1880.

NEW ZEALAND.

THE HARBOURS OF NEW ZEALAND

(REPORTS ON, BY SIR JOHN COODE, C.E., TOGETHER WITH COPIES OF DRAWINGS).

Return to an Order of the Legislative Council, dated 10th August, 1880.

"That there be laid upon the table copies of all reports that have been received from Sir John Coode upon the harbours of New Zealand."—(*Hon. Mr. Waterhouse.*)

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*** *The drawings accompanying the Reports will be found at the end of this paper.*

THE BLUFF (CAMPBELLTOWN).

SIR,— 5, Westminster Chambers, London, S.W., August, 1879.

I have the honor to submit my report on the Bluff Harbour, accompanied by the following illustrative drawings:—

No. 1 is a general chart of the south-eastern portion of the Awarua or Bluff Estuary, showing the harbour and Campbelltown. Nos. 2 and 3 are detailed plans mainly compiled from the special survey prepared in accordance with instructions framed by me when in the colony: the former shows the works hereinafter recommended for immediate execution; the latter a complete scheme of harbour improvements, of which any works to be undertaken from time to time should form instalments or portions. No. 4 gives details of the mode of construction proposed to be adopted. No. 5 is a chart illustrating the system of leading lights, &c., to enable vessels to enter or leave the port after nightfall.

Geographical Position and Physical Features.

The geographical position of Bluff Harbour (when taken in connection with the area and depth of water in the estuary) is certainly such as to justify the prediction that it is destined to become, at any rate, one of the chief southern harbours of New Zealand. As regards the South Island it is the first port of arrival from—and the last port of departure to—Tasmania, Victoria, South Australia, and Europe; it is no farther distant from Sydney than Manukau, which may be regarded as the western water-gate of Auckland, or than New Plymouth, at the south-western extremity of the North Island; it is even nearer to Sydney than Wellington. Both as regards general commerce, and as a mail-packet station for the South Island, Bluff Harbour therefore possesses unusual advantages.

The area of the Awarua Estuary, in which this harbour is situated, is 21¼ square miles at high water; the quantity of tidal water passing in and out through the entrance at ordinary spring tides is no less than 104,250,000 tons. The entrance is unincumbered by any bar, and is so situated that its aspect is upon the "weather" shore. There are two channels leading into and out from the harbour; the principal of these runs nearly north and south, the other east and west.

At the time of my inspection last year there was no steam-tug in connection with the harbour, consequently sailing vessels were then dependent upon the tidal streams for their times of entry and departure; but, inasmuch as these currents run fairly true through the respective channels, no difficulty has been experienced during the hours of daylight. I understand, however, that arrangements are now in progress for obtaining a steam-tug for the service of the port. As regards the navigation by night, I shall hereinafter describe in detail the system of lights which I have to recommend for adoption.

I should here mention that on the western side of the entrance, north and south of Starling Point, and under the shelter of the promontory of "the Bluff," there is a large area of sheltered water having depths varying from 3 to 6 fathoms at low water, and good holding ground, which is admirably adapted for anchorage, and is found to be most useful in westerly and south-westerly winds: this is a very valuable adjunct to the harbour. I may further mention that, as pointed out by Captain Thomson, the Harbourmaster, vessels bound for this port may find perfect shelter, with smooth water and safe anchorage, between Saddle Point and Port William on the north-east coast of Stewart Island, the best anchorage being "abreast of the Murray River, from half a mile to a mile off the shore, in from 5 to 12 fathoms water."

Present and Prospective Trade.

The trade of the port has been steadily progressive: taking the eight years from 1871 to 1878, both inclusive, the returns for which are now before me, it appears that the imports have risen from £85,534 in the former year to £226,864 in the latter; the exports have advanced from the value of £154,590 in 1871 to £391,970 in 1878; the increase both in imports and exports having been at the average rate of from 20 to 25 per cent. per annum.

In view of its geographical position and great natural advantages as a port, coupled with the fact that it is, and must always continue to be, the southern terminus of the railway system of the South Island, Bluff Harbour would seem to be of necessity the permanent natural outlet and inlet for the sea-borne traffic of the southern portion of the Provincial District of Otago; and, as such, the progressive advance of its trade may be fairly anticipated to be at least as great in the future as it has been in the past, more especially when its undoubted natural advantages shall have been supplemented by artificial works of improvement.

Existing Works.

The existing works consist of a timber wharf about 800 feet in length, having a depth of about 20 feet alongside at low water of spring tides, and 28½ feet at high water. This wharf is generally parallel to the shore, and is connected therewith by a viaduct. The present railway-station abuts on the root of the wharf, and is joined to the berthage by branch lines.

It will be seen from the drawings that abreast of the town, and about 350 yards therefrom, there is a sandspit extending in an east and west direction, the eastern end of the spit being submerged, with depths over it of from 4 to 6 feet at low water of spring tides. Between the spit and the shore in front of the town there is a wide channel, through which the tidal water passes to and from the north-western part of the estuary. The depths in this channel are, speaking generally, from 14 to 21 feet at low water of spring tides. Northward of the spit there is a fine channel, having, along a portion of its length, a depth of about 40 feet at low water; through this channel by far the greatest part of the tidal water required to fill the estuary passes on its way to the northern and eastern reaches.

At the time of my inspection the plan described in Mr. Brunton's report of the 26th July, 1877, was placed before me. It consisted of an embankment of rubble-stone, extending in a straight line from the shore just above Suir Street to the north-western termination of the present wharf. The object of this embankment was to train the flowing and ebbing currents which pass through the channel between the town and the sandspit, so as to cut off the southern end of the latter, and thereby to create and maintain a waterway having a sufficient depth for navigation purposes. There is no doubt that the formation of an embankment of the character and in the position proposed, with the view of ultimately creating deep-water berthage, is sound in principle; but effectually to accomplish the object in view, it would be necessary, in conjunction with and parallel to such an embankment, to form a low training work on the north side, in order to prevent the southward growth of the sandspit into the fairway.

In the report to which I have referred, Mr. Brunton proposed to construct, in the first instance, a quay-wall 10 chains in length, measured from the western end of the present timber wharf. The space between the back of this quay-wall and the embankment was to have been filled up so as to form a wharf 60 feet in width. The estimated cost of this embankment, quay, and wharf was £40,381. Mr. Brunton appears to have regarded the works just described as the first instalment of a comprehensive scheme for dock accommodation. Obviously it is sound in principle to so frame the works to be undertaken in the first instance that they could, without modification, ultimately form portions of, and be engrafted upon, a complete scheme. To this extent, therefore, the proposal put forward is free from objection, but the general arrangement of the works as propounded is capable of great improvement in some highly important respects. I refer more particularly to the proposal to provide gates for the purpose of impounding the water, which, to be successfully carried out, could only be satisfactorily accomplished by an enormous expenditure, bearing in mind the great length of embankment on the estuary side which it would be necessary to render water-tight. The construction of costly impounding works to retain the water in the dock at the high-water level of the day is, in this case, quite unnecessary, seeing that the rise of tide at springs is only 8 feet 6 inches; and also that no "scend," or wave undulation, could enter within the enclosed area to cause inconvenience. This being so, I have (as will be observed from the accompanying drawings) adopted the principle of ultimate floating basin accommodation without gates, as distinguished from wet docks with gates.

Another point in respect of which the proposal referred to me is capable of material improvement is that of the width of the enclosed water-space, which, in view of the rapid increase in the length of modern steamships, ought not, in my opinion, to be less than 600 feet. Instances have come under my observation in which much inconvenience has been experienced from deficiency of width. In framing works of improvement for a port like the Bluff, which is evidently yet in its infancy, special care should be taken to make adequate provision for the requirements which are certain to arise in due course.

I do not consider it necessary to enter further upon the details of construction proposed by Mr. Brunton, than to say that I am unable to approve of the suggested system of walls, founded at the foot of the bank, which, having regard to the character of the bottom, is not the best mode of construction to adopt.

Works Recommended for Execution forthwith.

The works I have to recommmend for construction are shown by red colour on Drawings 1, 2, and 3 respectively; the extent and general character of those to be undertaken forthwith being indicated on Drawing No. 2; whilst the complete scheme for harbour improvements, of which the works to be carried out from time to time should form portions, is shown on Drawing No. 3.

Upon referring to Drawing No. 2, and the sheet of details, Drawing No. 4, it will be seen that I propose to form a training embankment of rubble stone practically upon the same line as suggested

by Mr. Brunton and Captain Thomson, but stopping short at a point 450 feet westward of the outer end of the present wharf. Northward of this embankment, and parallel thereto, a half-tide bank, also of rubble stone, would be deposited from barges, so as to form with the southern embankment a channel or waterway having an uniform width of 250 feet at low-water mark. The half-tide bank would be provided with four beacons, fixed in the positions shown, and the southern embankment would be furnished with "turn-outs" for the wagons to pass, and thus facilitate tipping operations. The ebb and flood currents, when trained between the artificial works described, and caused to pass permanently over a fixed and definite track, may be relied on for the preservation of a depth of at least 22 feet at low water in the centre of the fair-way, and to create and preserve a corresponding deep-water approach across the toe of the spit or shoal at the east end of the proposed channel.

In connection with the southern embankment I would recommend the construction of a wharf of 1,000 feet in length, extending westwards from the eastern end of the bank, and parallel thereto throughout its entire length. This new wharf may be formed either with a facing of open piling, properly braced, and supporting a timber deck, in the manner shown on Figures 6 and 7, Drawing No. 4; or it may be a permanent wall of Portland-cement concrete, the under-water portions of which would consist of cylinders or rings of concrete placed one over the other, and sunk to an adequate depth below the bed of the channel. The cylinders when sunk would be filled up solid with cement concrete, and capped with a wall of concrete-in-mass, in the manner shown on Figure 11, Drawing No. 4. The concrete face would be permanent, whereas the timber would require renewal and repairs. The cost of the former is, however, considerably in excess of the latter, and in framing my estimate I have considered it desirable to give the price of each system, so that the decision as to which, under the circumstances, will be the preferable section to adopt, may be arrived at in the colony, seeing that the question for consideration resolves itself into one of first cost as compared with future expenditure on renewals and repairs. Should it appear desirable to adopt the timber wharf in the first instance, there is no reason why the permanent facing of cylinders could not be added at any time thereafter, when the piling may require renewal; indeed, I have assumed this mode of procedure on the section Figure 11, whereon the timber wharf to be constructed forthwith is indicated by dotted lines, whilst the permanent face of concrete is shown by full lines and colour. A convenient approach to the proposed wharf would be formed in the manner shown on the plan, viz., by embankment roots connected with an open timber viaduct of sufficient length to admit of the filling and emptying of the inner enclosure during each tide. Full details of this viaduct are given on Figures 4 and 5, Drawing No. 4.

As will be seen from the plan, the new wharf would be in direct communication with the existing system of railways, the curves adopted being sufficient for the passage of the rolling-stock without entailing the use of turntables or traverses.

At the western end of the training embankment, and in connection with the new channel, I have shown a patent slip of sufficient length for dealing with vessels of a very large class. The estimate provides for a slip adapted for taking up ships of 2,000 tons weight, and for machinery of the best type. It also includes the reclamation of a sufficient area to form a work-yard in connection with the slip.

Proposed Leading Lights.

Drawing No. 5 shows the system of leading lights which I have to recommend for adoption. It contemplates the provision of three lighthouse buildings, each fitted with an apparatus of the character described. The principle upon which the system is based is the exhibition throughout the fairway of the channel, and following its main curves, of a bright white light extending over an arc of 2 degrees, flanked on either side by a green and red arc respectively of about $7\frac{1}{2}$ degrees. In conformity with this arrangement the officers in charge of a vessel entering or leaving the harbour after nightfall would endeavour, as far as practicable, to keep a course on the white light, the fact of the red or green being visible, and not the white, serving as an indication whether the ship was on the port or starboard side of the white beam intended to indicate the centre of the fairway. For facilitating the identification of the main leading light, and to prevent its being mistaken by the mariner for that on Te Waewae Point, I propose that the apparatus should in this case be fitted with occulting gear, so as to show eclipses of the light, say, at every ten seconds, thereby rendering it easily discernible from the other and adjoining station light, and also from side-lights of vessels. The brilliancy of the two inner lights would prevent them being mistaken for the side-lights of ships after reaching the point where it becomes necessary to rely upon them for navigation purposes. For use in the daytime a beacon in line with the tower containing the main light would indicate the centre of the fairway southward of Starling Point.

It is not practicable, without considerable extra cost, to provide for lighting the east passage; but, when erecting the principal building to contain the occulting apparatus, arrangements would be made for the addition, when required hereafter, of a special light to be visible along this channel, and thus to enable mariners to approach within a safe distance of Te Waewae Rock.

Prospective Works.

Acting upon the principle to which I have already referred, I have laid down upon Drawings Nos. 1 and 3 a complete design for harbour improvements at the Bluff, of which the works I have recommended are intended to form the first instalment only. Any subsequent additions to the accommodation required from time to time should form portions of this complete scheme, so that modifications or the removal of executed works may not be required hereafter as the necessity arises for increased quayage and wharfage space. The design shown embraces two floating basins of $23\frac{1}{2}$ and 13 acres respectively, with centre wharf, swing-bridge spanning the opening between the two basins, sheds, bonded and other warehouses, a graving dock, and a complete system of railways. In view of the prospective character of these comprehensive works, I have not considered it necessary to enter upon their cost, although I am decidedly of opinion that at a future date the great facilities for trade which would be afforded by this design, when fully carried out, will not be more than will be required to meet the wants of the port.

Before, however, a final decision is arrived at by the Harbour Board with regard to the adoption of this design in its entirety, it is highly important that the site embraced by the complete system of works should be carefully bored, in order to remove all doubt as to the character of the bottom, and the presence, or otherwise, of rock above the depths described on the plan as those to be formed within the new basins. When in the colony I requested that a series of borings should be taken, but these have only been furnished to a very limited extent. Whilst, therefore, the probabilities are that no rock will be met with above the depths indicated, I am unable, with the data now available, to give a positive opinion on the point. To what extent, if at all, the design might require modification can only be determined after the borings have been made. There can, however, be no doubt or question as to the propriety of adhering to the first instalment of the works laid down upon Drawing No. 2.

Estimates.

	£
1. Rubble training-bank on south side of proposed channel, extending from north end of Suir Street to within 450 feet of the west end of the existing wharf; also timber viaduct with embankments at each end of same to form approach from Gore Street, together with the requisite railways to connect with the present colonial system ...	69,320
2. Half-tide training-bank, formed of rubble stone, deposited from barges, on north side of proposed channel	10,300
3. Wharf of timber, 1,000 feet in length, on south side of channel, and at east end of training-bank, including dry rubble wall and *débris* filling, to form additional width of roadway between wharf and training-bank, as shown by Figures 6 and 7, Drawing No. 4.	27,000
Estimated cost of training-bank, wharf, and approaches ...	£106,620
4. Patent Slip.—The requisite ironwork and machinery for the slip, delivered in the colony	9,000
5. Formation of foundations of piles and concrete cylinders, together with reclamation of site, forming pitched slopes, wharfing grid, engine-house, &c., together with the erection and fixing of the ironwork and machinery referred to in item No 4. ...	37,000
Total for patent slip	£46,000
6. For three leading lights and one port light, as described on Drawing No. 5, with houses and apparatus complete	£2,100
7. Permanent wharf of concrete.—If it should be decided to provide a permanent face of concrete to the proposed wharf in the channel, of the character shown on the left-hand side of the view Fig 11, Drawing No. 4, in lieu of the timber-work, then add to item No. 3, as above, for the concrete face and *débris* filling, and for the formation of a road surface as shown	£35,830

The foregoing estimates include a fair allowance for contingencies and supervision, as well as for the provision of plant. The quantities of work of the respective kinds have been computed from the detailed views shown on Drawing No. 4, and the rates at which the quantities thus arrived at have been moneyed out are based upon the local prices of labour and materials furnished from the colony. The mode of construction contemplated in each case is certainly not extravagant, and the works proposed—if carried out as recommended—would be found well adapted to meet the requirements of the case; and I am decidedly of opinion that less substantial structures would give rise to constant anxiety and expense. Whilst, therefore, I can say with confidence that the works suggested are neither stronger nor more substantial than experience has shown to be necessary, it is my duty to point out that the rates furnished to me (upon which as I have stated, the estimates have been based) are such as to render it not improbable that the works could be executed for a less total sum than hereinbefore stated.

It may not be out of place to remark upon what might possibly be regarded as a disproportion between the cost of the ironwork and machinery (item No. 4 in the estimate) and the amount given as the probable cost of the slip foundations with the requisite adjunct works (item No. 5). The large expenditure upon the latter arises from the nature and great quantity of the work to be executed, in order to produce a satisfactory slip, having regard to the conditions of the site. Notwithstanding the outlay required, I feel convinced that the site selected, all things considered, is the best that can be adopted, and that no saving would be effected by resorting to any other position.

New Railway-Station.

On the plans I have indicated the site for a new railway-passenger station at the west end of the town, which will inevitably be required hereafter. I have ventured to refer to the subject, and to define what in my view is the best location for such a new station, seeing that the existing arrangements, involving as it does the running of passenger trains along the entire length of the town, and between it and the proposed works, is very objectionable, and will entail inconveniences which will be more and more felt as trade developes and the town increases.

In conclusion, I have to express my obligations to Mr. Mitchell, the Chairman of the Harbour Board; Mr. Brunton, Engineer; Captain Thomson, Harbourmaster; and Mr. Serle, Secretary; each and all of whom facilitated, in every possible way, my inspection of the harbour and the surrounding locality. Here, as at the other ports visited, Mr. Blackett, Marine Engineer to the Government, greatly aided me in my inquiry and investigation.

I have, &c.,

JOHN COODE.

The Secretary, Marine Department, Wellington.

GREYMOUTH HARBOUR.

SIR,— 5, Westminster Chambers, London, S.W., December, 1879.

I have now the honor to submit my report on the improvement of the entrance and tidal compartment of the Grey River, together with three drawings which I have had prepared for the complete elucidation of the subject, and for the purpose of conveying my views thereon.

Drawing No. 1 is a plan of the river extending from the sea to a point 2½ miles above Cobden Gorge. The works I have to recommend for execution are shown by red colour on this plan; they will be hereinafter more particularly described. The survey which forms the groundwork of this drawing, together with the observations on the range of tides, and the heights of floods, &c., hereinafter adverted to, and used by me in the study of the whole matter, were made under the direction of Mr. O'Connor, C.E., District Engineer.

Drawing No. 2 contains the western portion of Drawing No. 1, and is intended to show the relative extent, position, and direction of the works proposed by Mr. Moriarty, C.E., in 1874, together with the modifications and additions subsequently projected by Mr. Carruthers, C.E., as compared with the works which I have now to recommend for adoption, and shall presently describe.

Drawing No. 3 shows the details of the training banks and breakwater on each side of the river and entrance. These also will be fully described hereinafter.

Physical Features.

Watershed and Rainfall.—The River Grey (or Mawhera) has its sources in the mountainous region which forms the extreme southern and western portion of the Provincial District of Nelson, and, like the other rivers in this part of New Zealand, is subject to violent floods. According to a tabular statement kindly furnished to me by Dr. Hector, the average rainfall of the Grey River and its tributaries is 90 inches per annum, or 25 per cent less than that of Hokitika; but, on the other hand, the area of the watershed of the Grey (1,572 square miles) is rather more than four times greater than that of the Hokitika River.

Floods in the Grey.—In times of exceptional floods the water-surface in the estuary of the Grey is about 14 feet 6 inches higher than under the normal condition at high water at the mouth of the Omotomotu Creek, which point is the head of the tidal compartment. The difference in the levels of the water-surface, as observed at the sea entrance between the same two conditions, normally and in time of flood, is about 4½ feet. The average gradient or fall of the water from the Cobden Gorge to the sea in time of exceptional land floods is at the rate of 72 inches to the mile.

Tides.—The range of tide at ordinary springs may be taken as 8 feet at the sea entrance and 6 feet at Cobden Gorge, the tidal range being about 8 inches at the mouth of the Omotomotu Creek at ordinary springs; although on the occurence of exceptionally high tides the lift at the Omotomotu has been known to amount to about 12 inches. When the river is in a normal condition—*i.e.*, in the absence of land floods or freshes—the gradient or fall in the water-surface from Cobden Gorge to the sea is 22 inches to the mile at the time of low water of spring tides, and 1 inch to the mile at high water of the same tides. In Erua Moana, or Revell's Lagoon, and in the Karoro Lake, which lie on the southern side of the river channel, and are connected therewith immediately to the westward of the Town of Greymouth, the ranges of tide, as observed by my request, have been ascertained to be as follows, viz.:—

	Springs. Ft.	in.	Neaps. Ft.	in.
Revell's Lagoon,—				
At entrance north end of Martin's Quay ...	8	3	5	3
South end of lagoon	6	2	3	7
Karoro Lake—				
At bridge, end of Arney Street	4	3	2	0
At south end of lake	4	3	1	10

Shingle Deposits in Tidal Compartment of River and at Entrance.—Having a watershed of nearly 1,600 square miles, the north-western portion of which attains an elevation of from 4,000 to 6,500 feet above the sea, and, being subject to flooding to such an extent as to raise the water-level nearly 15 feet, it will be readily understood that the River Grey brings down from the higher districts large quantities of shingle, gravel, and other detritus, portions of which are deposited, in the first instance, within the upper reaches of the tidal compartment, to be subsequently carried down towards the entrance. Arriving there, and coming within the influence of the sea waves, they are heaped up in the form of spits or banks, and are ultimately transported to the northward by the preponderating force of the seas coming in from the south on this part of the coast; meanwhile, however, these shingle-spits are subject to considerable changes, often seriously encumbering the outfall channel of the river; they render the navigation frequently difficult and sometimes dangerous. The evil just described is greatly aggravated by the large quantities of sand, shingle, &c., travelling along the coast from the southward.

The freedom of the navigation immediately within the entrance was impeded at the time of my inspection by the existence of a submerged shoal (the rippling over which attracted my special notice just below or seaward of the junction between the currents from the lagoons with those in the main river. Captain Allardyce, the Harbourmaster, mentioned to me that freshes have little or no effect upon this shoal, which is no more than might be expected under the present conditions. Changing its form from time to time, and occasionally projecting somewhat into the main channel, it then becomes a source of danger to vessels entering and leaving the port. I may mention that at the time of my leaving Greymouth in the steam-tug "Dispatch" to join the "Hinemoa," outside the bar, this shoal had encroached upon the line of channel, and the "Dispatch" touched very sensibly upon it.

Heaviest Seas, Gales, &c.—The heaviest seas at the entrance occur with gales ranging between S.W. and W.S.W. Captain Allardyce stated that seas coming directly from the westward are of very rare occurrence; that N.W. winds seldom or ever last more than twenty-four hours, and that these, as

a rule, soon fly round to the S.W., and expend their force from that quarter. From the configuration of the coast it is evident that Point Elizabeth affords protection to the northward of N.W., which is certainly an advantage to the Grey entrance.

Works Previously Proposed.—As hereinbefore stated, the works proposed by Mr. Moriarty, C.E., and by Mr. Carruthers, C.E., are shown upon the accompanying drawing No. 2; the former are tinted brown, and the latter green. By reference to this drawing it will be seen that Mr. Moriarty proposed an internal training wall, commencing at a point opposite to the north end of Johnstone Street and curving around towards the N.W. for a length of 3,300 feet; he also proposed a breakwater, extending thence outwards for a further distance of 2,100 feet in the same line, bringing the head of the breakwater into 12 feet at low water; this head, he suggested, should be turned outwards in a more westerly direction than the body of the work, "so as to present less resistance to the breaking waves, which will roll in on its end, and thus diminish the danger of its being washed down across the channel." The cost of these works was estimated by Mr. Moriarty at £94,998, say £95,000. He considered that after they had been in operation some few years an available depth for navigation of about 15 or 16 feet at high water neaps on the bar, and in the channel leading to the wharves, might be confidently looked for. Mr. Moriarty did not propose in the first instance to carry out any works on the north side either of the river channel or of the entrance, as he considered they might not be required at all; but if they were, that it would be better to defer them until the effect of those on the south side had been seen, and the river allowed to establish its regimé under the altered conditions resulting from the construction of the southern breakwater.

The foregoing particulars have been obtained from Mr. Moriarty's lucid and comprehensive report of 1874, and the plan which accompanied it. I have not seen any report by Mr. Carruthers on the subject, but, from a plan furnished to me when in the colony, I gather that, as shown on drawing No. 2, the works that he proposed on the south side of the Grey were intended to follow practically the same line as that laid down by Mr. Moriarty; the essential difference in the two proposals being that Mr. Carruthers adopted, as an integral paat of his scheme, a northern training-wall all the way down from Cobden Gorge nearly to the line of high water on the sea margin.

Works Recommended for Present Execution.

Having described the physical features of the river, more especially of its tidal compartment, and of the entrance, together with the proposals which have been made for their improvement, I now come to the works which, after a careful consideration of all the circumstances of the case, I have to recommend for execution:—

South Training Bank.—When at Greymouth I placed in the hands of Mr. Blackett a memorandum, intimating my opinion that the lower end of the training bank below Johnstone Street (at that time opposite Arney Street, *E* on the drawing No. 1) should be joined to the other end, *F*, of the spur bank then in progress just above the lagoon entrance, upon a line which I then indicated; I presume, therefore, that the training bank eastward of the lagoon entrance will have been completed before this report reaches the colony.

South Breakwater.—As will be seen by reference to Drawing No. 1 (as also No. 2), I propose that a training mound, 1,800 feet long, should be formed of heavy rubble stone. This work would commence near the west end of the timber bridge over the lagoon entrance, *A* on the Drawing No. 1, and run out in a west-north-westerly direction to the middle of the long tongue of shingle and sand which existed on the south side of the entrance at the time the special survey was made. Thus far the materials would be deposited by means of "end-tip" and "side-tip" wagons, in the ordinary manner, as shown in Figure 9 and Drawing No. 3; but seaward of this point the works would partake of the character of a *pierre-purdue* breakwater, running in the same direction for a length of 1,200 feet. The materials for this work would consist, for the most part, of the largest and heaviest of the blocks which can be procured from the limestone quarries eastward of the town, on the south side of the river, the stone being conveyed along the existing railway to the lagoon entrance, over which it would be carried by a temporary timber viaduct, for which provision has been made in the estimate. The whole of the stone should be deposited from a timber staging, as shown on Figure 11 (details of this staging are given in Figures 12 and 13), and so regulated that the large blocks shall be intermixed with not more than a sufficient proportion of stone of smaller sizes, thus attaining the greatest amount of solidity by having as few interstices as possible. Care should be taken that the largest blocks are deposited, as a rule, from the southern line of railway. The slopes on the outer extremity of this work would be protected by concrete blocks as indicated on the drawing, and a light would be placed there for the guidance of mariners at night.

North Breakwater.—Commencing on the beach above the high-water line, at the point *C* on Drawing No. 1, there would be a northern breakwater, the inner portion of which would run out in a west-by-south direction for a length of 900 feet, 650 feet of which would be formed as a rubble end-tip—see Figure 6, Drawing No. 3. The remainder of this breakwater (630 feet) would be rubble deposited from a staging, as on Figure 7, and in the same manner as the outermost part of the corresponding work on the south side, excepting that, in this, as in the case of the north training bank, the top should terminate at the level of high water of neap tides.

