through the parallel works, after they shall have been constructed.
4. The closure of the present western channel, after the new shall have been sufficiently developed to afford equal facilities for commerce, by the construction of a dyke from the western end of the Queen's Wharf to the northern jetty of the new channel.
5. The closure of all communication between the harbour and Ashbridge's Bay, with a dyke of light sheet piling or one of earth, three feet above the present datum plane, or zero of the gauge.

All of these works except those necessary to completely separate the harbour from Ashbridge's Bay, should be located and constructed in accordance with the plans and specifications herewith submitted. The closure of the Eastern Gap, and the construction of the breakwater and channel works, should be executed at the same time to secure the earliest benefit of the proposed improvement. If this be not done, I would then recommend the construction of the channel works and breakwater first, and the closure of the gap while the new channel is being dredged out. I do not think the diversion of the Don into Ashbridge's Bay necessary, except as a sanitary measure. So far as this would affect the channel and harbour, it is probable that the injury which may be done by the small quantity of sediment that the Don brings into the harbour, will be compensated for by the increased current it will

give through the channel when in flood. Should it be found a few years after the proposed works are completed that its deposits are injuriously affecting the depth of the harbour, it can then be diverted into Ashbridge's Bay, if it shall not have been previously done for sanitary reasons. It is quite probable that the closure of the Eastern gap and the growth of the city will soon make such diversion of the Don imperative as a means of promoting the public health.

Plans are not submitted for the dyking to separate Ashbridge's Bay from the harbour, because this work will be of a simple character, and comparatively inexpensive. I would recommend that its construction be open to competition, with the understanding that each bidder submit with his proposal the plan by which he intends to execute it, leaving to the Chief Engineer the selection of the best and cheapest proposal. This work will be exposed to very little servitude if it be sufficiently distant from the shore line of the harbour to be safe from floating ice. The greater portion of the marsh near the harbour shore is probably already 3 feet above zero, thus leaving only the sloughs to be closed. In any event the cost of the necessary work here will not probably exceed five thousand dollars.

If the closure of the Eastern gap be executed in accordance with the specifications and plans herewith submitted, I am of opinion that a sand beach will be formed in front of the dyke before the parts of it exposed to decay will be destroyed, and that no expenditure for the maintenance of the dyke will be required. The total estimated cost of the works recommended is \$250,633.85.

I have the honor to be, Sir, with great respect,

Your obedient servant,

JAS. B. EADS.

St-Louis, Mo., March 4th, 1882.

APPENDIX.

MEMORANDUM.

TORONTO HARBOUR, ONTARIO.

Toronto, formerly York, is situated on the northern shore of Lake Ontario, in lat. $43^{\circ} 38' 10''$ N., and long. $79^{\circ} 23' 45''$ W., 333 miles by rail south-west from Montreal, 161 miles from Kingston, and 39 miles north by east from Hamilton.

The harbour is formed inside of the Island, and has its principal entrance from the westward. An entrance known as the 'Eastern Gap' has existed for some years, but, owing to its shallowness, is not used by steamers or sailing craft of large dimensions. At the north-eastern corner the Don empties; and the eastern side is bounded by marshy lands of many acres in extent, which separate it from Ashbridge's Bay.

In 1758 this harbour was minutely described by J. Collins, Deputy Surveyor General, in a report presented to Lord Dorchester, Governor General, on the Military Posts and Harbours on Lakes Ontario, Erie and Huron. Mr. Collins stated it to be "near two miles in length from the entrance on the west to the isthmus between it and a large morass on the eastward. The breadth of the entrance is about half a mile, but the navigable channel for vessels is only about 500 yards, having from three to three and a half fathoms water. The north or main shore, the whole length of the harbour, is a clay bank from twelve to twenty feet high, and gradually rising behind, apparently good land and fit for settlement. The water is rather shoal near

the shore, having but one fathom depth at one hundred yards distance, two fathoms at two hundred yards; and when I sounded here the waters of the lake were very high." ("Toronto of Old," by Dr. Scadding, p. 16.)

The first survey of the harbour was made by Bouchetto in 1793, and a copy of his plan is attached hereto.

In his work on the "British Dominions in North America," published in 1832, Mr. Bouchetto describes the Harbour of Toronto as follows:—(Vol. 1, p. 83.)

"The Harbour of York is nearly circular, and formed by a very narrow peninsula stretching from the western extremity of the Township of Scarborough in an oblique direction for about six miles, and terminating in a curved point nearly opposite the garrison; thus enclosing a beautiful basin about a mile and a half in diameter, capable of containing a great number of vessels, and at the entrance of which ships may remain with safety during the winter. The formation of the peninsula itself is extraordinary, being a narrow slip of land, in several places not more than sixty yards in breadth, but widening towards its extremity to nearly a mile: it is principally a bank of sand, slightly overgrown with grass; the widest part is very curiously intersected by many large ponds that are the continual resorts of large quantities of wild fowl; a few trees scattered upon it greatly increase the singularity of its appearance, it lies so low that the wide expanse of Lake Ontario is seen over it; the termination of the peninsula is called Gibraltar Point, where a block-house has been erected. A lighthouse at the western extremity of the beach has rendered the access to the harbour safely practicable by night. The eastern part of the harbour is bounded by an extensive marsh through which the River Don runs before it discharges itself into the basin."

"No place in either province has made so rapid a progress as York. In the year 1793 the spot on which it stands presented only one solitary Indian wigwam; in the ensuing spring it was selected by Governor Simcoe as the seat of Government for Upper Canada."

With the growth of the population and the clearing and cultivation of the surrounding lands, and notably the disappearance of the Scarborough Heights to the eastward, from whence was derived the materials forming the peninsula, changes were soon apparent in the state of the harbour, and the necessity for its preservation early engaged the attention of those who were interested in its maintenance and improvement. They viewed with alarm the changes which had taken place in the dimensions of the peninsula, and the encroachment of the shoal from Gibraltar Point northward, to the great detriment of the entrance, and so early as 1833, as appears by the journals, Upper Canada Legislature, 1833-34, a select Committee reported on certain reports submitted by Captain Richardson and Captain (afterwards Sir) R. H. Bonnycastle, Royal Engineers, on its preservation. (App. p. 1, *et seq.*)

The Commissioners in their report recommended the construction of a work extending from the island along the top of the shoal to the buoy, in a manner to continue the island to the brink of the channel opposite the present pier (Queen's Wharf), contracting the channel to about 700 feet in width; and also to prevent the waters of the Don from entering the harbour. (App. p. 2.)