North Training Bank.—The works on the north side within the entrance would consist of a training bank 1,670 feet in length (*G* to *H*, Drawing No. 1), formed in the same manner as, and generally similar in character to, that on the south side eastward of the lagoon entrance, excepting that the materials in this northern training bank should be somewhat heavier, and the top of the bank should terminate at high-water of neap tides, as shown in Figures 3 and 4, Drawing No. 3.

The stone for the north breakwater and the training bank will be obtained from the quarry at Cobden Gorge, and conveyed therefrom to the site of each of these works over a temporary line of railway laid along the shingle-banks on the north side of the river. The best and largest of the material should be appropriated to the breakwater. Due allowance has also been made in the estimate for this temporary railway.

Order of Procedure.—The structural works should be proceeded with in the following order: The training mound and breakwater on the south side will be first undertaken, and carried on uninterruptedly until arriving at a point abreast of the low-water line of the sea-beach on the north side of the entrance; thereafter, the north and south breakwaters should proceed simultaneously, the latter being always kept somewhat in advance of the former. Concurrently with the commencement of the north breakwater, the north training wall should be begun at its eastern end, the tip-head being kept well in the rear of the outer works, in order to economize material.

Dredging.—The northern side of the channel, from opposite the lagoon entrance to abreast of Johnstone Street, should be dredged, so as to give a depth of not less than 9 feet at low water of spring tides over the area crossed by red lines, in so far as the same may not be scoured by the action of the tidal currents and flood waters. In the estimate hereinafter given, it is assumed that all the materials down to a depth of 9 feet below low water may have to be dredged, although it is very probable that no inconsiderable portion will be removed by the improved scour derived from the action of the two training banks.

The entire area to be filled in with dredgings at the back of the south training bank, eastward of the lagoon entrance, should be reserved as standage ground for railway wagons. I apprehend the time is not far distant when the whole of it will be required for that purpose.

When the development of the coal mines of the Grey Valley shall have increased to such an extent as to call for further accommodation of this kind, the area (indicated by red sprinkling on Drawings Nos. 1 and 2) southward of the inner end or root of the south breakwater, and seaward of the blocks marked as "Packers' Quay," should be used for the same purpose. This area will be filled up by accretion as the breakwater advances, and should be scrupulously reserved for standage ground. This appropriation will of course necessitate the construction of a permanent swing-bridge across the lagoon channel, but the structure need only be of a simple and inexpensive character.

Principles of Design Recommended.—With regard to the principles by which I have been guided in designing the works now recommended, I may say that, in dealing with a case such as that now under consideration, the amount of protection to be afforded against the heaviest seas is not the only point to be considered; a matter of at least equal importance is the direction best adapted for creating and maintaining the greatest depth of water in the entrance. Experience has satisfied me (and theory supports the conclusion) that this latter object can be best accomplished by so training and guiding the passage of the currents of tidal and fresh waters, and more especially the outgoing streams, as to cause them to impinge as directly as possible upon the seas which act most effectively, and therefore most injuriously, in heaping up sand upon the coast. It does not necessarily follow, as is frequently assumed—indeed, it may be regarded as the exception rather than the rule—that the direction of the breakers or surf falling in any part of the coast will be absolutely identical with that of the heaviest seas in the offing. It is only by carefully considering the circumstances and conditions of each particular case in all its bearings, and with all its local surroundings, that a safe conclusion can be arrived at.

Feeling assured, as I do, that the direction of the entrance works, as proposed both by Mr. Moriarty and Mr. Carruthers, would not secure the best results, I have adopted a more southerly direction as the best for securing the object in view. I should here remark that whatever may happen to be the position of the entrance channel, or the form of the sand-banks at the time when the lines for the new works are marked out for execution—and it may almost be said that both the position of the channel and form and extent of the banks are about "as uncertain as the winds that blow"—I would, nevertheless, advise that the lines I have laid down be virtually adhered to, for the new channel will inevitably follow the line of the works as they proceed.

It would be well, when the breakwaters advance beyond the shore-line, that frequent and careful observations be made therefrom by the officer in charge of the works on those occasions when the sea may be breaking in depths of from 2 to 3 fathoms at low water, so that a full record may be kept, and registered in such a manner as to be available for reference in determining, when the proper time arrives, whether any slight modification can advantageously be made in the direction of the outermost part of the breakwaters, and the precise extent of their overlap. I feel well assured, however, that such change, if any, will not be material. It is also possible that the width of 400 feet at low water may, in some small degree, be varied with advantage. Experience alone can determine with precision this, as well as the other points just named, but the width laid down on the drawing has been arrived at after calculation and careful consideration based upon the data available for the purpose.

It will be seen that I have projected the outer end of the north training bank somewhat beyond the shore-line, and that the breakwater on the northern side of the entrance is laid off at a different angle to that on the southern side. This has been done advisedly, and with the special object of forming a wave-trap, in which the greater part of any undulation that may pass in between the breakwaters will be expended upon the slope of the beach between the seaward termination of the north training wall and the root of the north breakwater.

Moreover, the north breakwater being kept down to the level of high water of neap tides, as hereinbefore described—the south breakwater it must be remembered being well above high water of the highest tides—the seas in heavy gales from about west south-west will overtop the work, and thus expend their force without causing an inconvenient amount of disturbance within. The comparatively low level of the top of the north training bank will act in the same manner, if in extreme cases any undulation should pass in beyond its outer end. I would further remark that the lines of the new works near the lagoon entrance have been so arranged that they will not only give the best results as regards the easy confluence of the outgoing currents from the lagoons with those of the main channel, but their form is such that they will serve as an additional wave-trap on the south side, and that at the same time their effect will be such that the submerged shoal, previously adverted to as prejudicial and sometimes dangerous to the navigation, will be removed by the additional scour that will be created under the new conditions; more especially when the channel leading into the lagoon shall have been dredged to the extent hereinbefore recommended.

High water of neap tides has been adopted as the level of the top both of the north training bank and the outer portion of the north breakwater for the purpose of utilizing the scouring forces both of the tidal and fresh waters to the greatest possible extent compatible with the avoidance of gorging during times of excessive floods. The half-tide training bank, laid down on Drawing No. 1, for future construction near Cobden Gorge and the mouth of the Coal Creek, should all be formed at the same relative level—viz., half-tide at this section of the river.

Estimate of Cost of Works now Recommended.

	£	s.	d.
1. Training mound and south breakwater, 3,000 feet in length, formed of rubble stone, and protected at the seaward termination by concrete blocks built *in situ*, including staging for the outer portion of the breakwater, and railway to connect with the existing system at the western termination of the southern training bank already executed; also a viaduct of open timber piling across the entrance to the lagoon	105,120	0	0
2. North breakwater, 1,280 feet in length, formed of rubble stone, including provision of staging for the outer portion of the work, and a temporary railway from Cobden Gorge Quarry, over which the materials for the breakwater would be conveyed	40,530	0	0
3. North training-bank of rubble stone, 1,670 feet in length	8,060	0	0
4. Dredging shingle-bank on the north side of channel, from opposite the lagoon's entrance to abreast of Johnstone Street, and depositing the surplus materials at the back of the south training bank over the area crossed by red lines on the plans	8,330	0	0
Gross estimated cost of works recommended for construction ...	£162,040	0	0

The foregoing amounts include a fair allowance for plant, contingencies, and supervision, and are based upon the local rates of materials and labour furnished with the other data from the colony. Item No. 4 provides for the working charges only of a dredger, and not for interest on the first cost of the machine. In considering the gross estimated outlay it should be borne in mind that the expenditure would be distributed over a period of from five to six years. Items 1, 2, and 3 assume that a sufficient quantity of large stone to insure the stability of the rubble mounds can be obtained at the quarries named. Before, however, proceeding with the works, or even prior to letting contracts for their execution, a sufficient extent of quarry-ground should be opened out to give accurate and definite information as to the relative yield of large and small material. In considering this question it must be borne in mind that the system of depositing from a stage, recommended for the outer or more exposed portions of the north and south breakwaters, will render practicable the construction of the moles when it might have been impossible to carry them forward as simple end-tips; and this will readily be understood when it is considered that the staging admits of depositing the materials, layer on layer, with flat slopes at the ends and along the sea-faces, the rubble being thereby dropped over a much greater range of area than by a system of tipping as an embankment from the end, and widing and feeding at the sides; hence, the slopes of the works, where deposited from a stage, would from the first be better adapted to withstand the action of the sea, provided the materials contain a fair admixture of heavy blocks. Again, the saving in settlement due to depositing from a stage as compared with tipping over end is very important in works of the class contemplated. For the less exposed inner lengths of the north and south breakwaters the conditions are in favour of the ordinary embankments system of depositing the materials.

Upon the completion of these works, and after the improved scour continuously acting over the same track has come fairly into operation, it may be expected that the navigable depth in the centre of the entrance and channel will be 10 feet at low water, or 18 feet at high water of spring tides, which will be sufficient for the navigation of vessels drawing up to 12 feet, allowing 6 feet for "scend" or undulation—a safe deduction except on the occurrence of heavy storms, but ordinarily a margin of 3 or 4 feet will suffice. Such a depth in the entrance, when permanently obtained, will, I imagine, be found adequate to the present and prospective requirements of the port for some years to come. At neap tides the depth would be 3 feet less than named above.

Future Extensions.

Having described the works I have to recommend for present execution, the principles by which I have been guided in designing them, and their estimated cost, it now remains for me to indicate the extensions which may be necessary hereafter when the trade of the port shall have been developed to such a degree as to call for still further improvements.

Works in River near Cobden Gorge.—It appears to me that, after the execution of the works hereinbefore described and recommended, those next in importance in the way of internal improvements will be the alteration of the line of the easternmost portion of Mawhera Quay for a length of 900 feet, and, concurrently therewith, the formation of the half-tide training bank on the north side of the channel westward of the mouth of the Coal Creek to a point about 650 feet below the outer end of the existing rubble stone groyne at Cobden Gorge, as shown by red dotted lines on Drawing No. 1. The half-tide training banks on the north side of the river eastward of the Coal Creek should be carried out at the same time upon the lines indicated by thick red dots on the drawing.

When the works last described shall have been executed, the area eastward of the Mawhera Quay, within the red-dotted line, described as "assumed future low water," will doubtless be filled up by the accretion of river deposits to such an extent that, with the addition of quarry waste or spoil from the hill at the back, it could, at a comparatively small outlay, be made available as standage ground for railway coal wagons, &c., &c. An important benefit to be derived from these works would be the maintenance of deep water in front of Mawhera Quay, where a shingle-bank has been accumulating

and extending for some years past. The increased scour produced by the training of the channel at this point, aided by partial dredging, would remove this shoal, and thereafter the improved outgoing currents might be relied on to prevent its reformation.

Works at Entrance.—With respect to external works it is no more than reasonable to anticipate that the development of the coal trade of this district will, before a lapse of very many years, render it desirable still further to increase the capabilities of the port. This being so, I have shown on Drawings Nos. 1 and 2 future extensions of 300 feet in the case of each of the breakwaters, the termination of the first instalment of the north arm being adapted to admit of subsequent prolongation in a direction parallel to the work on the south side. The effect of these extensions, after a time, would be the formation of a navigable channel, having a depth of 13 feet at low water and 21 feet at high water of spring tides, sufficient for the navigation of vessels drawing 15 feet, allowing 6 feet for "scend" or undulation, but, as before mentioned, ordinarily a margin of from 3 to 4 feet will be sufficient.

Improvement of Lagoon Channel.—As tending to increase the scouring action through the sea-entrance, and at the same time to the opening up of a better water communication between Karoro Lake and the harbour, I regard an improvement of the lagoon channel as a very desirable work, and one that should not be long deferred. The suggested line of channel is shown upon Drawing No. 1, and I would recommend that the depth along it should be so increased as to give at least 3 feet at low water of spring tides at the junction of the rivers, and that the bottom thence into Karoro Lake should be dredged so far as may be necessary to form a gradient of 12 inches to the mile. A possible effect of this improvement in the channel might be to admit the water more freely into Karoro Lake in times of excessive floods. It will be desirable, therefore, to ascertain whether any of the land along its eastern margin would be below the flood lines; and, if so, a low protection bank should be provided. This could probably be done at a nominal outlay by means of the materials raised in the process of dredging the channel. By the execution of this channel the tidal volume in the Karoro Lake and Revell's Lagoon, taken together, would be increased to the extent of 5,400,000 cubic feet at every ordinary spring tide, equivalent to an addition of 8 per cent. of the total tidal volume passing inwards and outwards twice daily from the River Grey and the lagoons combined, or 21 per cent. of the quantity now passing into and out from the lake and lagoon, exclusive of the river, an important addition to the scouring power, more especially as it would be available when most required—viz., during periods of drought and scarcity of fresh-water discharge.

Before concluding, I may remark that, in view of the more than probable great future development of the coal mines of the surrounding district, the time may be anticipated when the trade of the port shall outgrow the quay accommodation which it is possible to provide along the river front. I would therefore suggest that all the land seaward of the eastern margin of the Karoro Lake, and channel leading thereto, which may not have already been disposed of, should be scrupulously reserved for the construction of docks when the necessity may arise.

In conclusion, I have great pleasure in acknowledging the cordial co-operation of Mr. Blackett, C.E., Chief Marine Engineer of the colony, who accompanied me during my inspection, and rendered all possible assistance in making the local inquiry. My acknowledgments are also due to Mr. O'Connor, C.E., under whose direction the observations and documents transmitted from the colony have been prepared in an able and painstaking manner; Mr. Johnstone, Resident Engineer, also assisted. Captain Allardyce, Harbourmaster, rendered me valuable assistance during my inspection of the port and river. My obligations are also due to Mr. Nancarrow, Mayor of Greymouth, who, at the time of my visit, kindly assisted in making arrangements for facilitating the requisite inspection.

I have, &c.,

The Secretary, Marine Department, Wellington. JOHN COODE.

HOKITIKA.

SIR,— 5, Westminster Chambers, London, S.W., August, 1879.

I have now the honor to forward my report upon the subject of the improvement of the entrance and tidal compartments of the Hokitika River, together with three illustrative drawings, viz.:—

No. 1, a general plan of the harbour, showing the entrance, and the respective low-water channels, about half-way to Kanieri. No. 2, a sheet containing a general plan of the Mahinapua River and Lake, with sections, hereinafter more particularly described. And No. 3, a drawing showing details of the works recommended for execution.

I need only remark further, by way of introduction, that the primary objects to be attained in this case are: First, the placing of the river entrance in such a position, and forming it in such a manner, as shall utilize to the fullest possible extent the scouring action of the tidal and fresh waters, by directing the currents in the most effective lines, and confining them to a permanent track through the sand-spit and across the bar; and, secondly, the restriction and training of the river channel within definite limits, so that the fresh water and tidal currents shall create and maintain, or at least that they shall assist to the fullest possible extent in creating and maintaining, deep water alongside the wharves already existing and hereafter to be constructed upon the river-frontage of the town.

To arrive at definite conclusions in this exceptional case, I found it necessary, after my inspection of the locality, to request that a special series of observations should be made, in order to ascertain the relative levels or gradients of the water surface at the different stages of the tide, and in times of fresh-water "floods," both within the tidal compartment of the Hokitika River proper, and throughout the entire length of the Mahinapua River, and for a short distance into the lake. It was also necessary to obtain a detailed plan with longitudinal and transverse sections of the Mahinapua River, a work of no small difficulty and labour; and I desire here to express my sense of the entirely satisfactory manner in which these services have been performed by Mr. O'Connor, District Engineer, and Mr. Campbell, the assistant acting under him.

Physical Features.

The general conditions to which special regard must be had in dealing with the question of harbour improvement works at Hokitika are well described in the notes published by the Harbour Board in April, 1877, wherein they state that the river, having its source in the snowy mountains to the southward, is subject to floods both from the melting of the snow and from the heavy rainfall of the district, and that it is continually changing its channel through the shingle-bed, and encroaching upon one or other of its banks according to circumstances. They also call attention to the fact that the position of the river entrance is subject to great fluctuations, the changes being dependent upon the varying conditions of flood-waters from the back country, and the direction and force of the seas along this particular part of the coast.

Briefly stated, the conditions within the tidal compartment of the Hokitika River are as follow: The range of a spring tide at the entrance, under normal conditions, is about 9 feet, gradually diminishing until tidal action altogether disappears at a point about $1\frac{1}{4}$ miles below Kanieri Ferry. In the Mahinapua River the tidal influence ceases at a distance of about $3\frac{1}{2}$ miles from its junction with the Hokitika, just within the outfall, at the point marked × in red on Drawing No. 1.

The total volume of tidal water flowing in and out through the entrance during ordinary springs is about 58,000,000 cubic feet, and the maximum discharge at half-ebb is at the rate of 240,000 cubic feet per minute.

During extreme floods, the level of the water in the Hokitika River just within the entrance has been raised as much as 3 feet 6 inches above ordinary spring-tide high water, whilst at the head of the tidal compartment the level at the same time was 10 feet 10 inches above the ordinary water-line; and at Kanieri the highest recorded flood was 15 feet 4 inches above the normal level. It will thus be seen that during great freshes the water surface assumes abnormal inclinations, resulting in the generation of rapid, indeed I may say violent, currents.

The area of watershed draining through the entrance at Hokitika is, according to Dr. Hector, 382 square miles, and the rainfall over that area 120 inches per annum. It is no very uncommon occurrence to find a rainfall of from 2 to 4 inches at Hokitika in a single day.

It necessarily follows that the river is not infrequently in a state of intense flood, the hydraulic gradient being on some occasions as much as 11 feet per mile opposite Gibson's Quay. It is difficult to compute with precision the discharge of the Hokitika River in freshes; but taking the data of inclination of river surface and sectional areas furnished by the observations made for me in the colony, I have arrived at the conclusion that the discharge of the Hokitika in extreme floods is about 9,500,000 cubic feet per minute, whilst in ordinary floods it is about 5,000,000 cubic feet per minute. The normal fresh-water discharge of the river is 360,000 cubic feet per minute, which is one-twenty-sixth of the quantity in extreme floods, or one-fourteenth of the ordinary flood discharge. I further find that the fresh water passing out through the entrance in times of ordinary floods is rather more than twenty times as great as the maximum discharge of tidal water during springs.

I have dwelt thus at length on the subject of the relative volumes of fresh and tidal waters, as they prove conclusively that the conditions in the Hokitika River are of an exceptional character. In most cases the tidal water constitutes the chief agency in the maintenance of an entrance channel; but, from the facts just stated, it is evident that in this instance the enormous and frequently-recurring floods will exercise by far the greatest influence in keeping open a navigable approach from the sea. Nevertheless, the great fluctuations in the volume of fresh water to which I have alluded form an important element to be kept in view in devising entrance works, for, notwithstanding the discharge during ordinary floods is 5,000,000 cubic feet per minute, the aggregate delivery of tidal and fresh waters combined is, under normal conditions, not more than 600,000 cubic feet per minute. Any entrance must, therefore, of necessity be subject to frequently-recurring fluctuations, sometimes in the ratio of 8 to 1, and on exceptional occasions to a much greater extent.

Having described the agency by means of which a navigable connection between the sea and the river must be maintained, I may remark that the counteracting influence, tending to block or obstruct the entrance, is the mass of shingle passing along the coast, the travel or drift of which is, in this case, from south to north. The accumulation of shingle in the opening and on the bar can only be kept down by fixing the entrance and concentrating the whole of the available forces, by passing the currents through a definite and duly-proportioned waterway.

Under the conditions which have existed up to the present time, the position of and depth of water in the entrance have both been subject to great changes, varying with the strength of the land-floods on the one hand, and the sea-disturbance on the other. Hence it is that the river outfall has varied from a line bearing west (by compass) from the flagstaff at the signal-station to a point about three-fourths of a mile to the southward thereof. When the entrance was at the most northerly point it was never good for any length of time; moreover, much inconvenience was then felt from the swell, which ran up the channel in front of the town. When at its most southerly point the entrance channel was also unsatisfactory: clearly the best position is midway between the two extremes just described.

It will be evident, from what I have stated, that the depths in the entrance have been subject to great variations; but no exact records of these seem to have been kept. The low-water depths in the channel in front of the town are shown on Drawing No. 1. The abnormal scour of 29 feet at the end of the lower wing-dam is due to the interference of that work with the true run of the currents. Upon the completion of the permanent training works, hereinafter described, this obstruction should be removed. Fortunately the water-frontage of the town takes the form of a concave curve, having a radius of about 60 chains. This will insure the continuance of the deepest water along and immediately in front of the wharves and quays at Hokitika.

Proposed Works.

It appears that designs for harbour works at Hokitika were invited in the early part of the year 1877, and, upon the recommendation of Mr. Blackett, C.E., the Government Marine Engineer, the

design marked "*Animo et fide*" was accepted, subject to "some very considerable modifications in the details, position, and extent of the several works."

In his report of 30th November, 1877, Mr. Blackett properly described the natural balance of the forces, when undisturbed by heavy floods, as tending to keep the entrance where it was at that time. I may here remark that this is practically the position I have adopted (*see* accompanying Drawing No. 1) as being decidedly the best, having regard to all the circumstances of the case.

Mr. Blackett recommended the construction of a dam from the south bank of the river, so placed as to prevent the water from passing behind Wadeson's Island. He approved of the proposal to construct a training work, nearly a mile in length, on the south side of the channel, extending from a little above Old Racecourse Island to a point about opposite to Brittan Street, considering the necessity for a training work westward of that point as problematical. I fully concur in the proposal to form a dam between the south bank of the river and Wadeson's Island, regarding this as a work of necessity, but would recommend a somewhat different line from that proposed by Mr. Blackett. I am of opinion, however, that such a great length of training work on the south side of the channel is unnecessary. The width of entrance proposed in the accepted design was 726 feet.

At the time of my visit to Hokitika (17th to 19th April of last year), tenders had been invited for certain portions of the then approved works, and I understand that in the latter part of May, the offer of Mr. William Smith, of Kanieri, was accepted. His contract included a training work 1,950 feet long, from the wing-dam opposite Revell Street to the north-east side of the entrance, and a similar work, 800 feet long, on the inside of the spit on the south-west side of the entrance. The contract also comprehended a length of 50 feet at the commencement, or inner end, of each breakwater. The contract amount for these works was £27,593.

As will be seen by reference to Drawing No. 3, the character of construction which I have to put forward for adoption differs materially from that shown upon the contract drawings above referred to.

Recommendations.

The works I have to recommend for the improvement of the entrance at Hokitika are shown by red colour on Drawing No. 1. They have been designed with a view to fixing the outfall permanently in a position about midway between the limits within which the channel has from time to time been formed by the influence of the freshes and wave-action; it is so placed that the whole of the scouring agency due to the tidal and fresh-water discharge may be utilized to the fullest practicable extent in the maintenance of a navigable approach to the river.

Two points which have received my especial attention are, the width of the entrance and the direction in which it should point seaward. With regard to the first, the enormous differences between the discharges in times of flood and under ordinary conditions render the determination of the width at the entrance a matter of unusual difficulty, and one, in fact, upon which it is impossible to pronounce an opinion with absolute certainty. After careful calculation and consideration, I have arrived at the conclusion that a waterway of 600 feet will, on the whole, produce the best results, for, whilst an opening of this size would admit of the discharge of the flood-waters without the creation of such a "gorge" as would unduly scoop out the materials in the bed of the channel, and thereby endanger the stability of the piers, it would, nevertheless, be sufficiently contracted to insure the generation of a current of nearly one mile per hour during a portion of the ebb under ordinary conditions. I should have preferred, had it been practicable, still further to have curtailed the width of the opening. With the data before me as to the enormous occasional flood discharges, I have not considered it prudent to adopt a less width than 600 feet, but if in carrying out the works experience should show that the piers might with safety converge somewhat closer than I have shown in Drawing No. 1, then I would certainly recommend that the entrance be reduced accordingly; the curved lines I have adopted for the guide-piers admit of this being done up to a certain point during progress.

With reference to the second point—namely, as to the direction of the entrance, I am enabled to express a very positive opinion to the effect that it should point seawards west-north-west, as laid down on Drawing No. 1, so as to insure the discharge of the effluent waters practically at right angles to the beach, and directly opposed to the waves impinging on the coast. Experience in similar cases has shown me that no benefit would be derived by any attempt in this instance to shelter the entrance by changing the direction of the piers, or by creating an abnormal overlap of one work by the other.

I now come to a description of the works I have to recommend, the positions of which are indicated on Drawing No 1, and full details of their construction shown on Drawing No. 3.

Commencing at the point *A*, on the north side of the river near the old wing-dam, and extending from thence to *B*, a length of 1,520 feet, I have shown a facing of piling and planking upon the line laid down in a memorandum framed at the time of my visit to Hokitika dated 24th April of last year. [See Appendix.] At the south-west end of the piled facing before described (marked *B* on the plan) I propose to commence an east pier, extending from thence by a curve of 550 feet radius until it attains a length of 660 feet, when it would terminate at the point *C*. This pier would consist of two rows of continuous whole-timber sheeting of squared totara timber, driven close, with cross bulkheads, likewise of close piling, at intervals of 20 feet. The sand and shingle within the compartments thus formed would be excavated to the required depth, and the whole filled in solid and capped with Portland-cement concrete, in the manner shown on Figures 9 and 10, Drawing No. 3. A light would be exhibited from the outer end of this pier, a permanent gangway being provided, as shown, to admit of access by the lightkeeper. On the south-west side the training works would commence at the point *D*, a facing running therefrom on a curve of 400 feet radius to *E*, a distance of 680 feet. For the details of this face see Figures 2 and 3, Drawing No. 3.

From the point *E* to *F*, a length of 500 feet, I propose to construct a western pier, extending in a west-north-west direction, and forming with the east pier before described a permanent entrance of 600 feet in width. This western pier would consist of two rows of round totara piles, with bulkheads 60 feet apart, the main piles carried to 13 feet above high water, and the intermediate piles terminating at about half-tide, above which level the sides of the pier would be planked longitudinally, and the

whole filled in solid, as the work proceeds, with boulder stones from Kanieri, the latter being capped or paved with blocks of Portland-cement concrete. Full details of this structure are shown on Figures 4 and 5, Drawing No. 3. To protect the feet of the piles from abnormal scour on the river sides of both the east and west piers I propose to form an apron of bags of concrete, as indicated in the drawings; but a coating of this character will not be required along the footings at the back of these works, at all events not in the case of the west pier, southward of which the beach may be expected to accumulate with rapidity. It will be observed that the west pier overlaps the east to the extent of 300 feet: this will be necessary in order to provide for the permanence of the depth in the entrance, which, under ordinary conditions, should be about 10 to 12 feet at low water of spring tides.

The east pier will be subjected to very heavy seas striking it at an unfavourable angle, hence I have considered it necessary to proportion the strength of that work accordingly. To prevent undue scouring of the beach seaward of this pier by "run" and rebound, I have provided for the formation of a "wave-breaker" of blocks of cement-concrete, deposited pell-mell on the foreshore immediately seaward of the main structure.

To "fix" the beach northward of the entrance, and to prevent the encroachment of the sea in front of the town, I have laid down on the plan and shown in detail on Drawing No. 3 a series of wood groynes, which, although not of an expensive character, will be found of material service in securing the foreshore.

I have already alluded to the fortunate circumstance that the riverside frontage of the town presents a concave curve, along which the currents would insure the maintenance of the deepest water. For this reason it appears unnecessary to provide a training bank along the south margin of the channel, seeing that the concave curve will compel the current, in its passage seaward, to set hardest along the navigable track, and hence but little (if any) further improvement of depth would result from the formation of a second bank on the south side parallel to the existing face.

The only other works which I have to recommend are those necessary for the training of the river and tidal currents under ordinary conditions. They are shown on Drawing No. 1, and need no detailed description, except that they might, with advantage, be protected on the up-stream side by brushwood, embedded in the material of which the banks proper are to be formed. It will be observed that the top of the training bank opposite Sale Street is described as at the level of high water of spring tides: thus, whilst this bank will be of service in training and concentrating the currents under ordinary conditions, it will admit of the ready escape seaward of flood waters.

Estimates.

I estimate the cost of the proposed works as follows:—	£
1. East pier, 660 feet in length, with wave-breaker of pell-mell concrete blocks, and apron of concrete bags, as described	86,750
2. Six groynes along the sea-front, northward of the east pier	3,500
3. Training sheeting south side of entrance, 680 feet in length, with wing-groin complete	8,100
4. West pier, 500 feet in length, with apron formed of bags of concrete on the river-side	28,450
Total estimated cost of works in connection with the improvement of the river entrance	£126,800
Training banks near Wadeson's Island, and at the Ferry	3,600
Gross total of estimate	£130,400

The foregoing estimates include a fair allowance for contingencies and supervision, as well as for the provision of plant. The quantities of work of the respective kinds have been computed from the detailed views shown on Drawing No. 3, and the rates at which the quantities thus arrived at have been moneyed out, are based upon the local prices of labour and materials furnished from the colony.

The mode of construction contemplated is certainly not extravagant; and the works proposed, if carried out as recommended, would be found well adapted to meet the requirements of the case. I am of opinion that less substantial structures would give rise to constant anxiety and expense; nor could training-works of less length be relied upon for the maintenance of a deep-water entrance. Whilst, therefore, I can say with confidence that the works suggested are neither stronger nor more substantial than experience has shown to be necessary, it is my duty to point out that the rates furnished to me from the colony (upon which, as I have stated, the estimates have been based) are such as to render it not improbable that the piers and works could be executed for a less total sum than hereinbefore stated.

The observations made at my request have shown, as I anticipated at the time of my examination of the locality, that the present very restricted navigation of the Mahinapua River may be materially improved by a comparatively small outlay. Having regard to the fact that the Harbour Board's endowment land is situated at the extreme southern end of the lake, that the communication by road between the harbour and this endowment land and the neighbouring town of Ross is circuitous, and that the levels of the country are such as to render the cost of conveyance from the harbour very heavy, it certainly is desirable, in my opinion, that the navigation of the Mahinapua River should be improved, seeing that it would greatly enhance the value of the Board's property, and would have the further advantage of placing the whole of the land around the margin of the lake (which is six miles in circumference) in direct communication with the harbour, by means of barges of considerable tonnage.

The works for the attainment of this object are shown by red colour on Drawing No. 2. The quantity of dredging would not be large, and, as will be seen, there would be a navigable depth, after completion, of from $5\frac{1}{4}$ to $5\frac{1}{2}$ feet at high water of neap tides, and not less than 6 feet in any part at high water of spring tides, and when the water in the lake is at its ordinary level. The plan, Figure 1, shows the improved lines of river course, and it will be seen that provision is made for a towing-path

along the western bank. I would recommend, however, in view of the heavy expenditure required in fixing and improving the entrance to the river from the sea, that these subsidiary works in connection with the Mahinapua should remain in abeyance, until the more important works at the entrance have been completed. In any case, however, when the necessity arises for improving the navigation on the Mahinapua, the lines and levels I have laid down on the accompanying Drawing No. 2 should be duly observed.

Conclusion.

I must not omit, in conclusion, to record my thanks to Mr. Virtue, the Chairman, and to Mr. Craig, a member of the Harbour Board, who accompanied me during my inspection. Captain Turnbull, the Harbourmaster, gave me much useful information as to the changes which have taken place from time to time at the entrance, more especially during the thirteen years which he had acted as Harbourmaster. At the time of my inspection Mr. Blackett, C.E., and Mr. O'Connor, District Engineer, facilitated my inquiry and investigation in every possible way, and to them my thanks are also especially due, and are here tendered.

I have, &c.,

The Secretary, Marine Department, Wellington. JNO. COODE.

APPENDIX.

By a telegram received since the accompanying drawings have been prepared, I learn that already a facing has been almost completed on this line to the point *B*, and hence the details shown on Figures 7 and 8, Drawing No. 3—representing the mode of construction I should have advised for this facing—cannot now be adopted, although it is desirable that the piling as executed should be stayed, and backed with brushwood and boulders, in the manner indicated on the section, Figure 8. It will be observed that I contemplated filling the space at the back of the piling *A*, *B*, so as to form a level area adapted for wharfage and other purposes. Whether the nature of the work executed will now admit of this being done I am unable to determine; but this is a point which should receive early attention, seeing that the deepest water in the port may be expected along this portion of the river frontage, although its utilization as berthage would be subject to occasional interruption during heavy onshore gales from the inrun of waves.—J.C.

MILFORD LAGOON (TEMUKA).

SIR,— 5, Westminster Chambers, London, S.W., August, 1879.

Having carefully considered the documents and data received from the colony relative to the proposal to convert Milford Lagoon into an efficient harbour, I have now the honor to submit my report thereon, together with the accompanying illustrative drawing.

Physical Features.

Milford Lagoon is situated near the south-west end of the Ninety-mile Beach, on the seaboard of the great Canterbury Plain. It lies about 50 miles north of Cape Wanbrow, and about 10 miles north-north-east from Timaru. The length of the lagoon, in a south-south-west direction, is about two miles and a quarter; its average breadth, between the Opihi and the outfall of the Mill Creek, is about 140 yards at low water and 180 yards at high water. North-east of the Mill Creek the breadth is considerably less, ranging from 20 to 60 yards at low water, and from 30 to 100 yards at high water. Excepting a small area opposite Mill Creek, in and near the line of the outlet channel which existed when the survey was made in October last, the greatest depth was from 3 to 4 feet at low water of ordinary spring tides, as will be seen by reference to the accompanying drawing.

At the time of my inspection—in April of last year—the connection between the lagoon and the sea was entirely cut off by a considerable barrier of shingle, which then extended completely across the line where the channel of communication had previously existed. This barrier had again been cut through at the time of the October survey, as appears by the drawing. The existence or non-existence of such a channel depends, under present conditions, upon the relation between the scouring power of the tidal water, combined with that of the fresh-water discharge of the River Opihi and its tributaries on one hand, and upon the quantity of shingle transported along the coast by the waves of the sea on the other.

The conclusion arrived at during my inspection was to the effect that little or no shingle passed around Cape Wanbrow from the southward, and that the shingle travelling along this south-western portion of the Ninety-mile Beach (where Milford Lagoon is situated) is derived mainly from the materials brought down by the River Waitaki, and partially from the shingle cliffs, averaging about 35 feet high, which fringe the shore northward of Oamaru.

The supply from the two sources named, especially from the Waitaki, is very large indeed, and practically unlimited. Being personally acquainted with numerous coasts and river outlets in several parts of the world, I have never previously seen, nor have I any knowledge of, such vast quantities of shingle being elsewhere transported by the waves as those which travel along this portion of the seaboard of New Zealand. The shingle is drifted or propelled along the coast in a northward direction by the heavy southerly seas, the preponderating force being admitted on all hands to be from that quarter. The waves impinge on the beach at a slightly oblique angle towards the northward, thereby generating an almost constant travel of large quantities of shingle from south to north across the entrance to Milford Lagoon.

The quantity of tidal water flowing into and out from the lagoon at each tide during springs—when communication exists between it and the sea—as calculated from the drawings and data sent from the colony, is under 3,000,000 cubic yards. The fresh-water discharge is of course dependent upon the amount of rainfall over the watershed of the Opihi and its tributary streams: from a tabular statement of the areas of watershed of several of the rivers of New Zealand, kindly furnished by Dr. Hector, I find this area may be taken at about 890 square miles.

According to the published meteorological reports, the nearest station at which observations of rainfall have been taken is at Oamaru: from these it appears, as might be expected, that the quantity of rain in the district varies considerably. In Dr. Hector's tabular statement referred to, the average annual rainfall in the watershed of the Opihi is given at 28 inches. The four years for which I have the published returns show 16¼ inches in 1871, 20 inches in 1872, 28 inches in 1873, and 21¾ inches in 1874. In the last-named year rather more than 5½ inches, or one-fourth of the whole annual rainfall, occurred in the month of September, whilst the total fall for three successive months in the same year, April, May, and June, amounted to only 1½ inches, or a mean of ½ inch per month. Taking the average of the four years above named, there were four months out of the twelve in which less than 1 inch of rain fell within the whole month. It is obvious therefore that, as in so many other cases, it is mainly upon the tidal-water that dependence must be placed for the scouring power at Milford, although the fresh-water discharge would occasionally afford valuable assistance on the occurrence of floods or freshes.

Proposed Works.

Having described the general physical features, in so far as they affect the question under consideration, I now come to the proposal of Mr. T. M. Hardy Johnston, C.E., whose recommendations are described in his final report, dated 19th October, 1877, and are shown on the several drawings which accompanied it. From these it appears that the south pier, as scaled from the plan, is proposed to be 1,200 feet in length (from *B* to *D* on the accompanying drawing), and the north pier 1,050 feet (from *G* to *E*). From the inner ends of each of these piers wharf-walling would be constructed along the eastern shore of the lagoon, to the extent of 500 feet from *H* to *G*, on the north side, and 600 feet from *A* to *B*, on the south side. The mode of constructing these piers and wharves would be similar in principle throughout, and consists generally of timber-framing and blocks of concrete within, so placed as to admit of settlement. Where necessary the interstices between the blocks and piles are intended to be filled with liquid concrete, either as mass-work or in bags, the outermost or seaward faces of the piers being protected by large blocks deposited pell-mell.

Mr. Johnston further proposes to cut a channel between the River Opihi and Mill Creek, at a point about 1½ miles westward of the lagoon entrance (*I* to *J*, on plan), so as to direct a considerable portion of the flood-waters of the river through Mill Creek, with a view to create a more direct and equal scour through the channel between the lagoon and the sea, and facilitating the formation of a large and deep basin within the entrance. The banks of the Mill Creek at its lower end are proposed to be rectified and protected by training-walls of fascine work.

Estimated Cost of Works.

With regard to the cost of the piers and wharf-walling, just described, Mr. Johnston estimates that in their first stage, which he describes as provisional, they will cost £67,837, including £3,670 for the diversion of the Opihi River, and 10 per cent. for contingencies on the whole; also that the measures requisite for consolidating and completing these works would entail a further expenditure of £24,090, thus making a gross outlay of £91,927 for the harbour works proper; which, added to the sum of £7,500 for a branch railway to Temuka, would bring the total of Mr. Johnston's estimate to, in round numbers, £100,000.

Opinion as to Proposed Works.

The general principle of the design put forward by Mr. Johnston is sound, and would be quite suitable, assuming the forces at command in this case to be sufficient to overpower the shingle in such a manner as to maintain a good navigable entrance channel at all times. The character of construction which he proposes is also adapted to the conditions, in so far as it would admit of the subsidence which would be certain to occur as the work advanced, and, subsequently, in times of exceptional floods. The first and cardinal point, however, to be determined in this case is: Whether or not the scouring power due to the influx and efflux of the tidal and fresh waters is sufficient, under the most favourable conditions of training, controlling, and directing works, for securing a permanent approach, with a sufficient depth for navigation purposes, between Milford Lagoon and the sea? Upon this, I much regret to be obliged to say that I am unable to express a favourable opinion, for, having regard to the exceptionally large quantity of shingle continuously passing along this part of the coast, and also to the limited character of the tidal and fresh-water discharge under ordinary conditions, and the comparative infrequency of floods, it appears to me that the physical conditions which prevail at Milford are so adverse as to render the success of any works which may be undertaken there so extremely problematical, and the prospect of any adequate benefit being derived from them so uncertain, as, in my view, to render it inexpedient and undesirable that the large outlay should be incurred which would be necessary for their construction.

Instances can be adduced where a navigable approach of limited depth has been formed and maintained across the line of shingle-drift; but, in all the cases with which I am acquainted, where even a moderate amount of success has been achieved, there the travel of the shingle or sand has been much less formidable in extent, and less persistent and continuous in character, than along the sea-front at Milford. Moreover, were the piers to be completed to the full length contemplated in the first instance, namely—to 1,200 feet and 1,050 feet for the south and north moles respectively—I feel assured that by the time these structures had reached the points contemplated for their termination, the shingle along the beach would have advanced so far seaward as to travel around the end of the southernmost work, and, in the absence of the requisite scouring power to which I have alluded, would inevitably block up the entrance channel between the moles for a considerable portion of each year.

A material augmentation of the velocity of the currents might be produced by bringing the heads of the two piers closer together than 500 feet, the distance proposed by Mr. Johnson; but, notwithstanding all that it is practicable to do in this direction, the probabilities of success are so remote, that, having regard to the great outlay required, I am reluctantly unable to recommend the construction of any harbour works at Milford.

As the result of the works at Kakanui has been referred to in support of the proposed harbour at Milford, I may observe that, in so far as regards the quantity of shingle, and the rate of movement along the coast, which form such all-important elements at Milford, the conditions are so entirely different in the two cases that no comparison can be drawn between them. I may further remark that the piers proposed by Mr. Johnston would necessitate the erection of a series of groynes, for a considerable distance along the north-east side of the entrance, in order to retain the shingle in sufficient quantity to prevent the north pier from being outflanked by the sea, as it certainly would be in the absence of such provision, seeing that the supply of shingle would be cut off from the north side, whilst the beach was gathering southward of the south pier.

Estimated Cost of Mr. Johnston's Works.

With regard to the sufficiency of the amounts stated as the probable cost of the proposed works, upon moneying out the quantities computed from the drawings furnished by Mr. Johnston, and adopting the prices he has supplied as the basis, I find that the south pier and wharf-walling, together 1,800 feet in length, if completed to the full height contemplated by Mr. Johnston, would cost £229,700; and the north pier and wharf-walling, together 1,550 feet in length, likewise completed to the full height, £173,600: giving a total outlay required, exclusive of the cost of the groynes, of £403,300.

The greatest depth within the lagoon generally, and that only for about one-half its breadth, is from 3 to 4 feet at low water, or 10 to 11 feet at high water of spring tides, and about 8 to 9 feet at high water of neaps. A considerable amount of dredging would therefore be necessary in order to accommodate small coasting vessels and steamers, the cost of which should be added to the above-named sum.

I have, &c.,

The Secretary, Marine Department, Wellington. JNO. COODE.

NAPIER.

SIR,— 5, Westminster Chambers, London, S.W., March, 1880.

Having duly considered the facts and data contained in the several documents transmitted (in accordance with the memorandum which I framed when in the colony), for the purpose of enabling me to report on the works I should recommend in order to provide a suitable harbour for the Port of Napier, and having also examined the plans and report of Mr. J. McGregor, C.E., with reference to his proposal to form a harbour at Napier Bluff, I have now the honor to submit my report on the whole subject.

I should remark, by way of preface, that when in the locality I personally examined the whole length of the sea-beach and foreshore along the eastern front of the Town of Napier, and thence around by the Bluff to the harbour, and the beaches and boulder-banks on the northern side of the entrance. I also visited the mouth of the River Tuki Tuki, and the sea-beach for some distance to the north and south of it; my inspection of the sea-frontage of this particular district being greatly facilitated by the courtesy of the Hon. Colonel Whitmore, M.L.C., then Colonial Secretary.

I understand that my opinion is requested on the following points: First, with reference to Mr. J. McGregor's proposal for a harbour to be formed at Napier Bluff; second, the works I would recommend for the provision of a suitable harbour for the Port of Napier; and third, whether, in view of the future commerce of this port, it is desirable to construct a bridge across the harbour, commencing at the inner extremity of the west quay on the south side, and extending to the Meanee Quay, near the site of James Street, on the north side; and also, whether the introduction of one or more swing spans across the principal channels would modify any objection which might otherwise be possibly entertained to the erection of such a bridge.

Before proceeding with the consideration of these three important points, it is desirable that I should refer to a few of the governing physical conditions of the site, and briefly describe the works which have been already executed for the improvement of the entrance channel, and the effects which have been produced thereby. A careful study of the salient features is essential to a correct understanding of the principles involved, and cannot fail to afford a key to the proper solution of the questions upon which my opinion is desired. I may mention that inasmuch as the Resident Engineer of the pier works, Mr. Weber, presented a lucid report to the Napier Harbour Board in March of last year, wherein he dealt in detail with the changes which had taken place in the entrance from time to time prior to the construction of the training works, and described the conditions of the shingle travel, &c., it is unnecessary that I should again go over this ground, except in general terms.

Changes in Entrance Channel.

Numerous records are available showing the changes which have occurred in the configuration and width of the entrance channel, consequent upon alterations in the points and outlying banks since 1851, the date of the first survey of Port Ahuriri District. From these it would seem that, prior to the execution of the pier works, the distance between the points or heads of the shingle banks on either side of the entrance had steadily increased, and that, notwithstanding frequently recurring fluctuations dependent upon the prevailing weather, there was, as might have been expected, a loss of navigable depth proportionate with the increased width of water-way between the points; nor could the scouring agency be effectively utilized for keeping open the entrance whilst the banks were subject to frequent alterations in position and form, seeing that under such conditions the action of the currents was being continually brought to bear upon fresh ground. It is not a matter of surprise, therefore, that there was a loss of depth in the channel from 15 feet at high water, as shown on the Admiralty chart of 1855, to an average depth of 9 feet, as appears from the pilot's returns of 1873.

Source of Supply and Travel of Shingle.

Mr. Weber states that the bar consists of river gravel intermixed with limestone boulders, and he correctly adds that the gravel derives its origin from the Tuki Tuki, the mouth of which river is situated about six miles south-east of Napier Bluff. Immense quantities of shingle exist over a considerable portion of the district in which the Tuki Tuki takes its rise, and through which it flows; the supply of the shingle drift which incumbers the entrance at Napier may therefore be considered as practically inexhaustible. When inspecting the locality I carefully investigated the conditions which govern the travel of the shingle, and concur in the views expressed by Mr. Weber on this head in his memorandum of 20th March of last year, and his report of 25th March. The preponderating direction and force of the waves impinging on the shore being from south to north, a northerly travel of the shingle from the Tuki Tuki is thereby generated. Following the sinuosities of the coast, the shingle passes across the entrance to the harbour, the deep indentation of the coast north-eastward of Napier Bluff being favourable to the more sluggish travel and deposition of shingle at the head of the bight, and in the vicinity of the harbour entrance.

As an instance of the rapidity with which the shingle travels along the shore, I may refer to two facts given by Mr. Weber, namely, that the construction in 1875 of an experimental groin on the eastern shore, 200 feet in length, occupied six weeks, and that within a few days after its completion the shingle had made up to its end. Again, between the commencement of the pier works in July, 1876, and the date of his memorandum of 20th March, 1879, Mr. Weber estimates that 240,000 cubic yards of shingle had been trapped between the eastern pier and the Bluff, notwithstanding that the mouth of the Tuki Tuki, the source of the shingle supply, was closed for nearly eighteen months during that period, the beach from Tuki Tuki to Napier Bluff having been greatly denuded of shingle in the interval. Standing out prominently as one result of past experience, it may be stated that when the travel of the shingle was temporarily suspended by the experimental groin, the bar remained good, and the same effect was produced when the construction of the eastern pier for a time outstripped the growth of the shingle. Easterly winds bank up the bar. Fortunately, however, the prevailing winds are from north-west and south-west, or practically off-shore, at this port, and hence the intervals of obstructive wave-action are of less frequent occurrence than the periods of fine weather, although, as I have before explained, the northward travel of the shingle, which owes its initiation to wave-action impinging obliquely on the beach, proceeds with but little interruption.

Backwater.

The only agency which can in this case be relied upon for keeping open a navigable channel through the bar and shingle drift, is that of the currents produced by the alternate filling and emptying of the immense tidal reservoir of Ahuriri Lake. The area of this backwater is 9,300 acres, and the capacity of its tidal compartment during mean tides is fully 600,000,000 cubic feet; this large area being filled and discharged twice in every twenty-four hours, or thereabouts. There is also the fresh water from the Esk and the Tutaekuri, having an aggregage watershed of 406 square miles, which discharge into Ahuriri Lake; but the useful scouring effect to be looked for from this source is infinitesimal when compared with the daily discharge from the tidal compartment. Moreover, the fresh-water contribution is subject to fluctuations, and liable to periods of great drought on one hand and excessive rainfall on the other. Although some temporary beneficial effect on the entrance would probably be produced by the out-run of a heavy freshet, nevertheless, if a sufficient navigable depth in the entrance is to be permanently maintained so that the trade of the port can be carried on without interruption, this can only be secured by framing works upon the basis that the channel shall be kept clear by tidal water, independently of the fresh. This is quite practicable, seeing that the currents between the piers, due to the filling and emptying of the tidal reservoir, run at fully six knots an hour during portions of the flood and ebb, as has been shown by observations made for the purposes of this report; and this result is borne out by calculation here, the rivers at the time the observations were made having been exceptionally low. It is satisfactory to be able to state that an examination of the documentary records of different dates, so far as they are comparable, bear out the remarks in Mr. Weber's report with reference to the absence of any material changes in the bed of the tidal basin during the last twenty-eight years. This augurs well for the permanence of the scouring power.

Works already executed.

Reverting to the condition of the port when the Napier Harbour Act came into operation in 1876, I may observe that the works executed since that time consist of two parallel training piers at the entrance, placed 400 feet apart, and running in a northerly (magnetic) direction, the head of the east pier extending 370 feet further seaward than that of the west. The minimum depth in the fairway in March of last year (the date of the survey) was 7 feet 6 inches at low water, or 13 feet at high water of spring tides. At that time, in consequence of the accretion of shingle eastward of the east pier, the low-water line of the shore had advanced to within 110 feet of the end of that work, the shingle stretching to the westward across the entrance and passing the head of the west pier during easterly winds. It was a wise provision in executing these piers to provide an overlap of the west pier by the east to the extent just described, as this enables most of the shingle to continue its normal travel along the coast across the mouth of the harbour, without being trapped by the western work and deposited in the channel, as would have been the case had the terminations of the two piers been more nearly abreast of each other.

The works throughout consist of timber piling and framing, filled in with rubble stone, the outermost 400 feet on the east side, and 200 feet on the west side, being formed of greater width than the inner portions. The contract for the execution of these piers was signed in July, 1876, and they were completed at a cost of about £60,000 in April, 1878. Mr. Carruthers, the late Colonial Engineer, was the designer and Engineer-in-chief of the works, and Mr. Weber the Resident Engineer.

Mr. Carruthers's design was based on sound principles—namely, the fixing of the channel, and concentration and training of the efflux and reflux currents along a properly proportioned and definite

track. The mode of construction was judiciously chosen, as it enabled long lengths of work to be executed at a comparatively small outlay, and provided for the port the maximum amount of early useful effect from the expenditure incurred, although necessitating, not infrequent outlays hereafter, in the upkeep and repairs of the timber work. To have provided for a permanent mode of construction, such as would have avoided the necessity for these repairs, would have increased the cost of the works to such an extent as would in all probability have precluded their adoption; and this would have been a subject for regret, seeing that the piers, with proper repairs and renewals, cannot, in my view, fail to fulfil the object for which they were intended—namely, to keep open and maintain a permanent navigable approach to the port, when associated with the improvement of the channel, to which I shall presently refer.

The effect of the piers has been to deepen the entrance from an average of 9 feet at high water of spring tides in 1873 to 13 feet in March, 1879; also to afford a fixed straight course, in lieu of the tortuous and frequently shifting track which formerly prevailed. The shingle in the channel and on the bar has been scoured down, leaving a layer of boulders on the surface: these, being matted together by barnacles, have formed a skin which has been found to be proof against the scouring action of the tides. Mr. Weber states that this boulder skin was being operated upon by a heavy rake and dynamite, with satisfactory results, but that the process was of necessity rather slow.

Mr. McGregor's Proposed Harbour.

I come now to Mr. McGregor's proposal to form a close harbour between Napier Bluff and the existing entrance. Having already referred to the inexhaustible source of the shingle supply, and quoted instances in proof of its rapid accretion when its normal travel northward is opposed by a barrier on the shore, the ground is cleared for a consideration of this subject. Mr. McGregor has put forward alternative proposals: one for a close harbour, having 55 acres of available water space for shipping, with 24 feet at low water about the position of the entrance; the alternate plan contemplating a close harbour of similar shape, having an area of 120 acres, with a depth at the entrance of 27 feet at low water. The estimated cost of the former was £160,000, and of the latter £246,000. These estimates were based on the assumption that the sheltering work, which in each case was to be practically at right angles with the shore line, starting from a point a little more than a quarter of a mile on the harbour side of the Bluff, should be formed with a substantial facing and top of cement concrete, with a hearting of loose rubble stone, similar to the breakwater at Oamaru. Since, however, the foregoing estimates were prepared, I gather that it has been found expedient to make the Oamaru section of solid concrete throughout, the rubble hearting being dispensed with. Therefore, if a similar substitution of concrete for rubble were adopted for the outer pier at Napier Bluff, the estimated cost of the works must be added to accordingly.

The question must not, however, be decided upon the point of cost, nor upon the mode of construction proposed, but upon the broad principle as to whether the entrance to any harbour run out from this shore—either as proposed by Mr. McGregor, or otherwise—would not, in the absence of backwater, become so blocked by shingle after a time as to render the works practically useless. Having carefully considered this feature of the case, I am reluctantly compelled to express an opinion that such would be the result. The shingle travelling along the coast between the Tuki Tuki and Napier Bluff would gather against the back of the protecting pier, and, turning around the curve or knuckle, would pass along the outer kant and be deposited in the entrance and under the lee of the westernmost work.

In my view it is not possible, under the conditions which prevail at this place, to maintain a permanent entrance of adequate depth across the line of shingle drift without the aid of strong currents, such as are generated by the filling and emptying of the backwater, and, seeing that such a vast tidal reservoir is available for the keeping open of the entrance, there can, in my opinion, be no question that the proper course to adopt will be to devote any funds which may be available to the improvement of the existing entrance to the harbour, rather than to embark in any separate undertaking, which, in the absence of the necessary scouring agency, would inevitably prove a failure.