Captain Richardson's letter is but an amplification of the views of the Commissioners, of which he was one.

The opinions entertained by Captain (afterwards Sir Richard) Bonnycastle to make the harbour a secure and effectual one for large steamers and deep draught vessels were divided by him into three general propositions:—

- 1st. That of damming up the western estuaries of the Don;
- 2nd. The opening a passage through the eastern end of the peninsula; and

3rd. The construction of a breakwater from the shore at the western entrance, with works over the whole length of the shoal from Gibraltar Point, to confine the western entrance.

Sir Richard proceeded to debate the first proposition and arrived at the conclusion that it did not signify whether the breaches which the Don had made into the harbour be closed or not, and believed that the river is useful in a very slight degree.

With respect to the second proposition he plainly stated that if an opening be made through the beach the harbour would be entirely destroyed, and if it be done, extensive works must be run out into the lake, etc., to arrest and retain the shingle which is (was) brought by the wasting away of the Scarborough Heights from the eastward, and so to prevent a silting up of the channel so formed; but he feared that a navigable channel could not be kept clear, and that vessels would experience much difficulty during gales from the east around by the south to the west, in entering such a channel, and he summed up with the statement that there could not be any harm in making a small canal shut in by flood gates and protected by piers, and that under these restrictions no obstacle would be thrown in the way, and that it would be very useful for the purposes of trade.

The third proposition is discussed at length, and the conclusion arrived at was that the western entrance should be protected and maintained.

It appears that no action was in any way taken on this report, and though the matter engaged attention, little or no regard was paid to the state of the harbour, though a Mr. Roy, C.E., drew attention to its state in an article published in the *Monthly Review* in June, 1841. Search and inquiry have failed to obtain a copy of this paper.

Under date 4th May, 1847, Mr. C. S. Gzowski, then an engineer in the service of the Department of Public Works, reported that the entrance had narrowed to 250 feet in width, the bar having increased 280 feet in a northerly direction in seven years. (App. p. 17.)

In 1850, M. Sandford Fleming, C.E., read a carefully prepared paper before the Canadian Institute, in which he entered fully and minutely into the theory of the formation of the peninsula, described the changes which it was constantly undergoing, and its great increase in area since Bouchette's survey in 1793, and he debated the propositions which had been made and concluded:

1. That the foundation of the peninsula in its early stages may be attributed to the *debris* of the country traversed by the Don, in conjunction with a drift from an ancient promontory at Scarborough.
2. That the more recent portions were formed by materials from the Scarborough Heights.
3. That the formation is due to the travelling of the sand and gravel, under certain action of the waves.
4. That the harbour was being impaired and its only entrance threatened with early destruction by the same cause.
5. That its preservation may be permanently affected by the construction of certain specified works, at well selected points.
6. That the waters of the Don should be permanently excluded.
7. That the opening of an eastern passage would be a great accommodation to shipping; might improve the purity of the water in the harbour; and, if the necessary works to preserve it were properly executed, would have a beneficial effect.

Early in 1852, Mr. Walter Shanly, C.E., at the request of the Harbour Master, submitted for the information of the Harbour Commissioners a report on the state of the channel and the improvements required, (App. p. 18.) In it he stated that from the observations and soundings recorded during twenty years by the Harbour Master it was ascertained that the bar had advanced northwardly across the entrance at the rate of 19 feet yearly, and that the available width of the channel was scarcely 200 feet.

Mr. Shanly's theory of the formation of the peninsula is that the materials forming it were brought from the westward, and that the Don assisted as well, and he states that were the operations of Nature left unmolested, future generations might walk dry shales across to the outer lighthouse.

The remedy he proposed was dredging and the construction of crib-work on the southern side of the channel to define and maintain its width; and to divert the Don into Ashbridge's Bay.

Mr. Kivas Tully, C.E., in a letter dated 10th February, 1853, discussed fully the need of permanently improving the harbour, alluded to the opening of a passage through the peninsula, now known as the Eastern Gap, and suggested its improvement from an economical point of view—

1. On account of the saving of time to vessels arriving from or departing to the eastward, and
2. The tendency of the current created to maintain an open harbour later in the fall and earlier in the spring.

In the appendix, page 22, will be found an able review from the journal of the Canadian Institute, vol. 1, p. 162, of the letters and reports by Messrs. Bonnycastle, Shanly, Fleming and Tully.

In 1850 the harbour was placed in commission, Captain Richardson being Harbour Master. This gentleman, in January, 1854, submitted to the Commissioners a report on the state and requirements of the harbour, and alluded to the many changes which had taken place over a period of 50 years, and of the necessity which then existed for steps being taken to ensure the preservation of the western entrance in a navigable state, and to a depth of 14 feet and a width of 400 to 500 feet. He alluded to a breach through the peninsula to the eastward, near Privat's Hotel, which was then only 140 feet in width. Reference is made to an old chart of about 1800, on which the western entrance was shown to be about 1,455 feet in width from 12 feet inshore to 12 feet on the bar, and that the soundings in the channel were 3 and 3½ fathoms. (App. p. 2.)

This report bore fruit, for the Harbour Commissioners in March, 1854, offered premiums for the three best reports on the means to be adopted for the preservation and improvement of the harbour, the points to be discussed being:—

1. The effects, present or future, to be produced by the breach (Eastern Gap) through the peninsula on the harbour.
2. If prejudicial, the means to be taken to strengthen the coast against further encroachment.
3. If beneficial, the proper mode of making it useful, and the cost of doing so.
4. The advisability of opening a passage between the harbour and Ashbridge's Bay, or an opening from the lake into the lake, with an estimate of cost.

These premiums were obtained by Messrs. Hind, Fleming and Tully, and an extra premium was awarded to Captain Richardson for a report submitted by him.

The reports were published at the expense of the Harbour Commissioners, and will be found in the Appendix, p. 30 *et seq.* They furnish a vast amount of information respecting the harbour, and discuss fully the questions submitted by the Commissioners. No attempt is made by the writer to condense the views and opinions expressed in these different reports, because to do so would necessitate the use of extended quotations, which is not within the province of this memorandum.

No action was taken on any of the suggestions made by the writers of these reports as regards the construction of works; but it is gathered from subsequent reports by the Harbour Master—Captain Richardson—that dredging plant was obtained and used to keep the western entrance from closing up.