If the requirements of navigation should at any time be such as to render the construction of a harbour of refuge somewhere on this part of the coast of the North Island a matter of necessity, I should in that event give a decided preference to a site on the shore at a short distance to the westward of Cape Kidnappers, or on the southern shore of Poverty Bay to the westward of Young Nick's Head, as compared with Napier Bluff. I apprehend, however, that the necessity for a harbour of this class hereabouts has not only not yet arisen, but that it is not likely to arise for a long time to come, if at all.

Recommendations.

On the accompanying drawing the works I have to propose are shown by red colour. They may be divided into three groups, viz.: 1st. Works for the improvement of the entrance immediately required. 2nd. Works for the further improvement of the entrance, to be undertaken as soon after the completion of the first instalment as may be considered expedient, having regard to the outlay required thereon. 3rd. Prospective works for increasing the internal accommodation and berthage of the port. These last-named are not put forward even for early execution, but as affording the lines upon which additional facilities of this character should be provided, if the trade of the port should hereafter call for such accommodation.

First Instalment of Proposed Works.

By referring to the drawing, it will be seen that the first instalment of the proposed works would consist of extensions of the east and west piers respectively, each for a length of 400 feet in a straight line beyond the present terminations; thus leaving the ends of the piers in the same relative positions as at present. I regard the existing overlap of the west pier by the east as being just sufficient to

admit of the travel of the shingle across the mouth of the harbour, and at the same time to afford the fullest measure of concentration of the currents where most required. Mr. Weber has proposed, in his report of 25th March, 1879, to extend the eastern pier 400 feet; but unless this were accompanied by a corresponding prolongation of the western work, but little benefit would accrue to the entrance, for, notwithstanding that a considerable addition to the storage area for shingle eastward of the east pier would thus be provided, no practical addition to the scouring effect of the currents would be afforded. Moreover, after a time this increased area would also become filled, and the low-water line would again reach the end of the extended pier, whereupon the travel across the mouth of the harbour would be resumed, and it would then become imperative for the keeping open of the entrance that the west pier should be similarly prolonged. My view is that both piers should be extended simultaneously, and if funds cannot be found for the adoption of this course, that the works should remain at their present lengths, securing their outer ends to prevent damage by inshore gales. I regard the maintenance of the relative positions of the two existing pier-heads as of the highest importance, whether extensions be undertaken or otherwise.

The mode of construction I would recommend for the proposed extensions is similar to that of the existing piers, except that the continuous sheeting, or facing, both on the sea and channel sides, should be of whole instead of half timbers, and that the external piling should be battered at 1¼ inches to 1 foot instead of being driven vertically, the internal diagonal ties being securely double-bolted to the piles, instead of attached to the cross braces. The top of the innermost 150 feet of each extension should be inclined at a gradient of 1 in 50 from 6 feet above high water of spring tides, the level of the present piers, to 9 feet above high water, at which latter level the remainder of the work would be finished. The addition to the thickness of the sheeting, and the increased height of the extensions, are necessary in order to provide for greater wave-stroke and exposure than in the case of the present structures. During the execution of the foregoing works, the channel between the piers should be deepened for a width of 150 feet, so as to give 10 feet at low water, or 15 feet 6 inches at high water of spring tides, being the permanent navigable depth in the entrance which the pier extension and improved channel may be expected to afford.

It would no doubt be practicable to execute, in course of time, the requisite deepening of the channel by the use of dynamite and a rake, as practised prior to the date of Mr. Weber's report; but it is in every way preferable, in the interests of economy and progress, that this deepening should be effected in the usual manner by dredging, aided perhaps by the occasional use of dynamite to loosen, and if need be to break up, any boulders that may be closely packed together or too large to be lifted by the dredging apparatus. I may observe that, without pronouncing a positive opinion on the point, it is not made clear to me that these boulders have travelled along from Napier Bluff. The quantity of material to be removed is not large, and if advantage were taken of periods of slack water and low tides a dredge might be employed with useful effect, notwithstanding the rapid currents to which I have referred.

Second Instalment of Proposed Works.

The second instalment of the works for the improvement of the entrance would consist of a further prolongation of the east and west pier each to the extent of 400 feet, still maintaining a parallel waterway between the structures of 400 feet in width. The mode of construction would be the same as described for the first instalment, except that the seaward end of each pier would terminate with a mass of Portland cement concrete, deposited within a sheet-piled casing. The channel would be still further improved by dredging to at least 12 feet below low water of spring tides, or 17 feet 6 inches below high water, a bottom width of 150 feet being still maintained. This increased depth in the fairway would enable full advantage to be obtained for navigation purposes of the benefits to be derived from the prolongation of the piers.

Under existing conditions, the tide continues to run into the harbour until the water level has fallen 12 inches below high water at sea, and similarly it runs out at low water until the tide has risen 15 inches at sea, thus showing that the existing entrance is of insufficient sectional capacity to perfectly fill and empty the tidal reservoir. In the case of such a large area it is not practicable to fill the entire backwater to the level of high water at sea during springs, but nevertheless the improved channel will tend in this direction, and therefore add to the tidal volume.

Prospective Works.

I have indicated by red-edged lines on the drawing the manner in which the "Iron Pot" might be converted into a small tidal basin, having a capacity of 3¾ acres. I have also shown by dotted red lines how the berthage accommodation can be still further increased, if required at any time hereafter, by constructing in sections, as desired, an inner floating basin or dock connected with the proposed outer basin on the site of the Iron Pot. A swing bridge between the two floats would carry the main road from the railway-station across the entrance to the inner dock.

Estimates.

I estimate the cost of the proposed works as follows:—

First Instalment—	£
Extension of east pier, 400 feet in length	18,813
Extension of west pier, 400 feet in length	18,878
	37,691
Deepening entrance-channel to 10 feet below low water of spring tides	3,552
Total first instalment	£41,243

	£
Second Instalment—	
Extension of east pier for a further length of 400 feet, making, with the first instalment, 800 feet beyond the present termination, including concrete head	23,266
Extension of west pier a further distance of 400 feet, including concrete head	21,617
	44,883
Further deepening entrance-channel to 12 feet below low water of spring tides ...	4,638
Total second instalment...	£49,521
Gross estimate for the two instalments of pier extensions, with deepening of entrance channel to the full extent described on plan	£90,764

The foregoing estimates include a fair allowance for contingencies and supervision, and for the upkeep of plant. No sum has been put down for the hire of a dredger, but only for the working charges of the machine. It will be observed that the sum I have named for the extension of the east pier is considerably in excess of the estimate for this work given by Mr. Weber in his report of 25th March, 1879—namely, £12,000, or £30 per foot lineal of pier, whereas my estimate is £18,813 or £47 per foot lineal. The extra thickness of the sheeting and the additional height of the work, which I consider to be absolutely necessary, will mainly account for this difference. The estimate is based on the rates for labour and materials furnished by Mr. Weber in the memorandum prepared for my information.

Bridge across the Harbour.

With regard to the suggested bridge across the harbour, from West Quay on the south-east side to the intended Meanee Quay on the north-west, I have to state that, provided one opening span were formed over the deep-water channel near the centre, there would be no objection to such a structure as far as navigation is concerned. Seeing, however, that the proposed bridge is nearly half a mile in length, the cost would be so heavy that its construction would not, in my opinion, be justified in the present circumstances of the district.

Conclusion.

I must not conclude this report without expressing my obligations to Mr. Kinross, the Chairman, and Mr. John Alexander Smith, one of the members of the Napier Harbour Board, both of whom greatly facilitated my inquiries whilst in the locality. My thanks are also due to Mr. Carruthers, C.E., by whom the works at the entrance executed to this time were designed, and who was good enough to attend during my local examination, as also did Mr. Blackett, C.E., the Marine Engineer of the colony. Mr. C. Weber, Engineer to the Board, has furnished the necessary facts and data in a complete and satisfactory manner; and Mr. Kraeft, the Harbourmaster at the time of my visit, gave me useful information as to the set of tides in the southern part of the bay and at the harbour entrance.

I have, &c.,

The Secretary, Marine Department, Wellington. JOHN COODE.

NEW RIVER (INVERCARGILL).

SIR,— 5, Westminster Chambers, London, S.W., August, 1879.

I have now the honor to submit my report on the improvement of the navigation near the town of Invercargill, at the head of the New River Estuary, and about 9 miles from the sea. Being the point of junction between the lines of railway from the north, the east, and the west, Invercargill is obviously destined to become a place of considerable importance. The object sought to be attained in this case is the creation of such an additional depth in the channel leading up to the town jetty as will give 9 feet at low water of spring tides, equivalent to 17½ feet at high-water springs, and 15 feet at high-water neaps.

After due consideration of the circumstances of this case, I am of opinion that the object in view will be best accomplished by the formation of a channel and training bank upon the lines shown in red colour on the accompanying drawing.

By reference to this drawing it will be seen that I propose to form a channel from the upper end of "The Pool," situated about half a mile below the existing jetty, to a point just above the powder magazine, where the new channel would join with the existing river course. As indicated on the drawing, there would be a swinging basin at a short distance above the jetty, where vessels could be turned. From the upper or north end of this swinging basin the bottom of the new channel would be formed, at an inclination of 1 in 250, until it meets the present river-bed. The channel would, I consider, be sufficiently wide if executed with a bottom width of 100 feet; it could be widened at any future time to 150 feet if found necessary, which, however, is not probable; the depth should not be less than 9 feet at low water of spring tides, as already described. The side slopes would vary according to the nature of the material passed through: slopes of 12 to 1 are allowed for where in mud, 6 to 1 in sand or gravel, and 3 to 1 in clay. I may remark that an allowance is made in the estimate for the scouring away by the currents, during progress, of one-fourth of the quantity of mud shown upon the sections supplied to me from the colony, the dredging of the full quantity of sand, gravel, and clay have, however, been estimated for.

I should here remark that owing to a question with respect to the identity of some of the colours on the boring diagrams, and in the absence of written descriptions on the respective bore-holes, there is a doubt as to the level at which the rock exists in two or three cases; it is therefore desirable before any work is actually commenced, that trials should be made with probing rods or otherwise, along the line of channel, and (although scarcely probable that such will be the case) the line laid down on the

accompanying drawing may, if necessary, be modified, so as to avoid encountering rock within the limits of 9 feet below low water of spring tides, the level proposed for the bottom.

On the eastern side of the new channel, a training bank, 3,000 feet in length, formed of brushwood and rubble stone deposited from barges, should be constructed in the position shown on the drawing, and indicated by the letters *A*, *B*. This bank would be brought up to half-tide level, the top being 4 feet 6 inches wide, with side slopes of 1¼ to 1. A substantial stone beacon, with pole and ball, should be erected at the lower or southern end of the bank, together with a small beacon or perch midway between the southernmost or principal beacon, and the end of the jetty.

I estimate the cost of the channel, training bank, and beacons hereinbefore recommended, at £41,200, assuming that a suitable dredger and barges are available, and that the works will not be debited on account thereof with a greater amount than may be requisite for their upkeep and working charges during the formation of the channel.

The jetty extension, 400 feet in length, shown by red crossed lines on the drawing, would cost £10,400 if constructed with colonial timber; the expenditure upon the channel, training bank, and jetty extension would therefore together amount to £51,600, including a proper allowance for contingencies and supervision. If the jetty were extended 200 feet only, in the first instance, the cost of this would be £5,200, which, added to the estimate for the channel, &c. (£41,200), would give a total outlay of £46,400, for a less expenditure than which proper works cannot be provided.

In making the foregoing recommendations it has been assumed there is a depth of not less than 9 feet at low water of spring tides in the fairway of the present channel between the sea and the Pool. I mention this because the survey made by Mr. J. T. Thompson twenty-three years since (a copy of which has been sent to me with the documents), shows that opposite and just to the southward of Bushy Point—which is about 2⅔ miles below the town—there was, in 1856, a shoal place in the river with only from 5 to 7 feet over it at low water of spring tides, but, according to the information given me when examining the site, there was then not less than 9 feet at low water of springs in any part of the navigable track between Bushy Point and the sea.

At the time of my inspection the town jetty was not in a fit condition for the passage of heavy traffic over it. I have not included in the foregoing estimate any sum for strengthening this jetty, feeling that this can be determined more exactly in the locality, after a detailed survey and examination of the different parts of the structure.

The works I have hereinbefore described and recommended will, in my opinion, be found sufficient to meet the requirements of Invercargill for many years to come. Having regard to the physical conditions of the site, and its position with reference to the deep-water harbour at the Bluff, it would not, I consider, be expedient for the present to embark in more extensive improvements at this port than those I have recommended.

The training bank, having a concave curve, will insure the permanence of the deep water on the town side of the channel, and along the face of the proposed jetty extension. With the aid of this bank the new channel should be self-maintaining, but in the absence of the influence it would exert in directing the river and tidal currents the continuance of the full depth could not be relied on.

I must not omit to mention that Mr. Hatch, the Mayor of Invercargill at the time of my inspection, and Chairman of the Harbour Board, afforded me every possible facility in the course of my local examination. Mr. Austin, C.E., of the Public Works Department, rendered me great assistance in procuring copies of maps, &c., of this locality.

I have, &c.,

The Secretary, Marine Department, Wellington. JOHN COODE.

NEW PLYMOUTH.

SIR,— 5, Westminster Chambers, London, S.W., 20th February, 1879.

I have now the honor to submit my report on the improvement of the harbour of New Plymouth.

In addition to the personal examination made in May last, I have had before me the reports prepared by Messrs. Balfour and Doyne in 1865, and by Messrs. Carruthers and Blackett in 1875. The joint recommendation of the latter gentlemen received the approval of the Government, as required by the Act under which the Harbour Board derives its authority, but I understand that the Commissioners have decided to suspend operations until the receipt of this report.

So far as I could learn at the time of my inspection, there seemed to be some difference of opinion as to the expediency of constructing a harbour of refuge at New Plymouth. I ascertained by inquiry from Captain Holford, the Harbourmaster, that vessels from Europe, India, &c., approached this part of New Zealand from the south-west; and, inasmuch as by far the greater number of those are bound for Wellington, Nelson, or elsewhere within the Straits, it would, as a rule, be more advisable in bad weather for them to run for shelter into Blind Bay, or some one or other of the Sounds on the north side of the South Island, than to make for New Plymouth. It appears, therefore, that the provision of a sheltered anchorage at this site would be of value to sailing vessels employed in the coasting trade of this part of the colony rather than to vessels engaged in ocean traffic.

From a clear and comprehensive memorandum kindly furnished to me at the time of my visit by Mr. Kelly, the Chairman, I learn that the Harbour Board desires to obtain the greatest possible present benefit in harbour accommodation from the expenditure of a sum not exceeding £200,000, which is the maximum amount now available. Mr. Kelly states that the Board "objects to sacrifice the convenience of the present generation for a greater possible benefit to a future one, but is quite willing that the money available should go in the construction of part of a large scheme of harbour works, provided that its expenditure produces an immediate benefit as the work proceeds." The general soundness of these views cannot, I think, be questioned.

Looking to the probable future development of the resources of this very fertile district, I have regarded it as an essential feature in any design for harbour works at New Plymouth that, whilst

nothing should be done to sacrifice present convenience, or to incur an expenditure which will not result in the greatest possible benefit at the earliest possible date, the necessity for future extensions should be kept prominently in view.

The harbour works now to be undertaken ought therefore to be so arranged that they will admit of additions hereafter, as and when required; and so that incongruities, or the necessity for removing any portions of the executed works may be avoided. In this way only can a complete and comprehensive scheme be ultimately produced.

The merits and demerits of the designs by Messrs. Balfour and Doyne for works both at the "Sugar Loaves" site, and opposite to the Town of New Plymouth, have been clearly pointed out by Messrs. Carruthers and Blackett in their report of 27th November, 1875; it is unnecessary, therefore, to enter upon them here.

In the same report Messrs Carruthers and Blackett fully and fairly describe the relative advantages and disadvantages of the "Sugar Loaves" site and the "Town" site in the following terms. They say: "This (the 'Sugar Loaves') site we recommend as the best on all accounts, except its distance from the town, which will be about two miles, and the consequent necessity of the extension of the railway. On every other ground we are of opinion that there can be no comparison between this and the town site. It is close to the quarry, and the work could therefore be carried on more expeditiously. A much greater length of quay-room, with depth of water sufficient for large vessels, would be available; the holding-ground is better; the access to the harbour would be safe in westerly weather; and, finally, the whole of the works would be protected by the natural barrier formed by the Sugar Loaves, which would break the swell of the westerly and north-westerly seas—those being the heaviest to which the coast is exposed.

Concurring in these views, I have confined my attention to that part of the bay which lies between Mikoti (Mikotahi) and Moturoa on the west.

Accompanying this report are two illustrative drawings—namely: No. 1, a general plan of the roadstead, the foreshores, and the features of the adjoining country, extending from the Town of New Plymouth to the coastline outside Paritutu, reduced from the complete special survey made by Mr. E. C. Jones in 1877; No. 2 is a plan on a large scale, also prepared from Mr. Jones's survey, extending from Moon's Reef on the east, to Paritutu on the west. The respective proposals are shown by distinguishing colours on each of these drawings, as hereinafter explained.

The roadstead at New Plymouth is at present quite open for rather more than one-fourth of the compass, *i.e.*, from W. by S. to N. The heaviest seas are said to proceed from about W. and W.S.W. When from the southward of this quarter the seas on this part of the coast are stated to be not nearly so heavy as from the northward of that point up to W.N.W. With winds from the northward of this the seas are never very heavy. The bottom of the bay generally consists of by no means good holding-ground, the sand being in patches, with boulder stones occurring frequently. This, although prejudical to the site as a roadstead for anchorage, will not constitute a serious objection when the area is sheltered from the heavy westerly seas.

Bearing in mind the view I have previously expressed as to the paramount importance of providing the largest possible amount of present accommodation for the expenditure of the money now available, I have framed and had under consideration the two designs marked *A* and *B* respectively on Drawing No. 2. Design *A* is indicated by red colour and red lines, whilst Design *B* is shown in brown. Upon this drawing the full extent of the harbour projected by Messrs. Carruthers and Blackett is also denoted by green dotted lines and green colour.

It is proposed to construct, in the first instance, a west breakwater or mole, commencing at the salient point on the foreshore to the southward of Mikotahi, marked *A* on the drawing, near high-water level, and extending thence in a N.E. by N. $\frac{1}{2}$ N. direction for a length of 1,315 feet. The whole work would then trend to the eastward by a curve of 1,500 feet radius for a further length of 700 feet, terminating with a straight arm or kant 690 feet long, pointing N.E. by E. The total length of the breakwater to be executed under this section of the design would thus be 2,705 feet, and the line would correspond with that proposed by Messrs. Carruthers and Blackett, and approved in Council on 27th February, 1878.

The mode of construction I should recommend for the breakwater above described is shown upon the cross section annexed to this report. A work of this type is well adapted for the utilization of local materials and labour, and would necessitate only a very limited amount of diving operations. It also offers advantages over every other system for the successful employment of convicts. Seeing that it has been, and I presume still is, proposed to use convict labour to a large extent in the execution of harbour works at New Plymouth, it is essential that the mode of construction to be adopted should be of the simplest possible character, and dependent to the smallest extent upon the aid of skilled operatives. The breakwater should therefore be formed of rubble-stone, quarried at Paritutu, about 700 yards south-west of the starting-point, and conveyed thence over a self-acting incline, and deposited as *pierres perdues* from four lines of railway, carried upon a suitable timber staging of the type shown on the cross section. The materials would be distributed and consolidated by the waves until the normal angle of repose has been produced on the seaward face. This would be found to correspond very closely with the profile of the mole shown on the section. A protection parapet or bank of stone would be tipped along the crest of the breakwater, and faced on the south or harbour side by a substantial dry rubble-wall, skirting a roadway of 30 feet in width formed throughout the entire length of the work. On this road, and flush with its surface, there would be two permanent lines of railway of the colonial gauge.

Upon the annexed section the profile of the rubble-mound, as proposed by Messrs. Carruthers and Blackett, is shown by green-dotted lines. It will be seen that there is a general similarity between the two sets of slopes. There are two matters in connection with the proposed mode of construction which require a few words of explanation: First, with regard to the permanence of the mound and its sufficiency to resist the impact of the heaviest seas; and, secondly, as to the necessity for depositing the material from a timber staging. Upon the first of these heads, I may remark, after having

carried out extensive works in a similar manner at Portland (England) and Table Bay (South Africa), that it would be quite practicable to form a mound of the character recommended which will prove perfectly stable when the sea slopes have assumed their normal angle. The material available from Paritutu—a hard trachyte porphyry—is admirably adapted for a work of this class, and the wave-stroke is not so great as at Table Bay; hence there can be no doubt as to the sufficiency and permanence of the proposed mound at New Plymouth. Whilst, however, expressing the fullest confidence in the permanent stability of the work after the slopes have been flattened down to the inclinations shown, I desire to point out that during execution some fears will almost inevitably be engendered as to the sufficiency and ultimate permanence of the structure, in consequence of the occasional and recurring flattening down of the slopes by heavy gales during the process of forming the mound. But it must be borne in mind that the agency by which the material is distributed and trimmed to a proper slope is one of wave-action, the operations of the workmen being confined to depositing the stone, so that it shall ultimately produce a mound when "clawed" down by the sea with the least possible waste of material—a matter requiring care and judgment where the quantities to be dealt with are so vast. However much the apparent dislocation of the mound during progress may appear from the surface, it may be taken for granted that the action of the sea will only tend to distribute the rubble over the area required for the base of the work, and that the mole when finished will, as I have explained, partake very closely, if not actually, of the profile shown on the cross-section, although the seas of several winters would be necessary for the production of the ultimate slope as shown. In the meantime the rubble would be tipped on the top of the bank for the subsequent "feeding" of the slopes by the sea.

With regard to the necessity for a temporary staging from which to deposit the materials, it seems desirable that I should explain the reasons which have led me to recommend this mode of procedure, seeing that Messrs. Carruthers and Blackett proposed to form their mole of rubble without any such provision—and I speak after thirty years' experience in works of this particular class. Notwithstanding that the adoption of the stage would necessitate the employment of a special class of skilled labour, and be more liable to damage by seas of exceptional severity, than any other portion of the work, nevertheless great ultimate economy would result from the facilities it would afford under all circumstances for depositing the rubble, layer upon layer, with a long flat slope at the outer end during progress, and for "feeding" the sea-face throughout the length of the mole as may be required from time to time. Coupled with this there must be a considerable saving of material consequent upon a smaller section of mound, which would more than compensate for the cost of the temporary staging by reducing the expenditure on the permanent work. Moreover, it should be remembered that if made as a "flying-tip"—the alternative mode of depositing the rubble as compared with dropping from a stage—the slopes of the mole when first formed from the wagons, would be, as in the case of a railway embankment, at a steep angle, and thus subject to a much greater disturbance by heavy seas than would be the case were the bank to be deposited to flatter slopes, which could be readily done from a stage. For these reasons the adoption of the stage would, as I have said, result in a smaller ultimate section for the mound, and, consequently in a saving of material, as compared with the system of direct tipping from wagons running on tramways laid on the bank itself. I may further remark, with regard to this subject, that attempts have been made to form a mound of the character proposed without a stage; but the results have finally led to the adoption of a stage, as absolutely necessary for the economical and satisfactory progress of the work.

The outer end of the mole would be protected by blocks of cement concrete, each about 80 tons weight, formed *in situ*, and allowed to settle down by the action of the sea on the rubble on which they would rest. There would be a small cast-iron lighthouse at a convenient distance back from the end slope.

It will be readily understood from the description above given, coupled with the particulars furnished in the annexed cross-section, that no quayage accommodation for vessels would be afforded by the proposed breakwater itself. Shelter would be available under the lee of the work at all times for steamers and sailing-vessels of the class engaged in local trade, the depth covered by the breakwater at low-water spring tides being 24 feet at the outer end, while a considerable proportion of the area protected would be in from 12 feet to 24 feet at low water, or 24 feet and 36 feet at high water, the rise of tide at springs being taken at 12 feet. As the most ready means of providing berthage, I have laid down on the drawing three jetties, each of 500 feet in length, extending in an E.S.E. direction from the harbour edge of the proposed roadway along the breakwater. The outer of these jetties would consist of crib-work formed of piles, braces, and a decking of totara wood, filled in with rubble-stone from the proposed quarry at Paritutu, and arranged for berthing vessels along either face in fine weather; although on some occasions, owing to "scend" or undulation, it would not be practicable to use the outer or north-east side. The further shelter which would be afforded by this crib-work structure would enable the berthage on both faces of the two other jetties (which should be of open timber-piling and framing, also of totara) to be used on all occasions.

An approach to the breakwater from Barrett's Road would be formed somewhat in the manner shown in the drawings; the precise line for this new road can best be determined on the ground, seeing that sufficient details of the configuration of the site are not at hand here. It is not improbable, therefore, that the line I have sketched may require some modification.

I am informed by the Resident Engineer, Mr. Irvine, that the quantity of stone in Paritutu available for the purpose of the works is far in excess of that required. It will be well, before commencing operations, that this point should be again looked into, and clearly established, as the section I have proposed is of greater bulk than that recommended by Messrs. Carruthers and Blackett. I may mention that the construction of the mole from *A* to *B*, on Drawing No. 2, will require about 800,000 cubic yards of rubble stone, measured in the mound. Moreover, the disposition in the hill of the stone suitable for the proposed breakwater may be such as to render it desirable to modify the level of the top of the self-acting incline, and this can only be determined with certainty by opening out the face of the rock—and the entire quantity of stone of the proper quality, above the level of the head of the incline, at least—approximately ascertained.

It has been suggested that an opening, bridged by a viaduct, might be left between the coast line and the inner end of the western mole, with a view, I presume, of promoting tidal circulation within the area under the lee of the work, and so to prevent silting. A viaduct spanning an opening of this kind would prove a constant trouble and source of anxiety, and would necessitate raising its roadway to a much higher level than would be desirable along the solid work, hence requiring an inclined approach to connect with the road on the mole, and consequently interfering with traffic. Moreover, by dealing with the sand-drift in the manner hereinafter described, the necessity for the opening would be removed; and under the altered conditions it would certainly do more harm than good.

An extension of the west breakwater from *B* to *C* for a length of 1,050 feet in a N.E. by E. direction, in prolongation of the outer arm before described, is shown by red crossed lines on the drawings. The execution of this work in the same manner as the mole shown on the annexed cross-section would form the first instalment of extended harbour accommodation, when the requirements of the port shall have outgrown the facilities which would be afforded by the breakwater and jetties previously described. The second extension, also shown by red crossed lines, should consist of an eastern arm, commencing near high-water mark at the point *D* on Drawing No. 2, about 450 yards to the eastward of Bayly Road, and extending thence in a N.W. by N. direction for a length of 2,430 feet, terminating with a kant, W. by N. ½ N. and 655 feet long, so as to leave an opening or entrance of 500 feet in width, measured to the low-water edge of the harbour slope of the western mole. It will be seen that a most extensive harbour, having an area of 130 acres outside the one fathom contour line, would thus be formed. The shore end from *D* to *E* would consist of a rubble embankment, but from *E* to the outer end, at the point *F*, the work would be formed of blocks of concrete, set as masonry, and adapted for berthing vessels along the inner face.

The following table gives the acreages, depths, and lengths of berthage afforded by this design when fully completed:—

Areas Within the Harbour.