In 1856 it appears that the available width of the western entrance for deep draught vessels was only 260 or 270 feet, although dredging had been carried on for some time. At that date 400 feet was considered to be the least width, and 12 feet the least depth, which should be obtained. (App. p. 94.)

In his report for 1857, the Harbour Master states that many changes had been observed in the shape of the island; and that the point bounding Bloekhouse Bay on the western side had greatly increased northwardly. He alluded to damage done to the peninsula, that the embankment for its preservation was never finished, and did not advise its repair. (App. p. 95.)

From the report of 1858, it is gathered that a breach had been effected through the peninsula, and that the influx of water into the harbour from the eastward was deemed to be of great benefit. (App. p. 96.)

At the end of 1859 the neck of land at the peninsula had disappeared, and a navigable channel with from 7 to 8 feet of water had taken its place, and new formations of sand on either side appeared. (App. p. 98.)

In the report of 1860 it is stated that the western entrance having been dredged to 400 feet in width, and an average depth of 12 feet, both had been maintained; and that the island shoal had extended westwardly and threatened to encroach on the channel. The depth in the eastern channel was 6 feet. (App. p. 99.)

Capt. Richardson, in his report for 1861, refers to the opening at the eastern end of the harbour as having been the means of purifying the water in the harbour, and of contributing to the health of the city.

The island shoal had extended farther to the westward, and beyond the influence of the current deflected and guided by the Queen's Wharf, and the channel had been maintained at its width of 400 feet. (App. p. 100.)

Mr. S. Keefer, then Deputy Commissioner of Public Works, in reporting on a petition of the Council of the Corporation of the City of Toronto, that a survey of the harbour be made "with a view to ascertaining the cause of the dilapidations which have already taken place, and of devising some means of arresting their progress," refers to the reports of the gentlemen who had in previous years examined the harbour, and stated the results of his own examination, and advised that a careful survey should be made under the direction of an able hydraulic engineer, as "the subject requires to be treated both theoretically and practically, with a view to the satisfactory delineation of the causes which have operated in the formation, but are now apparently, directed to the destruction of the harbour; as well as devising some plan for directing them beneficially in future for its preservation and protection. The problem not being easy of solution should therefore be committed to the ablest hands."* (App. p. 101.)

*The date of this report should be 1862, instead of 1872, as printed.

No action was taken on this recommendation.

The Harbour Master, in his report for the year 1862, stated that a bar of sand had grown up inside of the eastern entrance over which the water was shallower than in the entrance itself. The "gap" or entrance had increased to half a mile in width, and the line of beach had so far receded that a boiler of a wrecked steamer which formerly was high and dry, was then 100 yards out in the lake and in deep water.

At the western entrance the island shoal had extended to .00 feet west of the then west end of the Queen's Wharf, and had advanced northwardly 40 feet. (App. p. 103.)

During 1863, following the suggestions of the Harbour Master, the Queen's Wharf was extended westwardly 200 feet, and, up to the end of 1863, a channel 400 feet in width, with a depth of 13 feet, had been secured.

The bar inside of the Eastern Gap had been thrown farther into the harbour, and had only 6 feet of water on it, thus limiting the passage to vessels of light draught. (App. p. 105.)

In his report for 1865, Captain Richardson stated that the Highlands of Scarborough, the source from which the materials composing the peninsula and island were derived, no longer existed, and therefore a wasting away of the latter was going on.

The western entrance maintained its width of 400 feet, and a depth varying from $11\frac{1}{2}$ to $14\frac{1}{2}$ feet, according to the height of the water in the lake. The island shoal still progressed westwardly, and during 31 years had increased in width 700 feet, or at the rate of 22 feet annually. (App. p. 107.)

Mr. Kivas Tully, Engineer to the Harbour Board, reported that during 1866, the western entrance remained at 400 feet in width, which was due to the extension of the Queen's Wharf westwardly (App. 108); and, in his report for 1867, again referred to the westerly increase of the island shoal, and stated that "the formation west of Lighthouse Point had increased during the last few years, and an additional tongue or arm" (now Hanlan's Point, see plan showing changes in the harbour during 1874, 1875 and 1879) "had formed, which trends in a northerly direction about 300 yards west of the island, making another bay; this formation no doubt will continue to increase." (App. p. 109.)

This tongue, or arm, now known as Hanlan's Point, has increased up to 1880 until it now extends northwardly beyond Gibraltar Point, and the shoal from it has been pushed forward yearly until in 1875 it had narrowed the western entrance to a width of 230 feet—see plan herewith.

In 1871 a report (App. p. 100 *et seq.*) was submitted to the Secretary of the Department of Public Works, by Mr. Wm. Kingsford, engineer in charge, who entered fully into the state and requirements of the harbour, and advised that the Parliamentary grant of \$20,000 should be expended in dredging, as "the present approach to Toronto by deep water necessitates an abrupt turn to enter the "Queen's Wharf Channel." In the improvement contemplated, easy entrance and egress should be secured;" and that "the increased navigation of the canal system of the Dominion points out that the entrance should ultimately be 16 feet deep."

Between 1st July, 1874, and 30th June, 1880, the sum of \$49,120.50 had been expended, principally in increasing the width and depth of the "Queen's Wharf Channel." Shortly after dredging was commenced it was found that, to obtain a depth of 16 feet at low water, it would be necessary to blast in solid ledge, and to a certain extent this was done. No attempt was made to straighten the abrupt turn, or

to render the channel any easier for entrance or exit, the object being the opening of a channel 300 feet in width with 16 feet of water on the old course.

On the plan of the western entrance herewith will be seen the encroachment of the point of the shoal northwardly, and the width of the navigable channel in 1863, 1875, 1879 and 1880.

A plan of the harbour is attached, showing its state in 1841 (?), and it may be compared with that showing the changes observed in the eastern and western entrances in the years 1874, 1875 and 1879.

At the Session of Parliament of 1880, the sum of \$12,500 was appropriated for expenditure in this harbour, part of that amount to be expended in dredging the western entrance, which in the spring of 1880, had been narrowed to 280 feet by the growth of the island shoal northward.

As the present entrance 'een pronounced to be abrupt, and it is known that to obtain a depth of 16 feet at low water would necessitate the removal of a large quantity of solid rock at a very great expense, it was judged that—as in former years the entrance was some 500 yards in width with deep water, a comparatively straight cut might be made through the point of the shoal, and a depth of 16 feet obtained without touching the rock. A line of easy entrance from 18 feet outside to the same depth inside was laid out, and a series of borings made showed that a depth of 17 feet below zero of the gauge on the Queen's Wharf could be had without the removal of any rock. This line is about 700 feet to the southward of the Queen's Wharf, and dredging operations have been commenced in the removal of the point of the shoal northward of this line. The material to be removed is fine sand.