At low-water spring tides	162 acres.
One fathom and upwards at low water	130 „
Two fathoms and upwards at low water	98 „
Three fathoms and upwards at low water	46 „
Four fathoms and upwards at low water	20 „
Five fathoms and upwards at low water	5½ „

Berthage.

West breakwater—	
No. 1 jetty	1,000 lineal feet.
No. 2 jetty	1,000 „
No. 3 jetty	1,000 „
	3,000 „
East breakwater pier—	
Inner face, *E* to *F*...	1,800 „
Total berthage	4,800 „

Although I have described the works necessary for the full completion of Design A, I have not done so with a view to recommending them for adoption now, nor indeed for many years to come, seeing that their cost would be altogether beyond the sum now available for works at New Plymouth. My object has been merely to indicate the character of the extensions, and the order in which they should be undertaken, as and when required.

Design B.

In the early stages of my consideration of this subject, it appeared to me that some saving in first cost might possibly result from the adoption of a work commencing just to the westward of the whaling station, and extending into 3 fathoms at low water, which, if thoroughly sheltered, would have been sufficient for the accommodation of the local trade, hence it was that Design B was framed, and sections and estimates prepared for comparison with those of Design A.

On Drawing No. 2, Design B is shown by brown colour and lines, the portion which corresponds with the western mole and jetties of Design A being tinted, whilst the extensions are etched. It will be seen that the western arm of this proposal would commence on the foreshore at the north end of Barrett's Road, marked *G*, and extend N. ½ W. for 1,300 feet, thence N.E. by N. ½ N. for 600 feet, and again N.E. ½ E. for 800 feet, making together a work of 2,700 feet from the starting-point. At 100 feet back from the extreme end there would be a jetty 270 feet in length, at a right angle to the protecting work, to prevent "run" or undulation along the harbour face. From *G* to *H* the shore end would be formed of rubble-stone deposited as an embankment, but the remainder, from *H* to *J*, and also the jetty, would consist of blocks formed of Portland-cement concrete, built as masonry, the former being a solid structure set off the end by means of a "Hercules," or special setting machine, whilst the jetty, which would be sheltered, would be formed with main and cross walls filled in with a hearting of rubble-stone. The whole of the masonry face would be available as quayage, alongside which vessels could be berthed. The extensions of Design B should be undertaken simultaneously. They would consist of the prolongation of the outer kant of the western arm from *J* to *K* (on Drawing No. 2) for a length of 200 feet, and the construction of an eastern arm, commencing at the point *L* on the foreshore 300 yards eastward of Bayly Road, proceeding from thence as a rubble embankment in a N.W. by N. direction 1,225 feet, and thence as a masonry work from *M* to *N* in a W. by N. direction for a further length of 700 feet, terminating at a point 300 feet distant from the south-west end of the jetty, so as to form an entrance to the harbour of that width.

The following table shows the acreage of sheltered water and the lengths of the quayage which would be afforded by this design:—

Areas Within the Harbour.

At low-water spring tides	50 acres.
One fathom and upwards at low water	30 „
Two fathoms and upwards at low water	18½ „
Three fathoms and upwards at low water	1¾ „

Berthage.

West pier jetty—	
Both sides	540 lineal feet.
Inner face, *H* to *K*	1,560 „
	2,100 „
East pier—	
Inner face, *N* to *M*	700 „
Total berthage	2,800 „

Estimates.

I estimate the cost of the works above described as follows, viz.:—

	£
Design A:—	
1. The breakwater complete to *XX* on Drawing No. 2, being 1,920 feet from the starting-point, and a jetty of crib-work and rubble-stone on the line of No. 3, including approach, road, and self-acting incline, &c.	197,240
2. The breakwater complete to *YY* on Drowing No. 2, being 2,220 feet from the starting-point, and a jetty of crib-work and rubble-stone on the line of No. 2, including approach, road, incline, &c.	237,960
3. The breakwater complete from *A* to *B*, with a jetty of open timber-framing and piling on the line of No. 2, including approach, road, incline, &c.	284,230
4. The breakwater complete from *A* to *B* on Drawing No. 2, including approach, road, incline from quarry, &c.	267,800
5. Jetty No. 1, constructed by crib-work, filled with rubble-stone, including formation of masonry abutment, &c.	34,500
6. Jetty No. 2, of open timber-framing and piling, including formation of masonry abutment, &c.	16,430
Design B:—	
West pier complete from *G* to *J* on Drawing No. 2, with jetty of masonry, incline, road from quarry, &c.	295,400
Extensions—Design A:—	
Extension of west mole from *B* to *C*	182,300
Extension of east breakwater pier from *D* to *E*, and approach road complete	427,700
Design B:—	
Extension of west pier from *J* to *K*, and formation of east pier from *L* to *N*, with approach road	211,700

The above estimates include a fair allowance for contingencies and supervision, also permanent railways of 3 feet 6 inch gauge, and are based upon the assumption that the works are executed by free labour in each case.

The point now to be determined is, which of the two western works—namely, that of Design A, or of Design B, should be adopted. I think there can be no doubt that the balance of advantage is in favour of Design A, coloured red in the drawings. Not only would this design afford a greater area of shelter in deeper water than Design B, but the mode of construction proposed would be better adapted for the utilization of convict labour than the masonry pier and jetty contemplated in the latter design. Moreover, without desiring to lay undue stress upon the importance of providing for future extensions, it will be evident that Design A is incomparably superior to B in respect of the scope which it offers for future development.

The alternative modes of procedure are as follow:—

If the amount which can be raised for the purposes of the works will not exceed £200,000, and convict labour will not be available, then the execution of the west mole to the point *XX* on Drawing No. 2, together with the construction of a jetty of crib-work filled with rubble-stone, might be undertaken with estimate No. 1. The employment of convicts will cheapen construction, although it is impossible now to determine to what extent, seeing that the number of convicts and the degree to which the works would be debited on their account cannot be stated. Much also would depend upon the length of the sentences of the men—long-sentenced convicts, by reason of the experience they gain upon the works, being far more useful than men who are imprisoned for short periods. With regard to the terms upon which convict labour is usually obtained on colonial works, I may remark that I am at present engaged in carrying out marine works where convict labour is largely employed, the works being debited only with the cost of the barracks and with such special overseers as may be required. In these cases a slight gratuity, termed "exertion-money," is given to the convicts as a reward for extra work. If convict labour can be had at New Plymouth upon this basis, the cost of the works will be reduced; and it is not improbable that the breakwater might be completed to *YY*, with a jetty of crib-work and rubble-stone on the line of No. 2, for the sum of £200,000. In either of the above cases, whether the mole terminated at *XX* or *YY*, a jetty for berthing vessels would be provided,

although in the former case, with a jetty on the line of No. 3, the depth alongside would be only from 13 to 14 feet at spring tides, and consequently the accommodation thus afforded would be limited.

There is yet another mode of procedure—namely, to carry the breakwater as far as practicable for the sum of £200,000 upon the line laid down, obtaining berthage hereafter; and I should prefer this course to stopping the work at *XX* with a jetty on the line of No. 3.

I have thought it desirable to go thus fully into the alternative proposals in order to anticipate points which might be raised in the colony. Briefly, however, I may summarise the recommendations as follows: If convict labour be available, and the amount to be expended on the works £200,000, then I would advise that the work should terminate at *YY*, with a jetty on the line of No. 2. If convict labour be not available, and the sum to be expended is also £200,000, then the breakwater should be carried as far as practicable for that amount without a jetty, in which case the work could terminate at about the point marked *YY*.

In addition to the mode of construction herein recommended, I have carefully considered whether the work could not be cheapened by the adoption of some other type of section; but, upon taking out quantities and preparing estimates of cost, I find that the system proposed and before described is undoubtedly the most economical under the circumstances.

To the southward and eastward of Paritutu there is, as shown upon the plans, a considerable area of ground covered by loose sand, which, during strong westerly winds, drifts towards the bay. It will be an important preliminary step to adopt measures for preventing further accumulations, and for fixing the sand which may be on the surface. I would therefore recommend that the *débris* from the quarrying operations should be run out from Paritutu in the form of a high embankment, in a southerly direction (on a line to be hereafter determined), with a view of deflecting the travel of the sand. The whole of the sand-covered area should be planted at the proper season of the year with seeds of *Arundo arenaria*, or some other species of bent-grass adapted for fixing the sand. With the same objects in view, but as an additional safeguard, I would further recommend that seeds of *Pinus maritimus* should be planted in the form of a belt along a line running S.W. from the centre of Paritutu. In each case the seeds should be protected by a light covering of bush, spread over the entire surface of the ground. If the above precautions are adopted, there will be no reason to apprehend a reduction of the depth of sheltered water under the lee of the proposed work from blown sands.

I desire, in conclusion, to express my thanks to Mr. Kelly (then Chairman of the Harbour Board), as also to Mr. F. A. Carrington, and Mr. Weston, who, at the time of my visit to New Plymouth, afforded me every assistance. Mr. C. D. Irvine, Resident Engineer, and Captain Holford, Harbour-master, attended to my wishes, and met all my requirements.

At New Plymouth, as at all the other ports inspected in New Zealand, I had the privilege of being accompanied and aided by Mr. Blackett, Marine Engineer of the colony, and to him my obligations are especially due. It would scarcely be justice to Mr. Blackett if I omitted to mention the fact that, although he had accompanied me on my tour of inspection for some weeks previously, it was only on arrival at New Plymouth that I became aware of the circumstance of his having taken any part whatever in proposing a plan for the harbour works at this place.

I have, &c.,
JOHN COODE.

The Secretary, Marine Department, Wellington.

OTAGO HARBOUR.

SIR,— 5, Westminster Chambers, London, S.W., March, 1880.

In compliance with the request that I should report generally upon Otago Harbour, and the Board's plan of improvements, and also specially upon certain questions remitted to me, I have the honor to state that having carefully considered the whole subject, paying due regard to the information contained in the numerous documents furnished, I now beg to present my report thereon.

My study of the questions connected with the improvement of the harbour has been greatly facilitated by the plan, on a large scale, showing the results of the survey completed by the Board's Engineer, Mr. Simpson, since the time of my inspection. This plan embraces the whole harbour from outside of the bar to the city, and will undoubtedly be found most useful, not only in the execution of works, but also as a record of progress, and as a standard for ascertaining and recording results and changes.

Recent Modifications.

I gather from some of the papers which have last come to hand, that since the time of my inspection the question of the extent of reclamation along the foreshore at Dunedin has been definitely settled, and that permission has been given to the Harbour Board to reclaim Ravensbourne, Burke's, and Shag Bays in consideration of their not reclaiming 80 acres at the head of the harbour lying to the southward of the city, as had been proposed.

Bearing in mind the paramount importance of preserving as much tidal water as possible in the uppermost part of the harbour, the abandonment of the proposal to reclaim 80 acres at its upper extremity is a departure from the original intention, which, in my opinion, cannot be regarded as otherwise than beneficial. With respect to the railway-station reclamation, I gather from Plan No. 5 that the eastern boundary of the new station-yard is intended to be within 100 feet of the edge of the quays which lie on the westernmost sides of the two southern basins. If it be found practicable to increase this width to at least 150 feet, I think it very desirable that this should be done, in order to avoid what I should fear would otherwise be ultimately found to be a great inconvenience, arising from want of space for conducting the trade along the dock side. I would therefore recommend that, if not now too late, this matter be reconsidered before the site be wholly appropriated to railway-station purposes.

Works in Progress—Docks.

With respect to the basins and quays in course of construction at the city, these are on the whole well devised. I should remark, however, with regard to the large "New Tidal Basin," that, according to Plan 5, the water space will be about 68½ acres, and the lineal feet of quayage 5,700 feet; I presume it is intended that further quayage shall eventually be provided, and I would recommend that such jetties as may be introduced into the basin for this purpose should be so arranged as to admit of the ultimate formation of a total of not less than about 15,000 feet of quayage. The steamers' basin immediately to the south of Rattray Street should also eventually have a jetty introduced into it, so as to give, say, from 1,500 to 1,800 feet lineal of additional quayage.

So far as I can gather from two or three of the plans, and more especially from Drawing No. 1, it would seem that the whole of the area to be reclaimed on the north-east side of the "New Tidal Basin" is intended to be ultimately appropriated for buildings and streets, apparently for an extension of the city. If I am correct in the assumption that this is contemplated, I would suggest that this proposal should be very carefully reconsidered, and would recommend that the entire area lying to the northward of the basin—namely, between the line of Frederick Street and the south side of the channel to be left for the passage of the "Water of Leith," eastward of Logan's Point, should be strictly reserved for purposes in connection with dock and harbour traffic.

New Channel between Dunedin and Port Chalmers.

The adoption by Mr. Simpson of the northern, in preference to the southern, channel between Dunedin and Port Chalmers as that in which the works of improvement should be carried out, is, I consider, judicious, seeing that this line will give the shorter route: it will afford easier curves in the sailing course or track of vessels, and at the same time will form a better approach to and passage from the docks at the city.

With respect to the precise line or track for the improved channel, the documents sent to me do not furnish definite information as to the quantity of dredging that had been actually executed, or the exact line on which it was being carried on at the time the papers were sent from the colony. I can therefore only say that I should still give the preference to the line which I indicated as an approximation when in the colony; but this was understood to be dependent in some degree upon the results of the borings to be made in the positions which I then defined. These borings have shown this line to be free from objection or obstacle, in so far as regards the absence of materials that would be difficult or costly to remove by dredging. Its general direction does not differ very materially from that proposed by Mr. Simpson; the difference between the two consists mainly in the positions of the south-eastern low-water margin of the channel, which I consider should be brought nearer to the north-western shore.

The following tabular statement will show the line I should certainly have proposed were the dredging operations now to be undertaken *ab initio;* and if in the dredging now remaining to be carried out a nearer approach to this line can be attained, even if only in a portion of the length, without any serious sacrifice of work already executed, I would recommend that this should be done. I have assumed that the ultimate bottom width of the channel would be 300 feet, that the depth in the first instance would be 18 feet at low-water of spring tides, to be ultimately increased to 21 feet, and that the side slopes would take an average inclination of 8 to 1:—

Points at which the distances are taken.	Distance of south-east training bank from the low-water edge on the north-west shore.
Opposite Curle's Point, at west end of Arden Bay	900 feet
Opposite Whitestone Point, which divides Shag Point from Burke's Bay...	950 feet
Opposite Green Point, *i.e.*, at 600 yards below old lighthouse at Ravensbourne	700 feet
Opposite Black Jack's Point, at south-west end of Ravensbourne Bay	650 feet

If the south-eastern training bank were placed as above indicated, a similar bank on the north-western side would not, in my opinion, be necessary, unless perhaps it might be for a length of, say, 2,000 yards below Whitestone Point, at the lower end of Shag Bay.

The advantage to be gained by the adoption of the line I have here described would be the utilization to the greatest practicable extent of the natural shore, as a guiding or training bank for the tidal currents.

It should be understood that I do not go so far as to say that, in the absence of a second or north-western training-bank, the line as originally laid out will certainly require an undue amount of dredging to maintain the navigable depth: but there can, I consider, be no doubt or question whatever that the line I have suggested would have a very decided advantage in this respect, seeing that its adoption would render it certain that a second training-bank would not be required for at least the greatest part if not the whole of the length; whereas with the line originally proposed the maintenance of the depth without dredging in the absence of a second training-bank would, to say the least, be problematical.

As already mentioned there is not sufficient information at present available here to enable me to say precisely upon what line and to what extent dredging may have been done; but, seeing that the adoption of the line I have indicated by the measurement in the foregoing tabular statement would effect a reduction in the quantity of dredging of somewhere about 1,800,000 yards (or say 25 per cent.) as compared with the line shown in red on Drawing No. 1 (cloth tracing) forwarded to me from the colony, it may still be open to consideration whether my suggestion on this head could not be advantageously adopted, even if it were only in part. The decision on this point should, as I have previously intimated, be determined by the extent of dredging which may have been executed up to this time upon the line originally proposed.

Training Banks or Half-tide Walls.

With regard to the necessity or otherwise for the half-tide wall or training-bank proposed by the Board's Engineer (No. 2 of the questions remitted to me), I may here observe, as will indeed have been gathered from the foregoing remarks, that I regard such a work as essentially necessary, in order to insure the maintenance of the artificial channel without frequent if not constant dredging; and I am of opinion that the bank should be undertaken contemporaneously with the formation of the channel.

I gather from the documents that the half-tide wall or training bank is intended to be formed of rubble-stone. As to this I would suggest, for the consideration of the Board and their Engineer, whether this training-bank could not be executed with fascines (faggots) at a material saving in cost. If so, it would be equally efficient in performing the work of training the currents, and, in point of durability would leave but little to be desired, seeing that the fascines would eventually become so embedded in and surrounded by sand, &c., that they might be regarded as practically permanent. In one of the rivers on the east coast of England with which I am professionally connected, I know of a case in which fascine-work put down nearly half a century since is still in existence, and acting satisfactorily in preserving the sides of the channel.

Being formed of alternate layers of fascines and clay, with a thin coating of stone on the top, and arranged so as to batter 6 inches for each foot of height, the base would be large, and consequently the weight per superficial foot but small, in proportion to the height of the bank itself, the settlement would therefore be relatively very slight; the sectional area of a training-bank thus formed would be less, and the cost also less, than if composed of rubble-stone. Moreover, in the event of a vessel accidentally touching the bank at any time, the risk of her sustaining damage would be reduced to a minimum as compared with a bank formed wholly of stone.

Above Black Jack's Point the southern training-bank should sweep gradually around, so that it would be generally parallel to the south-eastern or harbour frontage of the new docks, and about 1,000 feet distant therefrom. It would be well that, in the first instance, this bank should not be carried further towards the south-west than the point where it would be intersected by an imaginary line drawn in prolongation of the jetty at the end of Stuart Street; it could be continued at any time if circumstances should require. The width of 1,000 feet or thereabouts will be quite sufficient to admit of vessels of the largest class entering and leaving the basins without any difficulty. If a greater width were adopted, there would be reason to apprehend that an undue amount of dredging would be found necessary to preserve the requisite depth.

Reclamation of Ravensbourne, Shag, and Burke's Bays.

With regard to the question (No. 1), whether the taking of the Dunedin and Port Chalmers Railway straight from point to point of the three bays—Ravensbourne, Shag, and Burke's—would prejudicially affect the interests of the harbour: I consider that if the railway embankments be so formed as to present fair and even lines for the easy flow of the tidal waters along their river faces, their effect in preserving the momentum of the tidal currents will be such as will practically give an equivalent for the tidal water abstracted. I am of opinion, therefore, that the reclamation of the three bays will not be prejudicial to the interests of the harbour, provided the river faces of the embankments be formed in the manner above described.

Landing of Dredged Materials for Reclamations, as proposed by the Board's Engineer.

As to the third question—namely, my opinion of the method of reclaiming with the dredged materials, as proposed by the Board's Engineer: I have carefully considered this matter, and, in view of the large expenditure upon the special appliances required to carry the proposal into effect, estimated at about £24,000 for the barges, trucks, and incline, I am of opinion that it would be inexpedient to incur so large an outlay upon the preliminaries for what must necessarily be regarded as an experiment, and as to the satisfactory result of which, in point of economy, I entertain considerable doubt.

Mr. Duckham's Pneumatic Process for Landing Dredgings.

Question No. 4 has reference to the employment of Duckham's pneumatic process for reclaiming with the dredged materials. Looking at the fact that no inconsiderable portion of the borings are described as in "clay and sand," or in "compound sand and clay," this system is not, in my opinion, suitable for this case except, it might be, to a limited extent. There can be no doubt that Mr. Duckham's process is admirably adapted for dealing with materials in a semi-fluid condition, such as found at the Millwall Docks, where it is used for landing only soft silt and mud which have accumulated from time to time, and where there cannot be any admixture of clay or other solid matter.

As to other Methods of Landing Dredgings.

As to the question (No. 5), whether I could recommend a more expeditious and economical mode of reclaiming with the dredged materials than by the proposal of the Board's Engineer, or the pneumatic process of Mr. Duckham: I can only suggest either the adoption of mechanical "diggers," in connection with ordinary steam cranes, or the employment of a system of "skips" or "tubs" placed in barges in the manner described below.

If the former be resorted to, I would suggest the employment of self-filling and discharging diggers of the class introduced within the last few years, more especially of the hemispherical type, worked in connection with steam-cranes, by means of which the materials may be lifted from the barges and deposited in railway trucks on the land with a minimum amount of manual labour.

If the "skip" system be employed, I would suggest the use of the same method as was adopted by a contractor, Mr. Mitchell, under a patent of his own (now, I believe, expired) in part execution of a design of mine for the improvement of a river in Ireland some years since. In this case iron "skips" or "tubs" were placed side by side in chambers or cells in flat-bottomed barges, the skips fitting closely together in the barges, so that the materials delivered from the shoot of the dredger fell

of necessity into one or other of them. When the barges arrived at the point where they were to be discharged, the skips were lifted by steam-cranes, and, by means of a hook or other appliance at the bottom of the skip connected with a discharging-chain or rope, their contents were tipped into the railway trucks, and thereby conveyed to the point of deposit. If I remember rightly, the contractor at Dunedin was using an arrangement of this kind at the time of my visit.

I have much pleasure in acknowledging the courteous attention received during my inspection from the Hon. Mr. Reynolds, Chairman of the Board, and from Mr. Tewsley, Chairman of the Works Committee; also the aid rendered by the Board's officers, Mr. Simpson, the Engineer, Captain Thomson, the Harbourmaster, and Mr. Gillies, the Secretary, each and all of whom afforded me every possible assistance and facility for examining the works in progress and the port generally.

I have, &c.,

The Secretary, Marine Department, Wellington. JOHN COODE.

OTAGO BAR.

SIR,— 5, Westminister Chambers, London, S.W., 31st March, 1880.

In accordance with the Board's request, I have duly considered the question of the improvement of the bar at the entrance of Otago Harbour, and have now the honor to submit my views on the points upon which I understand the Board desire to be furnished with my opinion—that is to say, as to whether the measures to be adopted for the treatment of the bar should partake of a tentative or of a permanent character.

From the memorandum of your Engineer, Mr. Simpson, transmitted to me with the Board's instructions, I gather that the tentative measure referred to consists of the dredging of a channel in the line of the leading lights, and maintaining it to the required depth by periodical dredging.

Drawings.

I should premise that in studying this important subject I have been greatly aided by the very complete plan prepared by your Engineer, Mr. Simpson, showing soundings in great detail, not only over and seaward of the bar itself, but also within the estuary for a distance of more than two miles from Tairoa Head. This plan forms the ground-work of Drawing No. 2, which accompanies this report, No. 1 being the published Admiralty chart of the harbour. On both of these drawings the works which I shall hereinafter describe are shown by red colour.

Tentative Proposal.

First. With respect to the proposal to dredge a channel across the bar in the line of the leading lights, and to maintain it at the required depth by dredging operations:—

Bearing in mind the fact that the bar is the resultant, so to speak, of the power of the waves which heap up the sand, &c., and cause it to accumulate on the one hand, and, on the other, of the tidal scour which tends to keep down this accumulation, it follows that the benefit to be derived from any such operations as those directed to the creation and maintenance of deep water in the sailing track by means of dredging must of necessity, in the absence of permanent works, be very uncertain; and, to be of any real value, must be frequently repeated, if, indeed, as is by no means improbable, they were not required to be constant and continuous, in so far as the state of the sea on the bar might permit, seeing that much of the work of a dredger in the formation or clearance of a channel extending over some weeks, or perhaps months, would occasionally be undone in the course of a few hours.

There can be no doubt that if dredging on the bar is to be resorted to, a dredge-vessel of the hopper type is the proper kind of craft to employ. After making due allowance for the time necessary for such a vessel to go sufficiently far out to sea to dispose of the dredged material, without risk of any portion being carried back towards the entrance, and to return and take up her moorings, and allowing also for such occasional stoppages as will unavoidably take place, I do not think an average of more than 1,500 tons per day, for the days on which it may be practicable for the vessel to work on the bar, should be calculated upon, even with a dredger having a hopper capacity of 1,000 tons.

With regard to the quantity of materials to be removed in order to form a channel through the bar on the line of the leading lights, with a depth at low water of spring tides of 24 feet, and a bottom width of 200 feet, I find that such a channel or cut would necessitate the removal of somewhere about 120,000 tons of material.

Assuming, in the absence of borings or probings, that the whole of this quantity of dredging would be in sand, or other free material, the time that would be required to cut a channel of the dimensions above stated, taken at the rate of 1,500 tons per day—the rate before intimated—would be eighty days, or, say, three months of continuous working. It should not be overlooked, however, that so long a period as three months of continuous smooth water on the bar would not of course occur, and therefore the time over which the dredging operations would extend, although amounting to only eighty working days in the aggregate, would necessarily be prolonged to an extent dependent upon the prevalence and amount of sea disturbance on the bar. It is, further, important to remember that the wave-action, during so long a period as that of three months, could not be expected to do otherwise than to cause such frequent disturbances in the sand on either side of the dredged channel as would diminish both the width and depth of that portion of the new cut which might have been previously executed.

The frequency and extent of this prejudicial action would depend, as I have before stated, and necessarily so, upon the frequency and character of the changes of the sea disturbance, and therefore could not be predicted with any degree of confidence. The one point which is alone reasonably certain is, that the intervals of quiescence would be so short as to render the necessity for dredging operations so frequent as to be almost continuous during all but the finest seasons. It is only right to say, however, that experience extending over a series of years could alone determine, with any approach to

certainty, what the ultimate net result would be. I should much fear, however, that the depths of the water on the bar, although it is to be hoped that they might be frequently improved, would nevertheless be subject to periods of shoaling of such frequency and duration as would approach very nearly to the existing state of things, and thus render it very questionable whether the real improvement of the entrance to the port would be commensurate with the outlay that would have to be incurred.

Proposal for Permanent Works.

Secondly. With regard to works of a character that would effect a permanent improvement in the entrance: I have given much consideration to this phase of the question; but Mr. Simpson's plan, completed in March of last year, valuable as I have already stated it to be, does not, alone, furnish all the data necessary for arriving at definite conclusions with respect to the exact lines which should be adopted for works of a permanent character, nor the kind of construction best adapted to meet the circumstances of the case; the means of framing a reliable estimate of cost are, consequently, not at present available. I should here remark that, although I made a general examination of the entrance when at Dunedin, in the early part of 1878, the questions then placed before me had reference to the Upper Harbour alone. I refer to this in explanation of the reason for my not having included in the memorandum left by me in the colony of information required, or noted in a separate document, the particulars necessary for framing a definite design, and furnishing an estimate of the cost thereof.

Physical Features and Cause of Existing Evils.

The result of a careful study of this important branch of the question, by the light of the information at present available, has led me to the conclusion that the seas from the northward have had the effect of driving the sand, silt, &c., in suspension down into the bight on the southern shore between Williams's Point and Harrington's Point, until stopped by the tidal currents passing into and out from the upper part of the estuary. Having travelled thus far they have come under the shelter of the southern shore, and therefore out of the influence of any such forces as can carry them back again, the result being the existence of the extensive "sand-flat" on the northern shore within the entrance, and, as I have already pointed out, the unsatisfactory condition of the channel just within the bar.