It has been deemed desirable to include in the Appendix a letter by Mr. J. G. Worts, the Chairman of the Harbour Board (p. 115), and also the petitions to His Excellency the Governor General from the Mayor and Corporation of the City of Toronto, and the Harbour Commissioners, praying that steps be taken by the Federal Government to protect the harbour and preserve it for the future. (p. 117, *et seq.*)

As, throughout the whole of the reports published in the appendix, constant reference is made to the height of water in Lake Ontario, and the effects its variation periodically has had upon the changes which have taken place in the peninsula, now island, bounding the harbour on the south, and in the harbour itself, there has been attached an article from the "Canadian Journal," vol. 2, entitled "Variations in the Level of the Lakes," which may not be out of place in connection with the object of this memorandum. Through the courtesy of Mr. Kivas Tully, C.E., who as Harbour Engineer has an intimate acquaintance with the harbor, and who has many changes which have taken place during very many years, permission has been given to attach a copy of his paper on "The Fluctuations of Lake Ontario from the year 1854 to 1878," and of the chart prepared to accompany it. (App. p. 132.)

The writer believes that he has touched upon the salient points of the reports and documents which have been gathered and printed herewith. That it has been shown to us in early days, nearly 100 years ago, the width of the western entrance was nearly 500 yards; that on each successive examination this width was found to be gradually lessening; that through natural causes an opening was made through the peninsula at the eastern end of the harbour, and that a wide and comparatively shallow entrance now exists; and that for nearly half a century it has been the desire of those interested in the welfare of the harbour that steps should be taken to ensure its preservation for the future; that though many reports have been made and suggestions and estimates of cost submitted, none have been adopted nor acted upon, even in part; and the same forces of Nature which have acted through past years are still acting unchecked to the detriment and possible destruction of the finest harbour on Lake Ontario.

It may not be amiss here to state that the waters of the Don and the sewage from the city still empty into the harbour.

The questions have therefore arisen what course is to be pursued, what is to be done to preserve this harbour; and further is it necessary or desirable so to improve the eastern entrance as to maintain always a navigable depth of 16 feet; and to construct such works as may be required to restrain the encroachment of the Island shoal, and preserve the western entrance at such a width and depth as will give easy access and exit? On the proper solution of these questions depends the preservation of Toronto Harbour.

The writer has to acknowledge the assistance he has received from Mr. M. Baldwin, the Harbour Master, and Mr. Helliwell, the Deputy Harbour Master, in obtaining many of the reports published herewith; and his thanks are due to Mr. K. Tully, C. E., for his reports and paper on the lake levels.

Respectfully submitted,

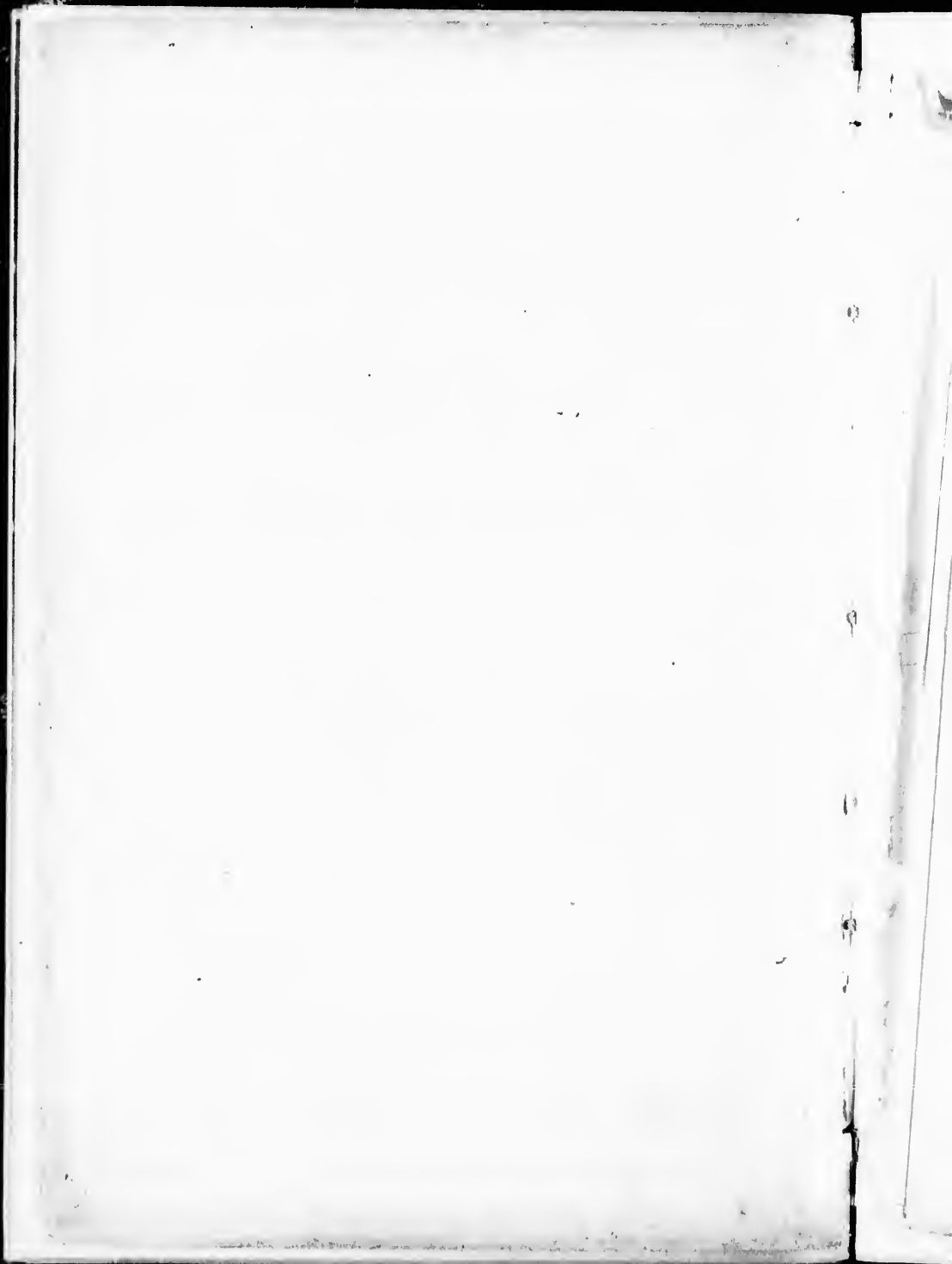
HENRY F. PERLEY,

Chief Engineer.