As to the bar itself, its great length and the shallowness of the water upon it are both greatly aggravated by the presence of this sand-flat, seeing that the tidal streams are thereby so deflected as to cause them not only to turn at a right angle at about half a mile to the southward of Harrington's Point, but also—and this is by far the most serious evil—to cause both the ingoing and outgoing tidal currents to flow in a direction which is practically parallel to that of the onshore breakers, and therefore to pass (both inwards and outwards) along a course in which their power to combat the accumulations created by the waves is almost neutralized. Moreover, after passing Harrington's Point, and still more to the northward of Taiaroa Head, the scouring effect of the currents is greatly reduced by reason of their diffusion over a considerable area. The depths in the channel between Harrington's Point and the sand-flat, where the width is about 1000 feet at low water, may be cited in proof of the sufficient power of the currents to create and maintain deep water if judiciously utilized.

Remedial Measures Recommended.

Adopting this as the correct view of the origin of the evils at the harbour entrance—and a lengthened and careful consideration of all the circumstances of the case has only served to confirm this reasoning—the key to the solution of the problem is not far to seek, and I feel assured that the only effectual and permanent method of treating the bar lies in the construction of two breakwater moles, so devised as to train and concentrate the tidal currents flowing into and ebbing out from the estuary, and thus to bring them to bear upon the bar in the manner and direction best suited to create and maintain a sufficient navigable depth for vessels of the largest class to enter and leave in all weathers.

By reference to the accompanying drawings, and more especially to No. 2, it will be seen that I have laid down the lines which I should recommend for the two moles, supposing that the detailed investigation, to which I shall presently advert, serves to show that there are no local impediments in the way of rock or other material which cannot be removed at a reasonable cost, within a depth of, say, 26 feet at low water, which I regard as the minimum to be ultimately attained in the entrance, after making a sufficient allowance for "scend" or undulation, as well as for a depth under a vessel's keel to admit of proper steerage.

The breakwater arm on the west side of the entrance would commence at the south-eastern point of the sandhills situated on the north shore of the estuary opposite to Harrington's Point, and run out straight in a North-north-east (magnetic) direction towards and over the site of the bar, and terminate in a depth of 28 feet at low water. The length from high to low water would be about 1,200 feet, and from low water to the outer extremity, or head, 5,000 feet, giving a total length of mole of 6,200 feet. The arm on the east side would commence at Taiaroa Head and run North by East (magnetic) for a length of 1,700 feet, terminating in a depth of about six fathoms at low water.

According to the Admiralty chart, the tidal currents through the north channel within the bar run with a velocity of "from one to two knots" an hour at the point where the distance between the inner or south-western face of the bar and the coast line is greatest. Judging by the depths maintained in the north channel generally, it is only reasonable to assume that the velocity of the tidal currents running through the proposed entrance (*i.e.*, on the line of the leading lights) will be from two to three knots. The currents would be deflected by the proposed works and directed continuously on one and the same line, and within a breadth confined to about 1,800 feet where it crosses the crest of the bar and 1,500 feet between the breakwater heads, where the strength of the currents would be brought to bear with the greatest effect in scouring the sea bed in the proposed entrance channel. In this way the two breakwater training moles shown on the drawings, and hereinbefore described, cannot fail to accomplish the object in view—namely, the establishment and maintenence of a depth in the entrance sufficient to admit of the largest vessels entering and leaving the port in all states of weather and tide.

Questions as to exact lines, Mode of Construction, and Cost of Proposed Works.

With respect to the exact lines for the breakwaters, the precise character of construction, and the cost of the works hereinbefore described and shown on the drawings, the information at present available in this country is not sufficient to enable me to determine these points with the confidence which is requisite before finally recommending the adoption of works of such magnitude. Not being able, for the reason stated, to decide at this stage upon the mode of construction which should be adopted, it is, of course, not possible for me now to give an approximate estimate of cost. Before I could definitely determine the character and cost of the works, it will be requisite that I should be furnished with the information referred to in the accompanying memorandum, which sets out in detail the exact nature and scope of the further data requisite for supplying a decided opinion of the points named.

Improvement of the Channel within the Estuary.

In conclusion, I should remark that there is indicated, by red dots on both of the accompanying drawings, a line which I consider it would be very desirable to establish, as that of the navigable channel or sailing course for vessels through that part of the estuary lying between Taiaroa Head and Dowling Bay, always supposing the nature of the bottom would admit of such a channel being readily formed either by scourage alone or by scourage aided by dredging, and, perhaps, to a partial extent, by some training work.

I am strongly inclined to the opinion that one indirect effect of the two breakwaters would be to enable the tidal currents alone to scour the eastern margin of the large sand flat to a very considerable extent, and thus to promote, if not actually to bring about, the transference of the deep-water channel so far to the westward as to cause it to approximate to, if not actually to attain, the line I have indicated on the drawings.

I have, &c.,

The Secretary, Otago Harbour Board, Dunedin. JNO. COODE.

MEMORANDUM of further information required for the purpose of determining the exact lines, the character of construction, and the cost of the works described in Sir John Coode's report to the Otago Harbour Board, dated 31st March, 1880, and shown upon the drawings accompanying the same.

A.—Borings, Currents, &c.

1. *Probings or Borings.*—At or as nearly as practicable to each of the 36 points indicated by red circles on Drawing No 2, and numbered 1 to 36 respectively, it is desirable to ascertain by probing or boring what is the general character of the materials underlying the surface, down to a depth of at least 30 feet below a datum line corresponding with low water of ordinary spring tides, and more especially as to their being such as would be capable of being dredged with greater or less facility, and, so far as can be estimated, the actual and relative facility with which such materials could probably be moved by dredging, and also (if feasible) by scourage; the fullest information practicable to be given in the notes containing the results of this investigation. It may be mentioned that, if (as is not improbable) sand should be found to exist at the greater number, if not all, of these spots, the probings may be greatly facilitated by using wrought-iron gas-pipes of $\frac{5}{8}$ or $\frac{3}{4}$ bore, and injecting water through them with a small hand force-pump. A similar series of probings or borings should be made at the several spots indicated by the red circles, numbered 37 to 44 inclusive, on Drawing No. 2; these also should be carried down to a depth, say, of 30 feet below the low water datum before described, and the results, as to the depths of water and the respective strata, to be in all cases figured below the datum of low water of ordinary spring tides at the Pilot Beach.

2. *Currents.*—At each of the four points marked thus × in red, on Drawing No. 2, observations should be made upon the set or direction and the velocity of the tidal currents, when the weather is free from any material disturbance: these to be taken at the first, second, and third quarters, both of flood and of ebb tides, and on the occurrence of spring and of neap tides.

3. *Surf at Entrance.*—From time to time during these investigations, when the surf is moderate or heavy, observations should be made and recorded of the direction and approximate height, more especially the former, of the swell or surf on the outer edge and on the crest of the bar, the direction and strength of the wind being also noted, and, as far as can be ascertained, the depth of water (below the datum) over the crest of the bar at the time. The persistency of surf, and relatively the prevalence of such from any particular quarter or quarters, to be noted, as also the frequency and duration of the periods when there is but little or no swell at the entrance.

B.—Materials suitable for Works.

4. *Character of Stone procurable.*—It is desirable to have full particulars of the character of such stone (if any) as may be procurable in the locality suitable for marine works. The points to be chiefly attended to are: hardness; durability when exposed to the action of the sea or otherwise; specific gravity; shape, as raised from the quarry; largest sizes; and relative proportions of largest medium and smallest sizes that will apparently be yielded by the rock in the locality; nature and depth of surface soil or baring necessary to be removed to reach the stone, ascertained by trial pits; direction and angle of the "dip" and "strike" of the rock; facility and cost of quarrying, also of dressing for masonry purposes, if required; positions of quarry sites with respect to the entrance, and approximate level of quarry floors above datum. Samples of the stone to be furnished. Sections should be taken over such ground as may appear to be most suitable for quarry sites, and full notes to be made, descriptive of any exposed faces of rock which may exist near Taiaroa Head on the east side, and the mainland near the estuary entrance on the west; and of lines most suitable for temporary railways for conveyance of stone from probable quarry sites to the starting-point or root of each of the breakwaters, and probable cost of same. Information should also be sent as to the mode and cost of obtaining possession of land, either for quarries or as sites for work-yards and buildings, &c., near the shore end of each of the suggested works.

5. *Shingle, Gravel, and Sand.*—It will also be important to know whether clean shingle and gravel,

or either, suitable for concrete can be obtained in large quantities near either or both sides of the entrance; and, if so, particulars should be sent of the position with relation to the entrance of the site or sites whence they can be obtained, and approximately the quantity, which may be arrived at from the area and thickness of the deposits; a box of about one cube foot containing a fair average sample of such shingle to be sent to England, also one or more samples of about one-eighth part of a cubic foot of clean sand from the beach; or, if the character of the sand on the beaches in different parts of the locality should vary, a sample of each might be sent, with notes as to the best mode of transport, and approximate cost per ton delivered at the starting-point or root of each of the breakwaters.

6. *Fresh Water Supply.*—Information will be useful as to the supply of fresh water available for steam power and general purposes near the sites of the suggested works, on either side, especially as to quantity, quality, and extent of fluctuation.

C.—Prices.

7. Unless intimation be given to the contrary, it will be taken for granted that the information as to prices of labour, timber, ironwork, &c., given in replies furnished by Mr. Simpson, in October last, to Sir John Coode's queries with relation to the Upper Harbour, will apply in the case of works at the entrance, subject to some addition being made for the distance from town. Any particulars by the Engineer as to the percentages or allowances to be made on this head will be valuable.

8. *Sections.*—Transverse sections should be furnished of the north-eastern portion of the sand-hills, and of the sand-flat on the western side of the entrance, upon the respective lines numbered 1 to 7 inclusive on Drawing No. 2; also a longitudinal section on the line *Z*, *Z*, on Drawing No. 2, and also on the lines of the proposed east and west breakwaters. The longitudinal scale for all the above-named sections to be 200 feet to an inch, and the vertical scale 20 feet to an inch. They should all be plotted with figured heights from a datum line corresponding to low water of ordinary spring-tides, as previously described.

JOHN COODE.

PATEA.

SIR,— 5, Westminster Chambers, London, S.W., June, 1879.

Having carefully investigated and considered the documents and data which have been forwarded to me from the colony, I am enabled to submit the following report on the improvement of the Patea River and Harbour.

Physical Conditions.

In their respective reports, Mr. Carruthers and Mr. Thomson have described the leading physical conditions of the river, and have referred to the benefits which would be derived from an improved entrance. Although these documents are doubtless in the recollection of many, it is nevertheless desirable, in order that the nature of my recommendations may be clearly understood, that I should here give a brief description of the river, more particularly of that portion between the bridge and the sea, to which my attention was of necessity especially directed during my visit to the locality in May of last year.

General Description of the Course of the River.

Patea River, which rises under the slopes of Mount Egmont, is about 60 miles in length; its course is extremely sinuous, and its bed encumbered by many obstructions. The influence of the tidal flow is said to extend to 20 miles above the Town of Carlyle. The information available on this head is vague, and but little which is reliable seems to have been recorded of the actual condition of the river beyond the eel-weirs which the Natives have constructed, about 6 miles above the bridge. The accompanying drawing (No. 1) gives a plan of that portion of the river to which I shall more particularly refer—namely, from about three-quarters of a mile above the bridge to the sea. It will be observed that along this length, with the exception of one abrupt bend northward of the bridge, the low-water channel is in fair train, and comparatively uniform both with regard to curvature and width, the latter being not less than about 200 feet. The river is represented as discharging into the sea at the north-west side of the boulder-bank, this being the normal position of the outfall under the conditions which formerly existed, but are now changed by the diversion of the ebb and flood currents, due to the partial construction of the work which was commenced soon after my visit to the colony.

Depth of the Existing Channel.

At the abrupt bend above the bridge much of the useful effect of the outgoing current is mis-spent, as we find that on the concave sides of the curves immediately below the projecting point on the north bank of the river there is an abnormal scour, and a useless depth of from $2\frac{1}{2}$ to $3\frac{1}{2}$ fathoms at low water. From the bridge downwards to the sand-hills the ruling depth is mostly 6 feet at low water; thence to the sea the channel rapidly shoals until the bar is reached, between the east end of the sand-spit and the boulder-bank, where the average depth at low water of spring tides is only 2 feet, and has been as little as 6 inches; there are, however, special conditions with reference to the frequent changes in the channel at the outfall, to which it will be requisite now to refer.

Changes at Entrance.

The prevailing winds are north-westerly, from which direction they are said to blow for nine months in the year. The heaviest seas on the bar are caused by winds from W.N.W. to N.N.W.; it follows, therefore, that the prevailing waves impinge on the beach with an easterly bias, resulting in an all but persistent tendency to drive the outfall channel towards the east. Hence it is found that the position of the entrance oscillates between the boulder-bank on the east and the western head, the opening up of the channel in the latter direction being due to the fact a strong fresh, not being able to escape with sufficient rapidity by the route near the boulder-bank, forms for itself a direct passage across the sand-spit, and thus runs seaward with less resistance than by the course along the western face of the boulder-bank. This new channel is in turn driven eastward by the surf, and hence it is

that the entrance is subject to continual change both in position and depth, the latter being, of course, greatest when the channel is near the west head, seeing that the outrun of the fresh which is found sufficient to force for itself a direct track through the spit also creates a channel of more than usual depth. 7 feet at low water having been found when the entrance has been in this direction.

The rise of ordinary spring tides is at least 6 feet: it has been known to reach 11 feet, the latter height, must, however be regarded as quite abnormal. The capacity of the tidal compartment with a 6-feet rise is 45,500,000 cubic feet, to which should be added, during a portion of the ebb, the fresh-water discharge, which amounts to 150,000 cubic feet per minute under ordinary conditions. The scour due to the passage through the entrance of this volume of tidal and fresh water, forms the natural and normal agency available for the maintenance of a deep-water approach to the Patea River. During floods and high tides the quantities named above would be greatly increased, consequently, in designing the works which I shall presently describe, precautions have been adopted to prevent the creation of a gorge on such occasions, or the formation of currents that would be prejudicial to navigation or to the works.

Prior to the commencement of the works, a considerable portion of the crest of the sandspit was less than 2 feet above low water of spring tides; it followed, therefore, that much of the tidal and fresh waters so essential for the preservation of a deep entrance escaped across the top of the spit, and were thus lost for scouring purposes at the bar, the embouchure of the river when the spit and boulder-bank are submerged forming a waterway of 1,500 feet in width. Again, during the period from half flood to half ebb, the water from the crest of the surf ran in over the spit and fell into the channel, one portion running downwards, the other upwards: the former creating a current directly opposed to the incoming flood, and to the track of any vessel entering the river, the latter serving to check the velocity of the outgoing current on the ebb. Moreover, as pointed out by Mr. Thomson, when the channel is near the boulder-bank, it is very difficult for sailing craft to enter the river, "because, although the prevailing wind is on the port beam coming over the bar, yet the instant they cross, they have to haul up, bringing the wind ahead, the loss of speed and the broadside sea rolling in over the spit tending to drive the vessel ashore." Mr. Wood, the Harbourmaster, called my particular attention to these facts, as illustrative of the difficulties with which vessels trading to Patea have to contend, and, consequently, of the need which exists for improving the entrance. Although the wind is generally fair for vessels going to sea, they are nevertheless subject, under the adverse influences described, to the risk of being driven by the swell on to the eastern shore or boulder-bank.

The result of all these impediments to free navigation is that but few vessels frequent the port, and those only of the smallest draft. It is no uncommon thing for vessels to be detained off the entrance from three to four weeks, and occasionally longer, unable to get into the river. It was stated that one which had come in just prior to my visit had been so detained outside for no less than five weeks. It is not therefore a matter of surprise that Wanganui is at present to a great extent the port for the Patea District, which apparently is one of great natural fertility. The development of the settlement is said to have been hindered by several causes, of which the want of a harbour is the chief.

Works in Progress.

At the time of my inspection no harbour works had been executed at the entrance, although a contract had been entered into by the Board for the construction of an arm upon and somewhat seaward of the boulder-bank, as shown by full green colour on Drawing No. 1. Under these circumstances, and as time was important, I recommended prior to leaving the colony that the position of the work then about to be commenced should be modified, by placing it on the line indicated by brown colour. According to the latest information which has reached me, this work had been carried forward to the extent of about two-thirds of its length (*i.e.*, two-thirds of the length coloured brown), the general result being that the entrance channel across the sand spit had been materially straightened, and the sand removed from the top of the spit to the extent of about 3 feet.

Recommendations.

The governing principles to be kept in view in designing an improved entrance for the Patea River are: First, to fix the position of the channel, so that the whole of the tidal and fresh waters may run continuously through a properly proportioned outfall; second, to carry the works well seaward, so as to remove the outfall as far as practicable from the disturbing action of the waves on the sand bottom, which action takes place to the fullest extent at the beach line, and diminishes as the depth of water increases; third, to modify the direction of the channel or sailing course, so that vessels entering would not be checked by a foul wind until well within the river, or driven to leeward by surf as formerly.

Works Recommended.

The works I have to recommend are shown by red colour on Drawing No. 1. They have been designed to meet the above conditions to the fullest practicable extent, having regard to cost. The modes of construction suggested for the more important portions are shown on Drawing No. 2, and will be found to contemplate the erection of structures as economical in character as it would be prudent to adopt, having regard to the trying conditions to which they will be subjected.

Extent of Works at the Entrance.

Upon referring to the drawing it will be seen that the works I have to recommend for the improvement of the entrance consist of an east and a west pier on the sea front, with a root and depôt to each; also a guide pier, with an embankment at its rear so arranged as to form a wave basin, and two parallel rows of half-tide training sheeting extended along that portion of the river which is abreast of the sand-hills.

East and West Piers.

The east pier would commence at the seaward termination of the work in progress, and extend from thence in a S.S.W. direction for a length of 930 feet, terminating at the Point *C*. The root of the

west pier would start from the foreshore, 420 feet westward of the salient point of the west head, and run S.S.E. for a length of 500 feet, where the pier proper would commence, and extend in the same direction 370 feet, thence curving towards the west, and terminating opposite the seaward end of the eastern pier, so as to form with that work a permanent outfall or entrance to the river 220 feet in clear width between the pier ends, calculation having shown that an opening of this width would under ordinary conditions induce a velocity at half-ebb through the opening of about two miles per hour.

The mode of construction I would recommend for the east pier is shown on Figures 1, 2, and 3, Drawing No. 2. It consists of "crib-work," formed of round piles of totara firmly braced with horizontal and diagonal ties, and filled in with a hearting of loose rubble. In designing this section I have been mindful of the necessity for providing against the removal by scour as the work proceeds of the superincumbent layer of shingle and sand now overlying the clay bottom. It is evident that as this pier is projected seaward the current across the end whilst in progress (at all events, for a considerable portion of its length) will be of sufficient strength to remove any material which may rest upon the tenacious clay believed to underlie the bottom of the sand-spit, and the bed of the sea immediately in front of the entrance to the river, at the depths indicated on the drawing. In works of this character, and under such conditions, it is no more than a proper precaution to provide for the effects of occasional freshets, so that the footings may not be undermined should any abnormal scour take place after completion.

The sea face of the root and depôt at the shore end of the west pier would be formed in the manner shown on Figures 10, 11, and 12, Drawing No. 2, by a skeleton work of piling, supported by frames at intervals of 10 feet, and afterwards filled up to the proposed level of the depôt with material to be obtained from the head.

The west pier would consist of masses of Portland-cement concrete, deposited *in situ* within two rows of close whole-timber sheeting, as shown on Figs. 4, 5, and 6, the top of the work being finished at the level of high water of ordinary spring tides, where the concrete would be 30 feet in width. A permanent gangway to afford access to the end of this pier would be provided in the manner shown. The close sheeting—like the mode of construction adopted for the east pier—provides for the abnormal scour, and would thus obviate the possibility of the foundations being undermined after completion. The structure would be formed in lengths of 20 feet, bulkheads being driven between the sheeting at the requisite intervals.

It is anticipated that the works, when carried to the lengths described and terminating at the points *C* and *E*, respectively, in 10 feet at low water of ordinary spring tides, will be sufficient for the maintenance of a navigable depth in the entrance to this extent, which would be equivalent to at least 16 feet at high water ordinary spring tides. After deducting 4 feet from this depth for "scend" or undulation, a net draft would remain for vessels navigating the entrance under unfavourable conditions of 12 feet.

It will be observed on the drawing that I have shown by dotted lines future extensions reaching to 15 feet at low water, or at least 21 feet at high water of spring tides. I have not however estimated for these extensions, although they may be undertaken at any subsequent time, should the trade of the port extend to such a degree as would justify the considerable further outlay which their construction would entail.

A lighthouse would be provided at the head of the east pier, connected with the shore by a gangway formed on the upper timbers, as shown. This light would be removed in the event of the piers being extended.

I have considered it desirable to give in the estimate the separate cost of the two piers if carried only to the points *D* and *B* respectively on Drawing No. 1, where the ends of the works would temporarily terminate in 8 feet at low water. If the opening were formed permanently at this spot, however, it would be more liable to fluctuations in depth, due to the action of waves on the sand bottom, than if the piers were prolonged to the 10-feet contour, finishing at *C* and *E* respectively. Moreover, it is not improbable that at the latter points, or very close thereto, an examination would show that the bottom is of clay and free from sand. Certainly this would be the case were the piers prolonged to the full extent shown by the dotted lines.

As already described, the ends of the proposed piers would terminate abreast of each other. I have adopted this aspect for the entrance in preference to one turned more easterly, because experience has satisfied me that in cases of this kind the discharge of the tidal and fresh waters directly on to the sea, and at right angles to the coast-line, is preferable to an oblique discharge and a more sheltered opening. Moreover, in the latter case, deep water would prevail at the lee pier-head, which is objectionable, and on some occasions might be a source of danger; whereas, with the opening as I have planned it, the centre of the navigable channel would more nearly correspond with the centre of the opening between the piers.

Guide Pier.

The guide pier would be 500 feet in length, commencing at the point *F* and terminating at *G*, so as to give a low-water channel 200 feet in width. It would be curved to run parallel to the proposed eastern margin of the river, and, in conjunction with the embankment and the face of the eastern end of the head, would form an admirable wave basin, wherein waves entering between the pier heads during gales would, to a considerable extent, be dissipated and absorbed, thus materially reducing the disturbance or undulation in the river.

It will be observed that the top of the close sheeting of the guide pier is at high-water level, and corresponds with the upper face of the west pier. This level for the top of the solid or training structures would admit of the free run, both into and into and out from the river, of high tides or of extraordinary floods, rising above the level of ordinary springs. To prevent the sand from being carried over into the space enclosed within the two piers, it might possibly be desirable to slope down the landward end of the west pier from the level of the surface of the depôt to the top of the work, as shown on Drawing No. 2.

Training Sheeting, and Planting.

Mr. Thomson has alluded to a constant stream of sand being carried into the river from the sand-hills during westerly winds, which might be prevented by planting. I would recommend that this should be done at the proper season, with seeds of the *Arundo arenaria*, or some other species of bent-grass adapted to the climate, and suitable for the purpose.

I have considered it desirable to provide in the design for the construction of two rows of half-tide training sheeting, one on either side of the river, commencing on the right bank at the point *H*, and terminating at *J*, being a length of 1,480 feet. An opening of 100 feet in width would be formed between the ends of the sheeting and guide pier, through which the tidal water at the rear of the former, when below its level, may readily pass. On the left bank the training sheeting would commence at the point *K*, and be carried downwards to *L* (being a length of 870 feet), parallel to the training work on the right bank so as to form a low-water channel of 200 feet, which is the proper width. From *L* seawards the eastern foreshore would form a natural training bank, rendering an artificial face unnecessary.

New Channel to be Dredged.

The foregoing works are those which may be described as strictly appertaining to the improvement of the entrance. Closely following, however, upon the increased navigable depth in the outfall, the necessity would arise for an equivalent increase of depth in the river, hence I have stated in estimate, item No. 8, the cost of dredging a channel from the sea to the town, so as to give a depth of 8 feet at low water, equal to at least 14 feet at high water of spring tides, which would suffice for the full utilization, for navigation purposes, of the high-water depth of about 16 feet in the entrance, when the works are carried to the extent contemplated by the red tint on the drawing.

New Wharf.

At the river end of Essex Street, as marked on the plan, near the existing short jetty on the right bank of the river, I propose to form a wharf of 300 feet in length, of open timber piling, adapted for the berthage of vessels along either face, with their heads pointing up-stream. I have also dotted an extension of this wharf, which might be undertaken hereafter. Along this concave site the maintenance of deep water might be depended upon, and the space between the wharf and the shore could be filled so as to form warehouse plots and standage spaces, although this could only be done at a sacrifice of the berthage along the inner face.

Swinging-Basin.

Abreast of the extension of this wharf I have indicated a site for a swinging-basin, which should be dredged to the full depth in the channel, so that vessels might here be enabled to turn, preparatory to going to sea.

Alternative position for Wharf.

Along the left bank of the river, and below the bridge, I have dotted an alternative position for the wharf, together with an approach from the main road to Wellington, and a bridge crossing the small kloof; along this line also the deep water would be self-maintaining. It will be for the authorities to determine on which of the two sites the wharf should be constructed in the first instance; the cost will be practically the same in either case.

Estimates.

I estimate the cost of the works hereinbefore recommended as follows, viz.:—

	£
For the construction of the piers, and training sheeting necessary for the formation of a depth in the entrance of 8 feet at low water, and at least 14 feet at high water, of spring tides:—	
No. 1. East pier, from *A* to *B* on Drawing No. 1, with root and depôt	47,370
No. 2. West pier, including root and depôt from the shore to point *D*	80,790
No. 3. Guide pier from *F* to *G*, with embankment to form wave-basin	6,030
No. 4. Half-tide training sheeting from *H* to *J*, on the right bank of the river, and from *K* to *L* on the left bank	10,600
Total cost for the above described works completed to the points marked *D* and *B*	£144,790
For the prolongation of the east and west piers to the extent requisite to afford a depth of 10 feet at low water and at least 16 feet at high water of spring tides:—	
No. 5. Prolongation of east pier from *B* to *C* on Drawing No. 1	17,120
No. 6. Prolongation of west pier from *D* to *E* on Drawing No. 1	35,380
Total cost of works recommended in connection with the improvement of the entrance	£197,290
	£
No. 7. Forming a wharf with approach to same, at Carlyle, as shown on Drawing No. 1 ...	8,450
No. 8. Dredging a navigable channel of not less than 8 feet at low water and 14 feet at high water, between the proposed wharf and the sea, including the purchase of the requisite dredging plant	30,200

The above estimates include a sufficient margin to cover contingencies, and all charges connected with the execution of the works. They have been arrived at by adopting the rates received from the colony (as far as they were applicable) and applying them to the quantities of work of different classes, calculated from detail drawings, the essential portions of which are shown on the accompanying Drawing No. 2. The amounts named will doubtless appear high: but when it is considered that the local rates, so far as regards labour, are more than double those which prevail in England, and also that

cement, which forms an important item of expenditure, when delivered at the works would cost about three times as much, and, further, that other materials range at high rates, it will be evident that any works which may be undertaken at Patea must of necessity involve an unusually large outlay compared with their extent.