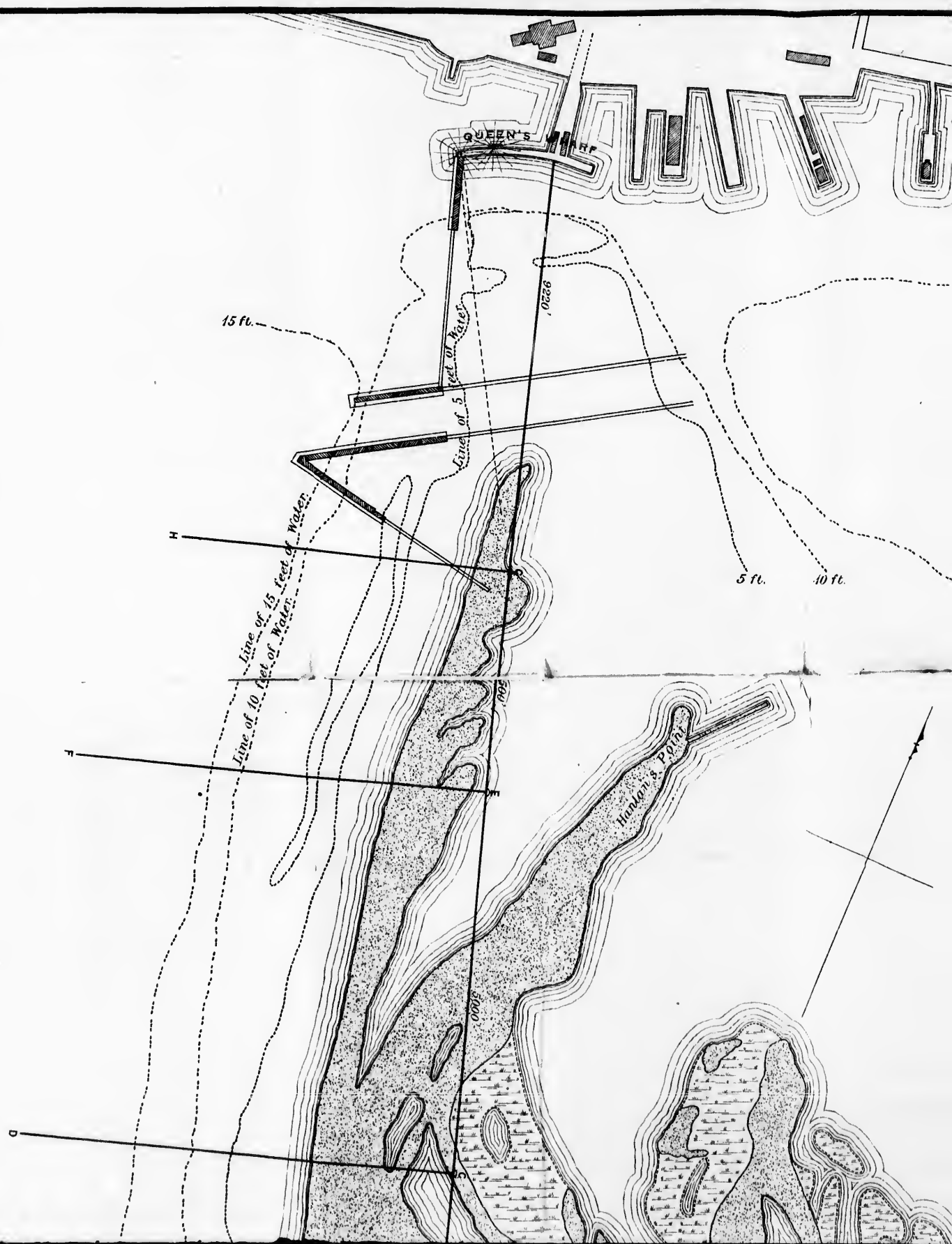
CHIEF ENGINEER'S OFFICE,

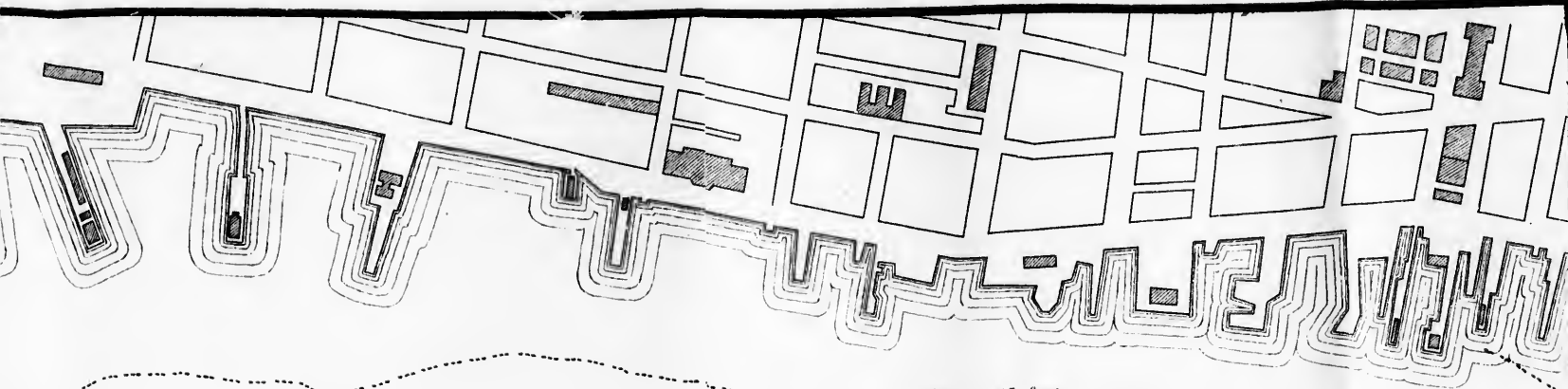
DEPARTMENT OF PUBLIC WORKS,

April 11th, 1881.

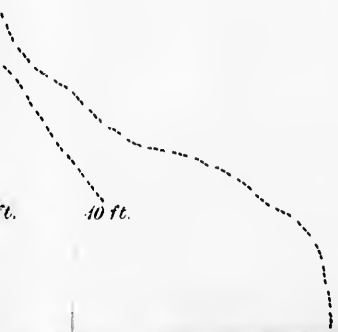




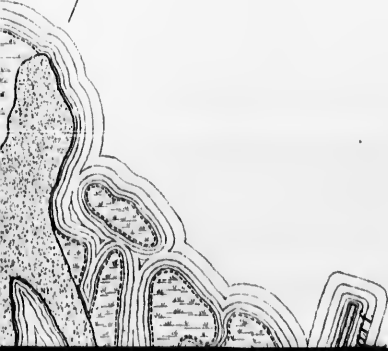


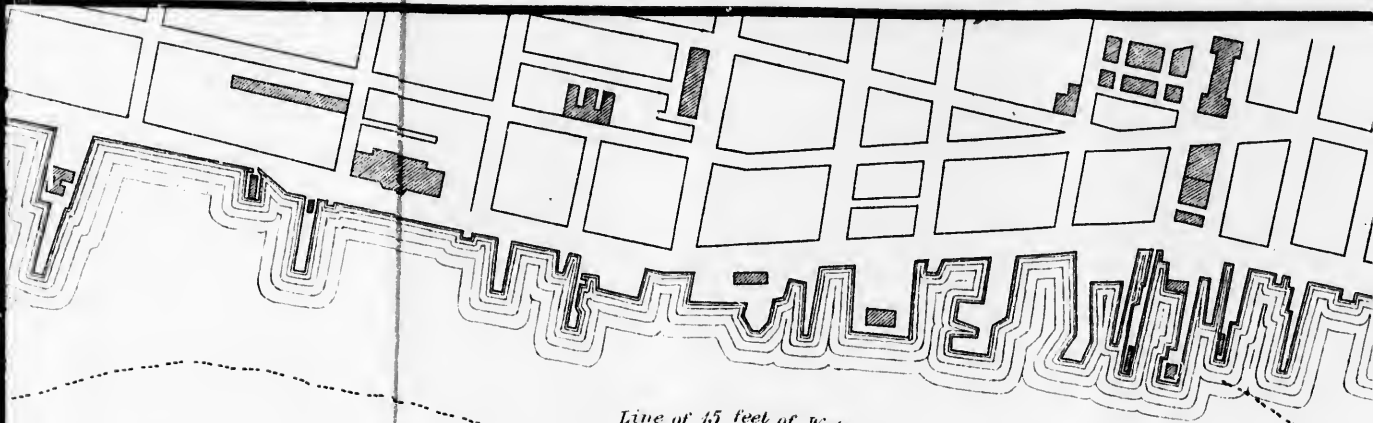


Line of 15 feet of Water.



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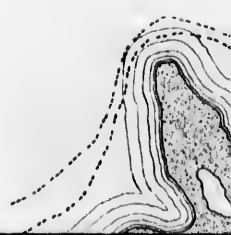


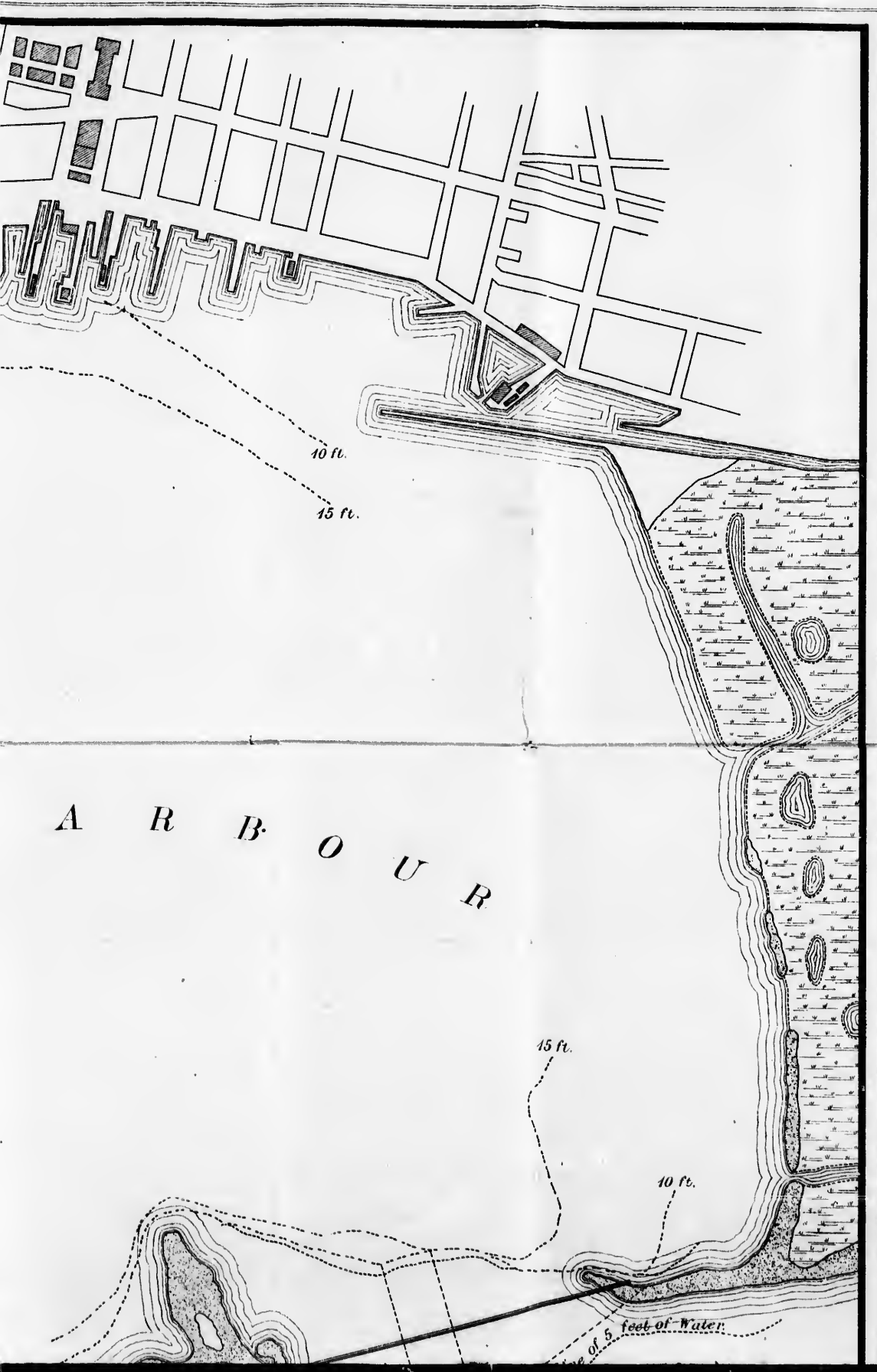


Line of 15 feet of Water.