The sections, whilst they provide for substantial works, are, I believe, of the least expensive description which can be adopted to fulfil the requirements of the case as regards sea-stroke and scour, and at the same time to insure permanence; nor would works of a less comprehensive character than those recommended suffice to accomplish the object in view, more particularly with regard to the attainment of the requisite depth in the entrance.

With reference to this latter point, I may observe that, although when the works reach a depth of 8 feet at low water—namely, at the points *B* and *D* on Drawing No. 1—considerable benefits will accrue from the entrance having been fixed, thus insuring the passage of the whole of the tidal and fresh waters over a duly proportioned and defined channel, nevertheless they should be continued to the full extent shown by the red tint—namely, to *C* and *E* respectively, these being regarded as the terminal points of the first stage of the east and west piers, whereby a permanent depth in the entrance of 10 feet at low water, or not less than 16 feet at high water, of spring tides might be relied on.

The execution of the piers and training sheeting contemplated in the expenditure of £197,290 would occupy about eight years: hence the outlay would be distributed over that period, the annual sums required during the first two or three years being relatively more than afterwards. If the funds necessary for the execution of the two piers at least to the points *B* and *D*, say, £130,000, be not forthcoming, deferring for a time the guide pier and training sheeting, I see no alternative but to postpone the improvement of the entrance until the necessary means can be provided for accomplishing the work in a proper and effectual manner.

An exception may be taken to the use of wood to such a large extent in the proposed structures. In the case of the guide piers and training sheeting, if it should be found that rubble can be obtained of a suitable character and in sufficient quantities for the works, at a cost which would result in a saving as compared with the outlay required for the piling, then I would recommend that these works (*i.e.*, the guide pier from *F* to *G*, and the training banks from *H* to *J*, and *K* to *L* respectively), should consist of rubble-stone in the form of mounds, their faces being left rough and without pitching. Mr. Thomson, in his reply to one of my queries, has stated that rubble of a medium size could be delivered on the south-east side of the river entrance at 5s. per cubic yard: upon this price I have based my estimate of the cost of filling the east pier between the piled faces with a hearting of rubble-stone.

For the piers the use of sheet piling to the extent shown on Drawing No. 2 is absolutely necessary, in order to provide for abnormal scour after completion; and if care be exercised in the selection of the totara, more particularly with respect to its being free from sapwood, there is every reason to anticipate that it will be found a satisfactory material. The use of concrete for the west pier would increase the cost of that structure to the extent of £29,000 beyond the sum named in Item No. 1 of the estimates.

Removal of Obstructions.

There can be no question as to the desirability of removing the obstructions which now exist to the free flow and ebb of the river currents, more particularly at the eel-weirs to which reference has previously been made. The removal of these weirs will undoubtedly increase the capacity of the tidal compartment, by lowering the low water and raising the high water in the upper reaches of the river above the bridge, as pointed out by Mr. Thomson. The removal of these obstructions is also very desirable, and will tend to improve the regimen of the river.

Future Diversion of River above the Bridge.

On Drawing No. 1 I have indicated, by crossed red lines, a suggested diversion of the river course immediately above the bridge, in order to obviate the two objectionable bends, and the consequent waste of current energy, to which I have previously referred. This diversion, although not absolutely essential, is nevertheless a work to be kept in view, and, when funds permit, should be carried out upon the lines laid down.

Bridge Abutment.

I understand that one of the abutments of the bridge is being undermined. This should be examined, and, if need be, prompt measures taken for securing the structure.

In conclusion, I have to express my obligations to Mr. Sherwood, the Chairman of the Harbour Board, to Mr. Thomson, the Engineer, and Mr. Wood, the Harbourmaster; they each and all facilitated my inspection in every possible way. To Mr. Blackett my thanks are also due for his assistance at Patea, as at other New Zealand ports visited by me.

I have, &c.,

The Secretary, Marine Department, Wellington. JOHN COODE.

TAURANGA.

SIR,— 5, Westminster Chambers, London, S.W., 29th November, 1879.

I have now the honor to submit my report on the improvement of the harbour of Tauranga, in illustration of which I send two drawings—namely, No. 1, an Admiralty chart extending from the town to the sea, with soundings corrected up to February last; and No. 2, a plan, showing in detail the soundings made, in accordance with my request, at and near the shoal or bar which stretches across the navigation channel at the point where it joins the Waikareau, or Faulkner's Channel, about a mile below Mission Point.

The shoal just adverted to constitutes the great, indeed the only serious, impediment to the passage of vessels of ordinary draught from the sea to and from the Town of Tauranga. The most effectual means of removing this impediment, at a reasonable outlay, will therefore form the subject of this report.

The shoal in question is evidently due to the conflict of the large body of water running out from

the western or Waikareau arm of the estuary with the water from the southern or navigation branch. These two tide streams meet each other practically at right angles, thus producing a considerable "heading back" and useless absorption of much of the scouring power, and, as is always found in such cases, a bar or shoal is found across the mouth or channel, the stream in which is the weaker of the two. This evil is further aggravated by reason of the preponderance of westerly winds over those from the eastward, both in duration and force, in consequence of which the materials swept along with the waves from the westward are driven towards the eastern or leeward shore of the estuary, and there accumulate.

Having regard to these facts, which may be said to describe the disease in this particular case, we obtain a clue to the measures which should be adopted by way of remedy.

Seeing that it is both impracticable at any reasonable cost, as well as undesirable in every sense, to stop permanently the eastern end of the Waikareau Channel, it only remains to be considered how the two currents, which now conflict, can be so regulated and controlled as to insure a greater depth in the navigable channel leading to the town. There are two modes of accomplishing this object—namely, either by concentrating the scour in the navigable channel by means of a training bank along its western side; or the same end may be attained by forming training works at the mouth of each channel, so devised that the two streams may unite and run seawards without opposition. Either of these remedies should produce the desired result: the former, by causing a stream of preponderating strength to run in the navigable channel leading to and from the town, would dissipate the present shoal, and result in the lodgment of a bar of somewhat similar character in the mouth of the Waikareau; but no ill effects would be caused by this latter obstruction, and the fairway in the navigable channel, by reason of the increased scour, would be maintained at an adequate depth.

The training bank I would suggest to accomplish the object referred to above is shown by red colour on the accompanying drawings. It would commence at the north-east point of the sand-spit, and extend therefrom in a direction almost north and south, but curved to a radius of about 16,000 feet for a total length of 1,000 lineal yards, with a "perch" or beacon at its termination. It will be seen that the waterway will be about 400 feet less in width at the north than at the south end, thus concentrating the currents to that extent. This training bank would be formed throughout of rubble-stone deposited from barges. Its top would be 6 feet in width, and at a uniform level of high water of ordinary neap tides, the slopes being $1\frac{1}{2}$ to 1. In forming the bank care should be taken to deposit at an early stage of the work a thin layer of stone over the site of the mound, so as to economize materials by preventing the scour of the sand upon which the bank will subsequently rest. If the work were carried on with a steep end without this provision there would be much deeper water at its seaward termination during progress than subsequently, or than would be necessary for the safety of the bank, and thus more stone would be consumed than would be required if the plan referred to were adopted.

With regard to the alternative proposal for increasing the depth in the navigable channel, by training the currents in both channels at their confluence, so that the streams might unite and run seaward without interference: this would necessitate not only a training bank on the west side of the navigable channel of greater length than that shown on the drawings, but also two banks of similar construction, one at each side of the entrance to the Waikareau, that on the south side being joined to the training bank on the west side of the navigable channel so as to form therewith a V-shaped tongue. The other bank on the north side of the entrance to the Waikareau would be curved, and parallel to that on the south side. Thus the works for the latter mode of procedure would be fully twice as extensive and costly as those shown on the accompanying drawings, and may therefore be abandoned in favour of the former proposal, especially as it may be considered reasonably certain that the less costly project will be found to afford the relief required; and, if not, the training bank contemplated would form an essential instalment of the more extensive scheme. I do not apprehend, however, that any further works will be required in addition to the training bank of 1,000 yards in length shown on the drawings, except a wing or side bank to the westward of its northern termination, as shown by red dotted line on the drawing, which may possiby be necessary, although in all probability the main training bank will be found of itself to fulfil the objects in view without such a wing.

The precise line for the proposed training bank, and the extent to which it should contract the sectional area of the waterway at the mouth of the navigable channel, necessarily depends altogether upon the relative strength of the currents at different periods of the tide in the two channels at their present point of junction. The information available here, although ample for the determination of the principle to be adopted and the character of the work to be executed, is not sufficient to enable me to decide with certainty upon the precise direction for the training bank, so that on its completion the stream in the navigable channel shall be of preponderating strength, as compared with that into and out from the Waikareau arm of the estuary. I would therefore suggest that, if it should be decided to proceed with this bank, a set of observations on the strength of the currents should be taken, under the direction of Mr. Blackett, the Chief Engineer of the Marine Department, before actually commencing the work, and that he should be asked to decide therefrom to what extent, if at all, a departure is necessary from the direction of the bank shown on the accompanying drawings, in order to insure a sufficient concentration of the current where the two branches will meet.

Estimate.

I estimate the cost of the works recommended will be as follows:—	£
74,238 cubic yards of rubble-stone, deposited from barges at 6s. 8d. ...	24,746
One perch or beacon	50
	£24,796
Contingencies, 10 per cent.	2,480
	£27,276
Say £27,300.	

It will be observed that I have adopted the price of 6s. 8d. per cubic yard for the stone, which ought, in my view, to be found sufficient, having regard to the large quantity required, and to the fact that the general yield of the quarries for size may be taken without selection, so long as the stone is hard and durable.

With regard to the proposal made by Mr. Jordan, the Engineer to the Harbour Board, in his report to the Chairman of that body—namely, to endeavour to increase the depth in the channel, pending the receipt of this report, by dragging heavy harrows across the shoal by one of the small steamers plying in the port—I desire to point out that if such a course has been adopted, and has proved efficacious in obtaining limited and partial relief (and this, I gather, was all that was expected therefrom), such benefits must of necessity, having regard to the agencies in operation, be of a temporary character only, and require frequent application. The true and permanent remedy is to remove from the fairway of the main navigable channel the conflicting agencies now in operation which tend to the formation and growth of the shoal, and this, I have no doubt, will be accomplished by the training bank I have recommended.

I desire to express my obligation to Mr. Edgecumbe, Chairman of County Council, to Mr. McKellar, Collector of Customs, and to Mr. Turner, in charge of the Survey Department. These gentlemen kindly attended during the time of my inspection and facilitated my local inquiries; nor must I omit to mention that the Harbourmaster, Captain Marks, furnished me with all the information I desired to obtain within the scope of his department.

I have, &c.,

The Secretary, Marine Department, Wellington. JOHN COODE.

THAMES RIVER (WAIHO).

SIR,— 5, Westminster Chambers, London, S.W., June, 1879.

I have now the honor to submit my report on the improvement of the entrance to the River Thames.

I should premise that, at the time of my inspection, the Harbour Board brought under my notice certain proposals in the way of new works, which they regarded as matters requiring immediate attention, and desired that my views thereon should be communicated to the Government before I left the colony.

These proposals were: (1.) A new timber-jetty near Te Kopu, 395 feet long, and extending out to 5 feet or 5½ feet of water at low water, on the east bank of the river. (2.) An extension of the present wharf at Shortland, 200 feet in length, and in the same line as the existing wharf. (3.) An extension of the present goods wharf at Grahamstown, 105 feet in length, and in continuation of the present line. (4.) The reinstatement of the Tararu Jetty, raising the level of the deck 4 feet higher than in the original structure, and utilizing the materials thereof as far as practicable. (5.) A reclamation of the foreshore between the Grahamstown Passenger Wharf and the Powder Magazine, by the construction of a timber facing to trap the mining waste as it comes down. (6.) Repairs and renewals at the Grahamstown Goods Wharf. So far as practicable these works are shown by brown colour on the drawings sent herewith, which I have had prepared from data supplied by the Harbour Board.

As will doubtless be remembered, I reported before leaving Auckland that neither of the above proposals would interfere with the works which I should have to suggest when dealing with the general question of harbour and river improvements.

So far as regards the extension of the Shortland Wharf, the reinstatement and lengthening of the Goods Wharf at Grahamstown, and the reclamation of the foreshore between the Grahamstown Passenger Wharf and the Powder Magazine, it is unnecessary here to offer any further remarks.

Tararu Jetty.

The first of the further works to which I have to direct attention is the extension of the Tararu Jetty. Assuming that this jetty will have been reinstated, as proposed, and that the level of the deck has been raised to the extent of 4 feet, I would recommend that it be extended in a west-north-west direction for a length of 600 feet from its outer termination, in the manner shown by red colour on Drawing No. 1, and on Figs. 4, 5, and 6, Drawing No. 2. I have fixed upon this direction for the extension in order that vessels lying alongside may be "end-on" to the sea. It will be observed from the detailed views that it is proposed to adapt the jetty for berthing vessels along either face. The deck would be 40 feet in width over-all, and at an uniform level of 10 feet above high water of ordinary spring tides. The structure would consist of bays of round piles placed at intervals of 10 feet, measured along the jetty, four piles to each bay, firmly braced and tied with horizontal and diagonal timbers, and supporting a deck formed of whole and half balks, carrying planks of 3 inches in thickness. Provision would be made for laying a double line of railway hereafter, if deemed desirable, when the re-entering angle between the existing structure and the north-east face of the new extension would be filled by a triangular addition, as shown by a dotted line on Figure 4. The railways on the extension could thus be placed in direct communication with the land system by curves, around which it would be practicable to run vehicles without necessitating the use of a turntable.

I would recommend that the whole of the timber required for this extension, except that for the deck, should be of totara, and that the deck should be of matai. The timbers for those portions of the work which would be in the water, and exposed to the attacks of sea worms, should be as free as possible from sap. Both the *teredo navalis* and the *limnoria terebrans* have a strong partiality for sapwood in all varieties of timber; but if especial attention is paid to the selection of the wood for the submerged portions of the structure, there is every reason to believe that totara will be found an admirable material for this jetty. It has, moreover, a further advantage of being a timber of colonial growth.

The proposed extension would afford berthage of 1,150 feet in length along its inner and outer

faces, in a depth of from 8 to 9 feet at low water, and from 18 feet 6 inches to 19 feet 6 inches at high water of spring tides.

Assuming that the formation of the channel over the bar hereinafter referred to is postponed, a further extension of this jetty, as indicated by dotted red lines, might be undertaken hereafter, when the requirements of the trade may out-grow the accommodation which would be afforded by the work recommended for construction forthwith.

It will be observed from the detailed views that the mode of construction I have suggested would result in the formation of a work possessing much greater strength and stiffness than either of the existing jetties or wharves; less material could not, however, be employed without prejudicing the permanence and stability of the structure or impairing its utility.

Extension of Jetty at Te Kopu.

The second work to which I have to refer is an extension of the proposed jetty at Te Kopu. Bearing in mind the advantageous position and depth of water at this place, and the certainty of the maintenance of at least the present depth along the right or eastern shore of this part of the river, I have shown on the drawings by red colour and in dotted red lines, respectively, two extensions of the work of which I expressed approval in my report of 25th May of last year. The prolongation tinted in red should be executed forthwith, and the further extension carried out hereafter when found desirable. It will be seen that the suggested works would commence from the westward termination of the jetty which I have previously approved, and extend, in prolongation of that work, for a length of 160 feet. From thence it would turn in a north-westerly direction for a length of 300 feet, so that craft lying alongside would be directly fore-and-aft with the currents of the river—a material advantage, affording also the means for berthing vessels alongside either face of the jetty. The mode of construction I would recommend is shown on Figs. 2 and 3 on Drawing No. 2, and is somewhat similar to that previously described for the Tararu Jetty; the character of the timber to be employed would also be the same. The deck would be 40 feet wide over-all, and placed at the level of 7 feet above high water at spring tides. Provision would be made for laying two lines of railway hereafter, to be connected with the shore by curves passing over a triangular platform placed in the re-entering angle, between the inner face of the extension and the north face of the approach, as shown by a dotted line on Fig. 1, Drawing No. 2.

Improvement of the Outfall of the Kauaeranga, below Shortland Wharf.

I have indicated on Drawing No. 1 an improved course which might be given to the lower portion of the channel of the Kauaeranga. The harbourmaster, Captain Best, informed me at the time of my visit that there appeared to be a natural tendency for the currents to form a channel somewhat in the direction shown by red colour on the drawing. This should be encouraged by artificial means to the extent of excavating a cut down the foreshore, so that the tidal and river currents might follow the new course, and thus scour the channel, and improve both the depth and the direction of the navigable approach to Shortland Wharf.

Turnwater Bank and Telegraph Crossing.

On Drawing No. 1 I have also shown by red dotted lines the position and direction of a turnwater or training bank of rubble-stone, which I would recommend to be carried out on the right or eastern side of the river, opposite to Orongo, at the Telegraph Crossing. It was apparent at the time of my inspection that such a work as this was very desirable, in order to prevent the splitting of the tidal currents, whereby the stream is divided into two branches, one following the main track of the river, the other that of the subsidiary channel between the long sand-bank (which is dry at low water) and the right foreshore of the river. The training bank I have recommended would close this subsidiary channel, and cause the whole volume of water, both tidal and fresh, to pass along the direct and main course; the improved scour due to this concentration of the currents would exercise a beneficial influence in deepening the water at the tail or seaward end of the sand-bank to which I have referred.

Suggested Improvement at Entrance of River.

The great obstacle to the navigation of the Thames is the shoal or bar which exists at its mouth. Upon referring to Drawing No. 1 it will be seen that for a length of two miles, and entirely across the entrance to the river, there is a depth of from 4¼ feet to 6 feet only at low water of spring tides; whereas between the landward side of this shoal and Te Kopu there is, with one slight exception, a navigable depth of not less than 12 feet at low water; seaward the depth regularly increases, and is free from further obstruction. The rise of tide at springs is 10 feet 6 inches, hence on the crest of the bar, at the shoalest part, there is 14 feet 9 inches at high water of those tides, and about 2 feet less at neaps. This depth, allowing for "scend" or undulation, is barely sufficient for the passage of ordinary coasting vessels under favourable conditions of weather, and is altogether inadequate for the accommodation of a regular steam service into and out from the river by vessels of a reasonable size.

It is not improbable, in fact I may say it would seem to be inevitable, in view of the growth and development of this rich and important district, that sooner or later the question of the formation of a deeper approach to the river will have to be taken in hand: I have therefore shown on Drawing No. 2 what, having regard to the information now available, would appear to be the best position for a cut or channel to be dredged across the shoal in a W.N.W. direction. The bottom of this channel would, in the first instance, be not less than 8 feet below low water of spring tides for a width of 220 feet, as explained on the note and section Fig. 7, Drawing No. 2. As soon as this preliminary cut has been carried through it should be deepened, so as to afford a navigable approach to the river of not less than 12 feet at low water of spring tides, over a width of 200 feet.

The question naturally arises as to whether such a channel would be kept clear by the natural scour due to the efflux and reflux of the tidal and river waters, without being trained and contracted

by guide banks, or aided by periodical dredging. This is a highly important branch of the subject, and one upon which I am unable, with the data now before me, to give a positive opinion. Looking at the fact that the flood and ebb currents are shown on the new survey to run in a direction parallel to that which I have selected as the best site for the channel, with a velocity of from two to three knots per hour, there are good grounds for believing that the channel, when once formed, would be maintained with but little aid other than the scour caused by the passage through it of the tidal and river currents. There are thus strong probabilities that training or guide banks of rubble-stone—the formation of which in consequence of their length would be attended with great expense—would not be required, although in this case, as in most others of a kindred nature, occasional dredging may be necessary at certain portions of the channel for the constant maintenance of the improved depth.

Much light would be thrown on the probability of the channel necessitating the formation of training banks, or otherwise, if the nature of the material which forms the shoal were clearly ascertained. For if it should be shown that the material consists of mud or silt deposited by the combined action of the sea and river, there would be reason to apprehend that the currents would require concentration and training between guide banks such as I have referred to. On the other hand, if it should appear that the sea-bed consists of a natural "hard" or obstruction which the currents are unable to scour away, there would be sufficient grounds for proceeding with the work upon the understanding that guide banks would not be necessary. Hence, before coming to a definite conclusion on this question, the site of the proposed channel should be carefully examined, and borings made at the points indicated and numbered on Drawing No. 1, carefully referring all results to an uniform level of low water of ordinary spring tides, noting the strata passed through down to, say, 22 feet below low water, and giving the results of each boring with a number corresponding with that figured on the plan. In any event, I do not apprehend that the materials which form the shoal are of a character which cannot be easily dredged, neither is there any doubt as to the practicability of keeping open the channel after it has once been formed, seeing that if necessary the currents may be trained and directed within guide banks, and the scour aided by periodical dredging. The points upon which further information is required affect the extent of the works, their first cost, and the charges for maintenance, but not their practicability or permanence, relative to which I imagine there can be no doubt, although the cost may be such as to necessitate their postponement until the trade of the locality is sufficiently developed to warrant the outlay.

The best and most economical dredge plant for the formation of the channel would be a powerful steam hopper dredger of the kind patented by Messrs. Simons and Co., of Renfrew, one of which has, I understand, been supplied to the South Australian Government, and has for some time been in successful operation at Adelaide. Having regard to all the circumstances of the case, I should suggest the purchase of a similar dredger for the work at the Thames. This craft would dredge 1,000 tons of material into a hopper formed as a hold in the ship, and proceed to sea and deposit the cargo of spoil at a distance of from seven to ten miles from the proposed channel, just below the low-water mark of the western shore of the Frith. A vessel of this character would do the work of an ordinary dredger and the usually attendant hopper barges. Under normal conditions she would make one trip per diem, equal to the disposal of 1,000 tons of material out of the channel; but in the summer, when the weather and tide are favourable, she could occasionally make two trips per diem, equal to the disposal of 2,000 tons of dredgings. A craft of this size and power would execute the work with sufficient rapidity, unaided by other dredging plant. Her crew would consist of thirteen to fifteen men. She would draw 7 feet 6 inches light and 11 feet loaded, and would steam with a full load from six to seven miles per hour. Operations would be commenced at the upper or landward end, and the work extended seawards: this order of procedure offering certain advantages with regard to the navigation of the dredger, and being in other respects preferable at the Thames to the more ordinary practice of commencing at the seaward end and working backwards. I have preferred a straight channel to one having a bend, because, in the case of the former, two leading lights will be sufficient to guide a vessel by night through the entire length of the new cut, the track being buoyed for navigation during thick weather in the daytime. I have shown two lights: one at Opaui Point, and the other on the left bank of the river to the south-east of it. It would also be necessary to erect two further leading lights on the salient angle of the foreshore northward of Te Kopu, for the guidance of mariners when passing over that portion of the river landward of the inner end of the new cut. In conjunction with the formation of the proposed channel across the bar, it will be requisite to dredge the small patch or shoal below Te Kopu to the extent indicated on Drawing No. 1.

Estimates.

	£
I estimate the cost of the works as follows:—	
No. 1. Extension of Tararu Jetty, 600 feet in length	17,750
No. 2. Extension of Te Kopu Jetty, 300 feet in length, with a viaduct approach 160 feet long	11,900
No. 3. Diversion of channel at the outfall of the Kauaeranga, to improve the approach to Shortland Wharf	2,250
No. 4. Formation of a channel across the bar or shoal at the entrance, having a depth of not less than 8 feet at low water of spring tides for a width of 220 feet, including the purchase and delivery of a suitable steam hopper dredger, as hereinbefore described	65,000
No. 5. Deepening the channel provided in last item, so as to give not less than 12 feet at low water of spring tides for a width of 200 feet, an additional sum of ...	37,000

The total cost of the 12 feet channel would thus be £102,000, including the purchase of the dredger.

The above estimates provide for contingencies and all other charges. In the case of Items 1, 2, and 3, the sums have been arrived at by applying the rates furnished by the colony to the quantities

ascertained from the details shown on Drawing No. 2. A reduction in the lengths of either of the jetties would effect a proportionate saving in cost. Items 4 and 5 have been computed upon the basis that the materials to be removed are such as can be dredged freely.

Conclusion.

I desire, in conclusion, to express my thanks to Mr. Davis and Mr. Graham, of the Harbour Board, and to Captain Best, the Harbourmaster, who accompanied me and afforded every facility during my inspection. At the Thames, as elsewhere during my visits to the several harbours in New Zealand, Mr. Blackett greatly aided me in the course of my inquiry.

I have, &c.,
JOHN COODE.

The Secretary, Marine Department, Wellington.

By Authority: GEORGE DIDSBURY, Government Printer, Wellington.—1880.

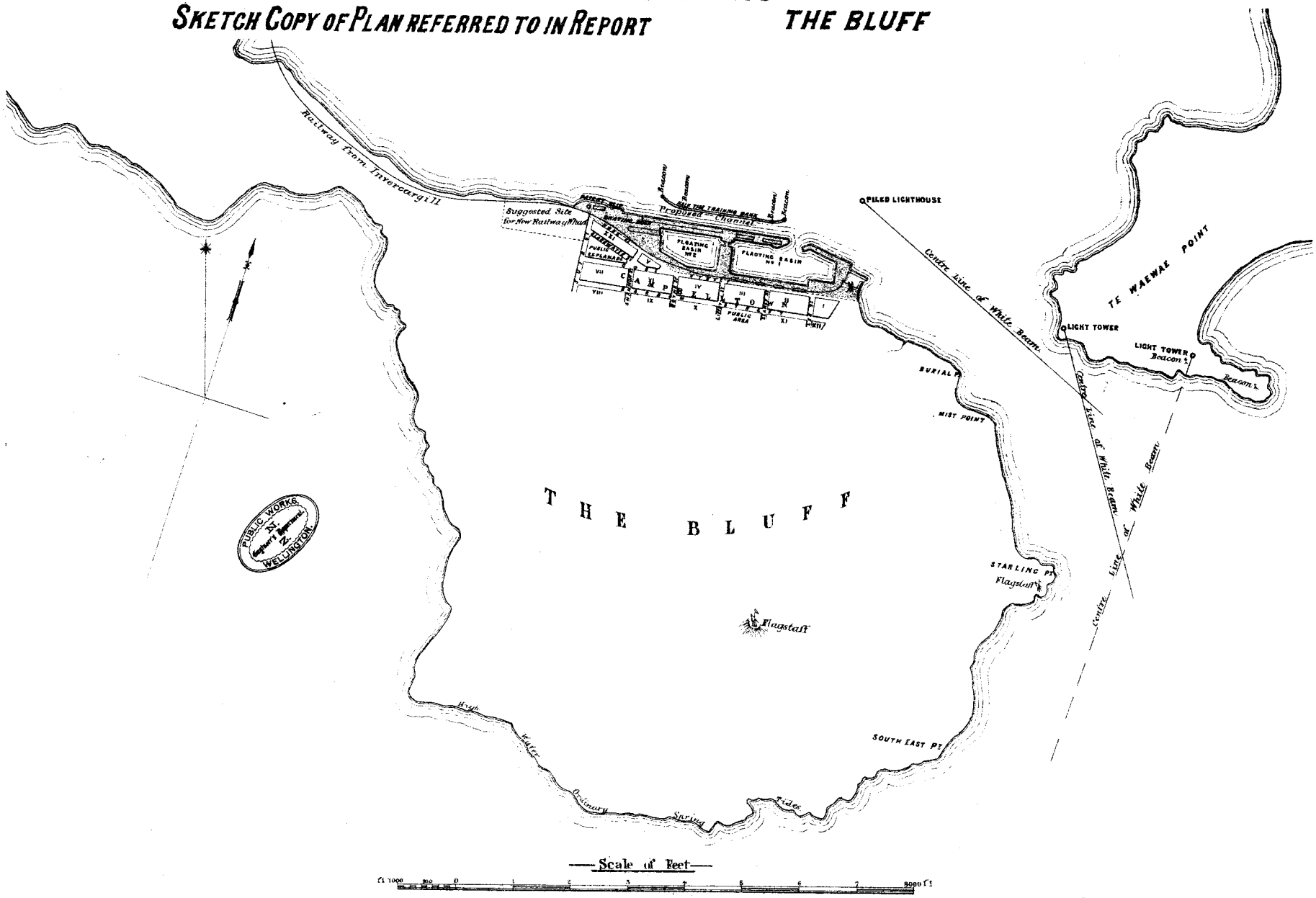
Price 1s. 6d.]