T O R O N T O

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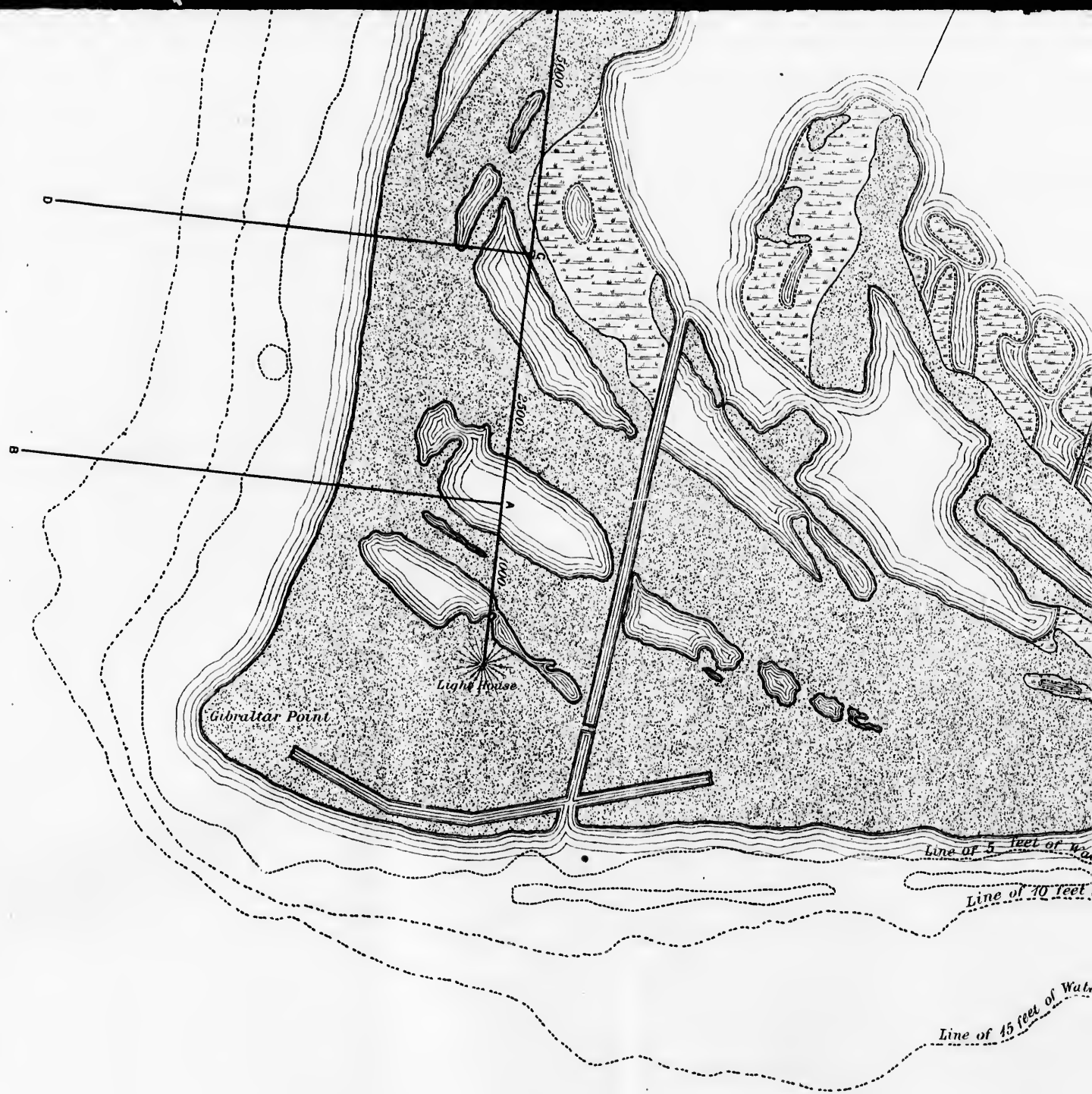
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15 ft.

15 ft.

10 ft.

of 5 feet of Water.

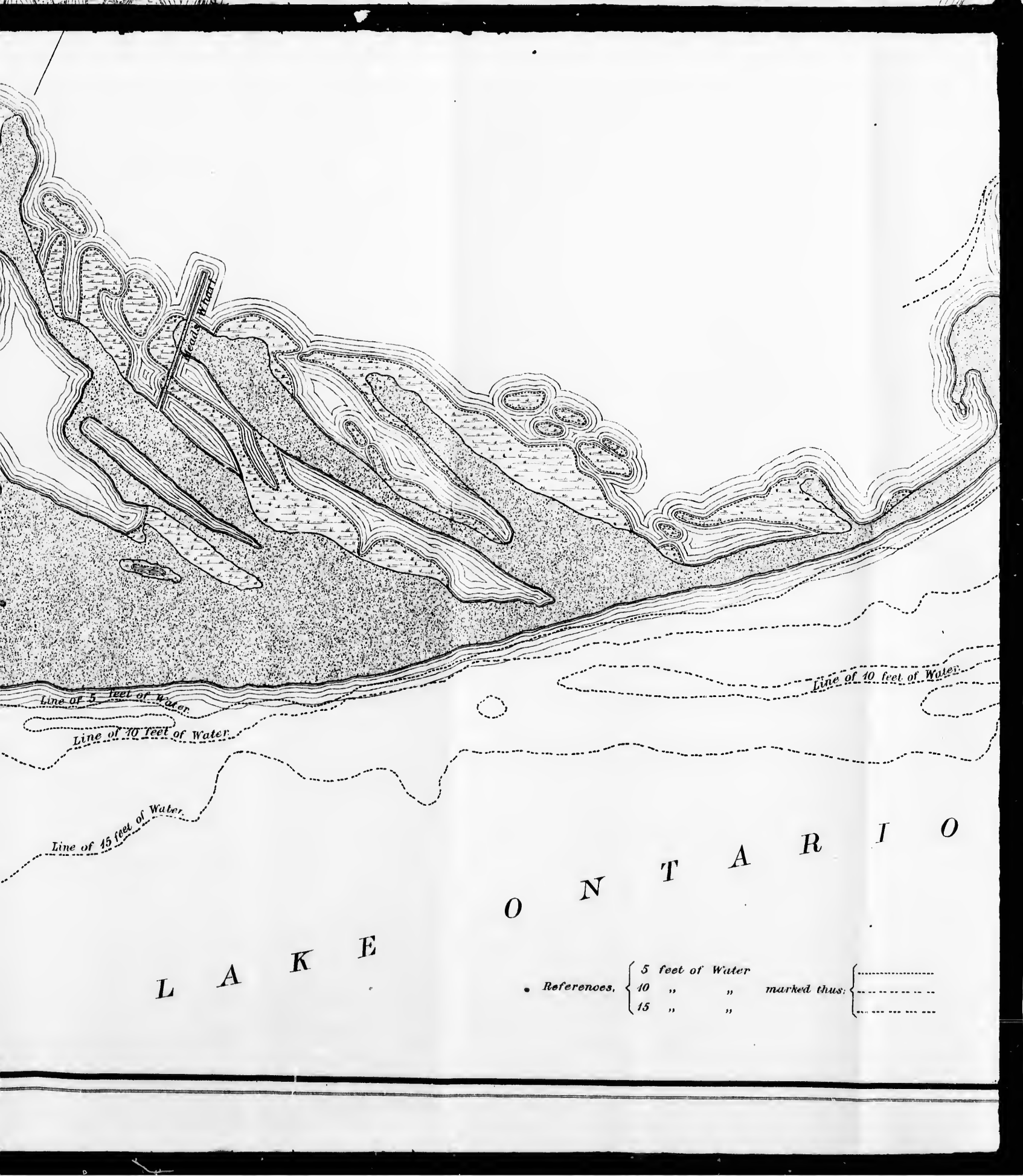


SCALE.



Scale 600 feet to one Inch.

L



Line of 5 feet of Water

Line of 10 Feet of Water

Line of 15 feet of Water

Line of 10 feet of Water

L A K E

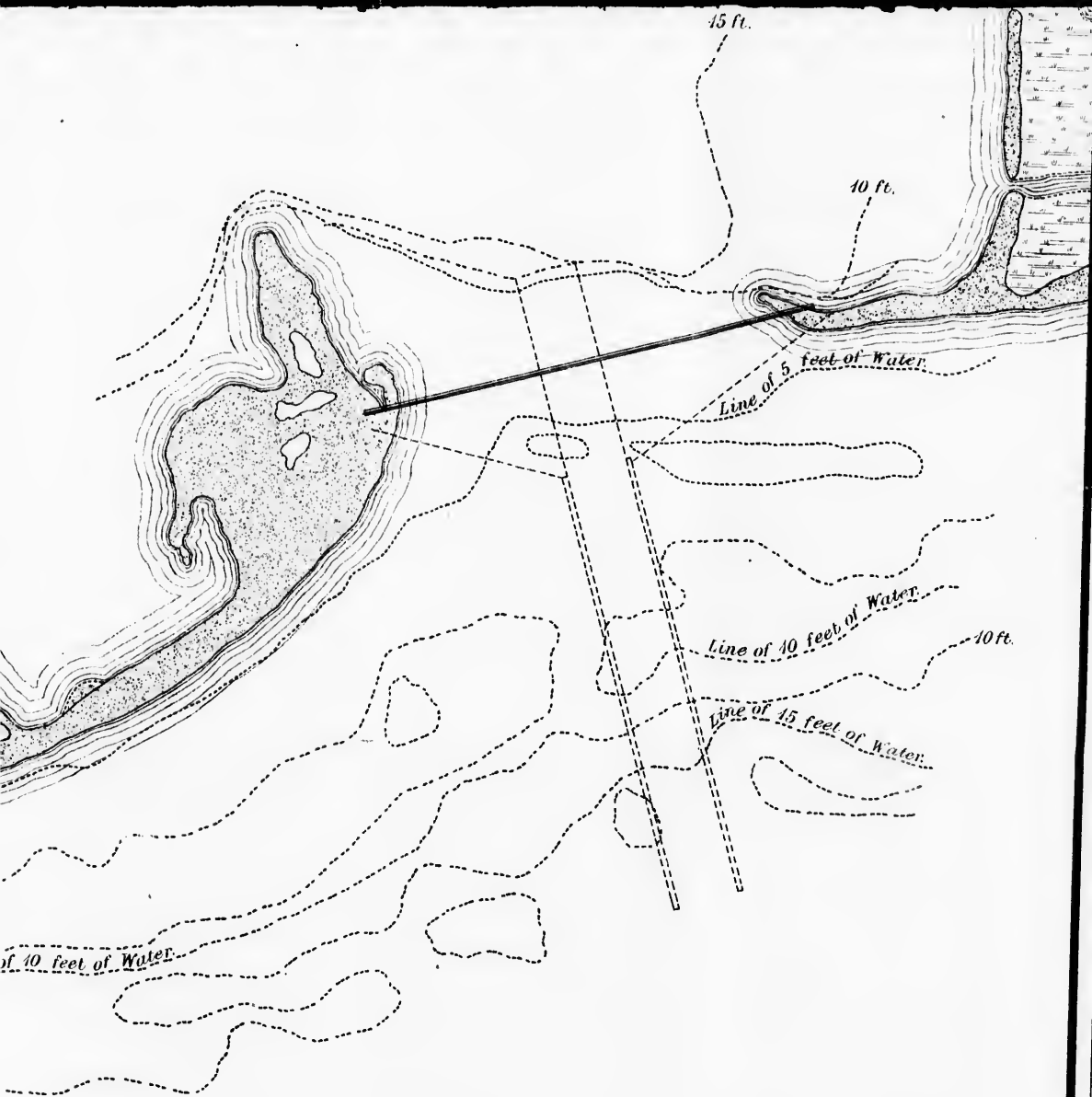
O N T A R I O

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A K E O N T A R I O

• References, { 5 feet of Water
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I O

Sketch Plan to accompany Report by

Geo. B. Eads, C.E.

St. Louis, Mo.

March 14th 1882.

A. Mortimer, lith. Ottawa.