NEW ZEALAND HARBOURS

DRAWING No. 1.

SKETCH COPY OF PLAN REFERRED TO IN REPORT

THE BLUFF

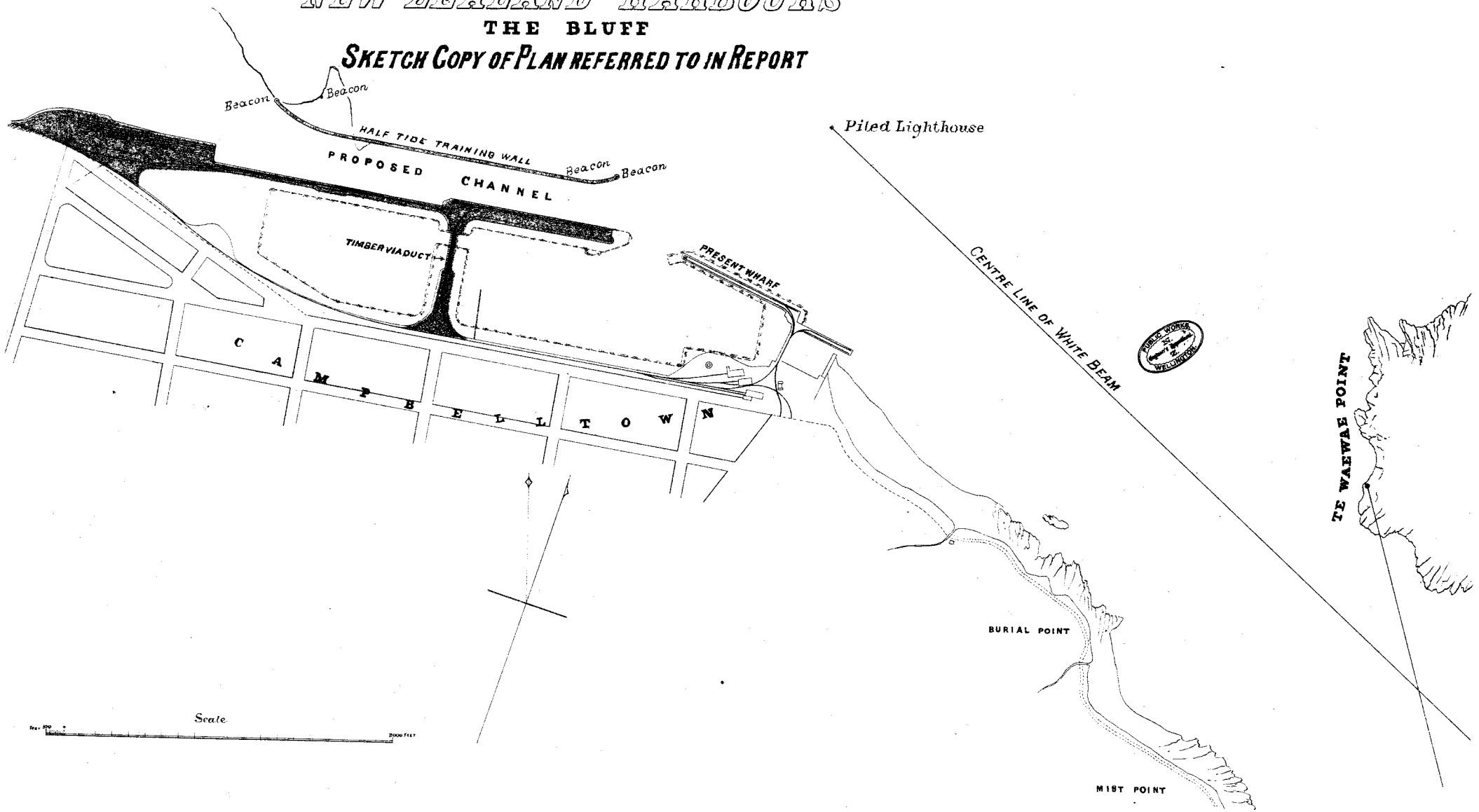


NEW ZEALAND HARBOURS

DRAWING No2

THE BLUFF

SKETCH COPY OF PLAN REFERRED TO IN REPORT

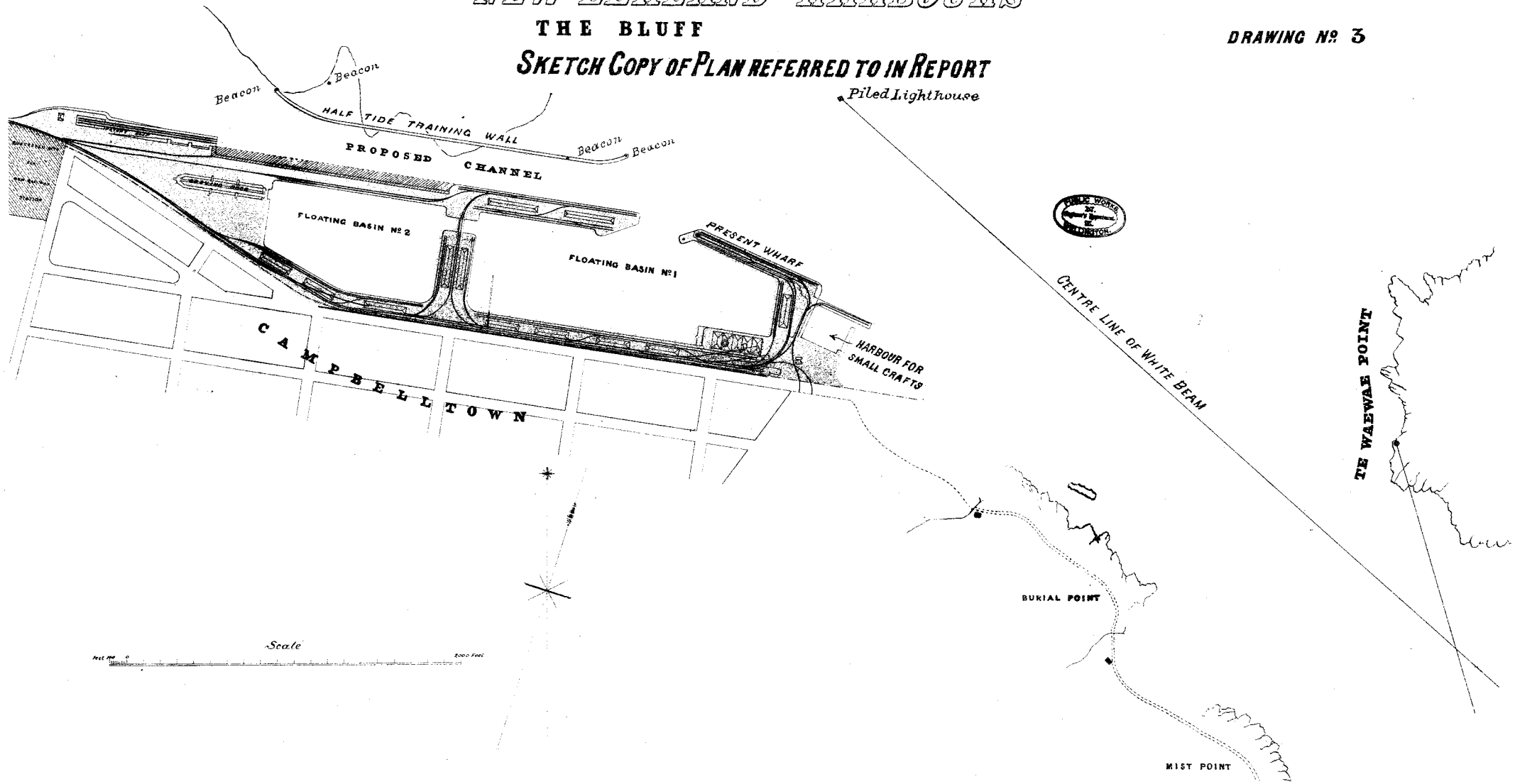


NEW ZEALAND HARBOURS

THE BLUFF

DRAWING Nº 3

SKETCH COPY OF PLAN REFERRED TO IN REPORT



NEW ZEALAND HARBOURS — THE BLUFF — DRAWING No. 4.

SKETCH COPY OF PLAN REFERRED TO IN REPORT

Fig. 2.
Cross Section of Rubble Training Bank South side of Proposed Channel on line A.A. Fig. 1.

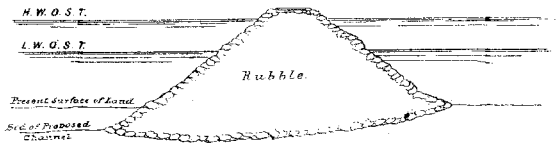


Fig. 1.
Distorted Longitudinal Section of Rubble Training Bank. South side of Proposed Channel.

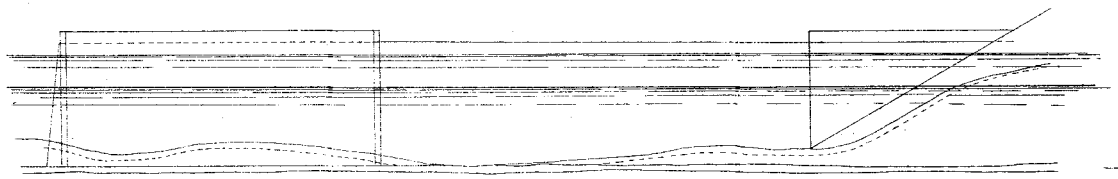
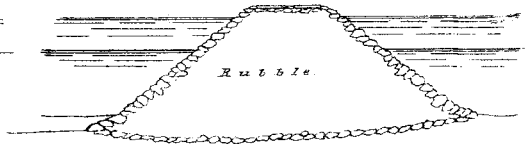


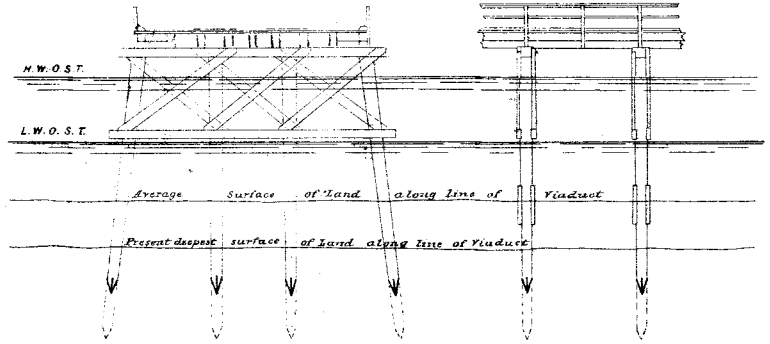
Fig. 3.
Cross Section of Passing Place on Rubble Training South side of Proposed Channel on line B.B. Fig. 1.



Proposed Timber Viaduct to outer Wharf

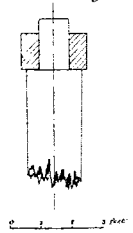
Cross Sec. Fig. 4.

Part Elevation Fig. 5.

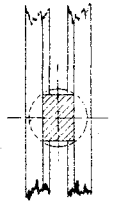


Details of attachment of Cross Ties to Piles.

Sectional Elev. Fig. 8.



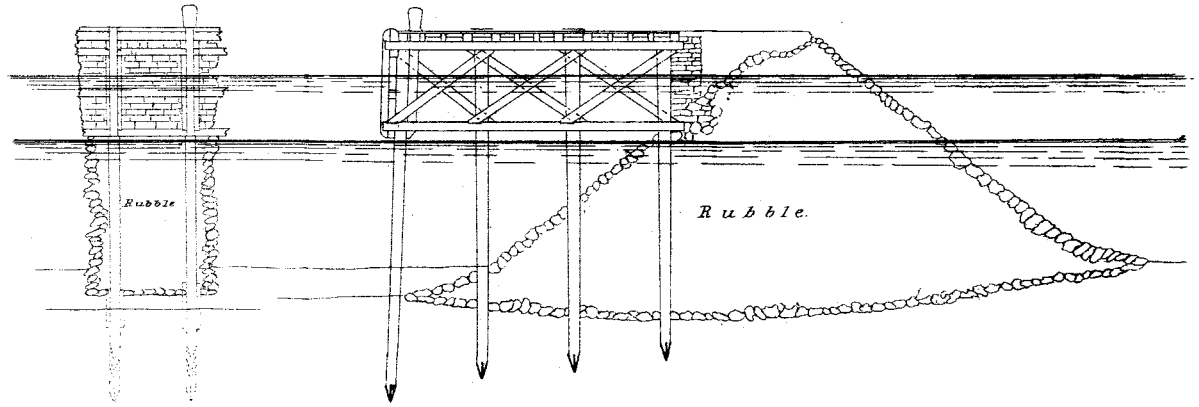
Plan Fig. 9.



Outer Wharf South side of Proposed Channel if constructed with Timber Framing

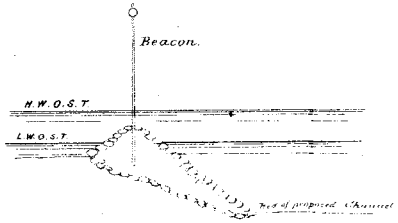
Part Elev. Fig. 6.

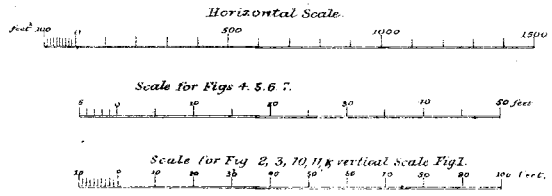
Cross Section on line C.C. Fig 7.



Cross Sec. of half tide Training Bank on North Side of Proposed Channel

Fig. 10.

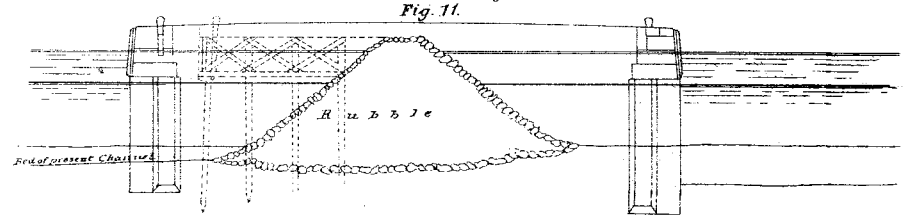




Cross Section of Proposed Wharf & Quay face of Basin formed with Portland Cement Concrete.

Note. The Concrete face may either be formed in the first instance in lieu of the timber framing (Fig 6 & 7) or it may be executed hereafter when the timber decays.

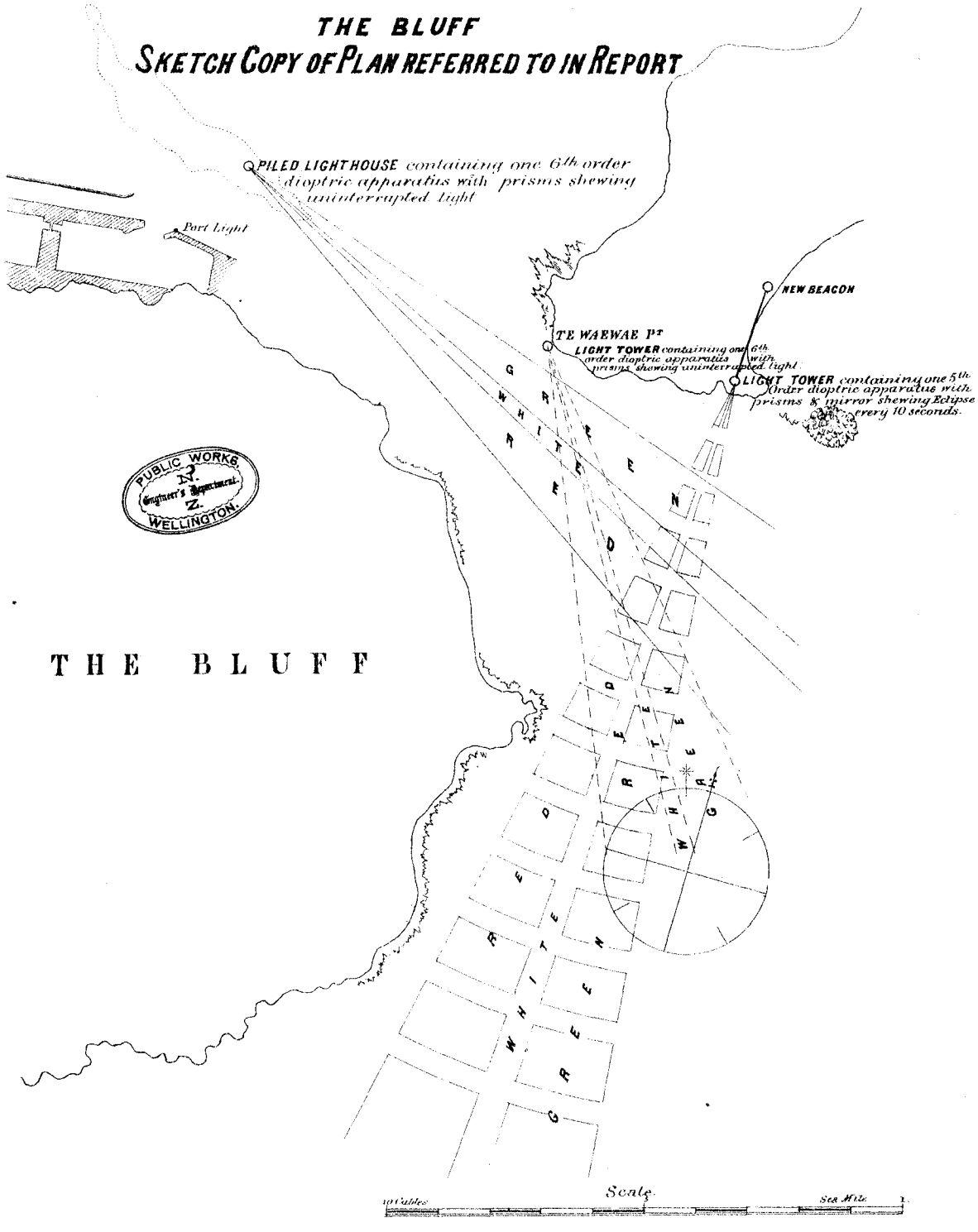
Fig. 11.



DRAWING No.5.

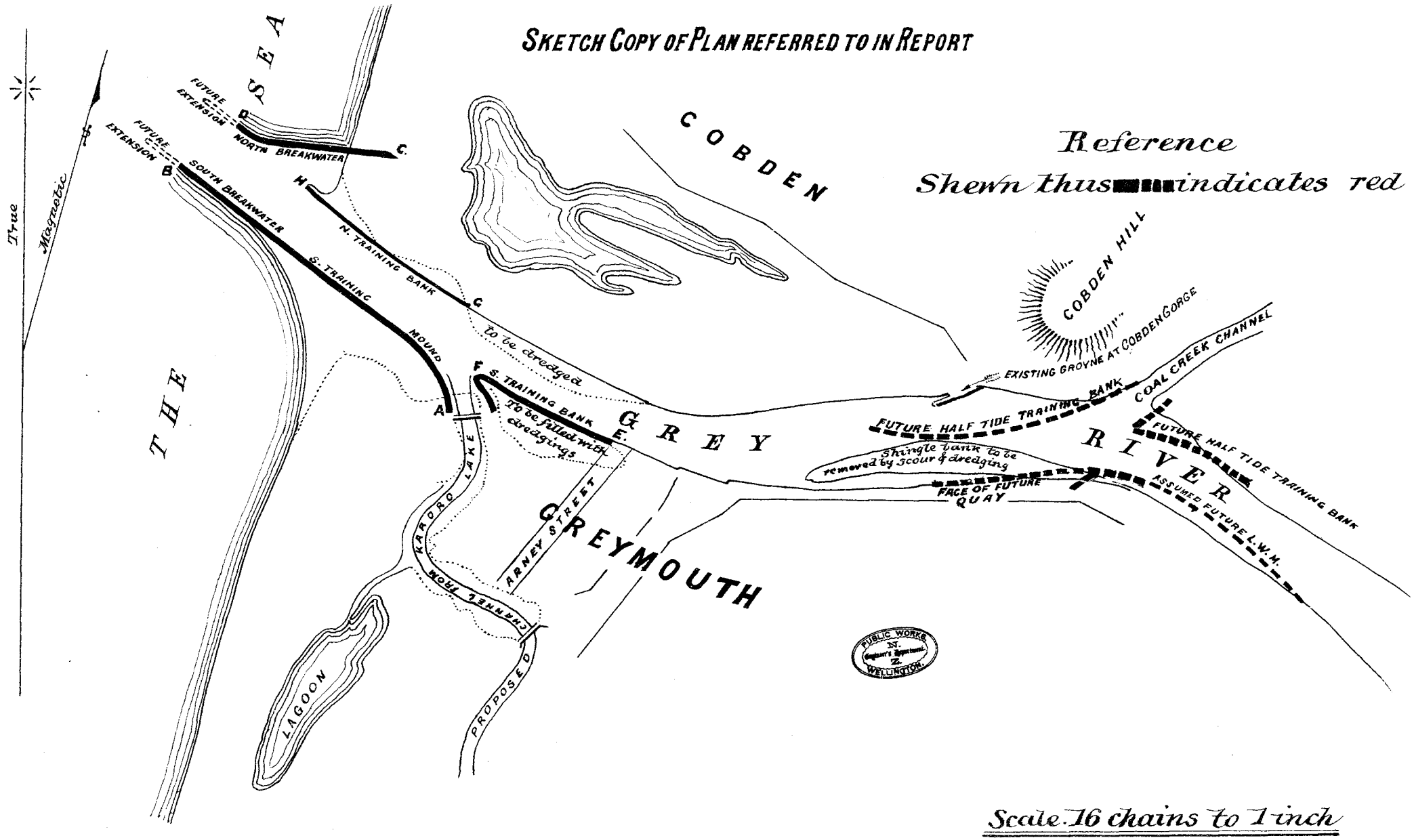
NEW ZEALAND HARBOURS

THE BLUFF
SKETCH COPY OF PLAN REFERRED TO IN REPORT



NEW ZEALAND HARBOURS — CREYMOUTH — DRAWING No. 1.

SKETCH COPY OF PLAN REFERRED TO IN REPORT



Scale 16 chains to 1 inch

DRAWING No. 2.

NEW ZEALAND HARBOURS

SKETCH COPY OF PLAN REFERRED TO IN REPORT

GREYMOUTH

Mr Moriarty's Design is shewn thus ═══ indicates Brown.
Mr Carruthers' do do do ····· do Green.
Sir John Coode's do do do ▬ ▬ ▬ do Red.

Scale
Ft 100 0 500 1000 1500 2000 2500 Ft

PUBLIC WORKS. N. Engineer's Department Z. WELLINGTON.

Magnetic North

Flagstaff

Line of Mr Moriarty's proposed work

Line of Mr Carruthers' proposed work

Future extension

North Breakwater

Future extension

Light

South Breakwater

Proposed Basin

North Training Wall

South Training Bank

Training Mound

Low Water Line

Present Low Water Line to be dredged

South Training Bank

Packers Quay

Flagstaff

To be filled in with Dredgings

Proposed Channel from Kawatiri Lake

Johnston St

Shingle Bank to be removed by scour and dredging

Face of future Quay

NELSON QUAY

MAWHERA QUAY

COBDEN

GREYMOUTH

NEW ZEALAND. HARBOURS

SKETCH COPY OF PLAN REFERRED TO IN REPORT

DRAWING No. 3.

GREYMOUTH

Fig 2
Cross Section of South Training Bank
on line A.A. Fig 1.

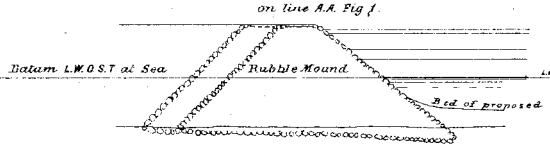


Fig. 1.
Distorted Longitudinal Sec of South Training Bank.

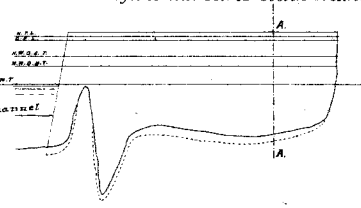


Fig. 4.
Cross Section of North Trainigg Bank.
on line B Fig 3.

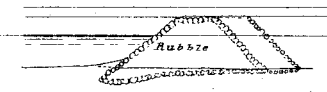


Fig. 3.
Distorted Longitudinal Section of North Training Bank.

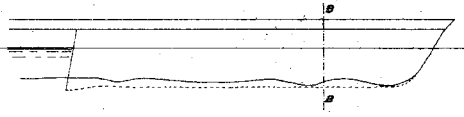


Fig 7.
Cross Section of North Breakwater
on line D.D. Fig 5.

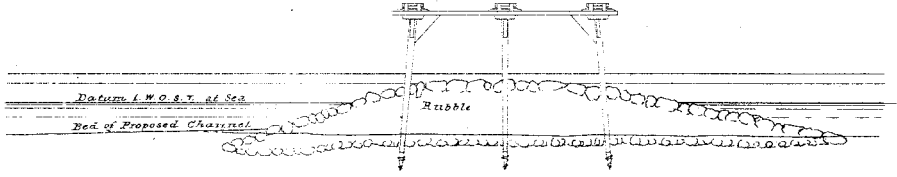


Fig. 6.
Cross Section of North Breackwater
on line C.C. Fig 5.

Fig. 5.
Distorted Longitudinal Section of North Breakwater.

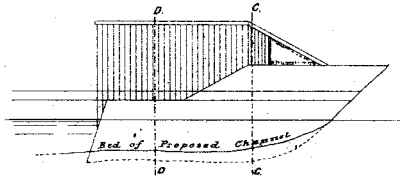


Fig 10.
Cross Section of South Breakwater
on line E.E. Fig 8.

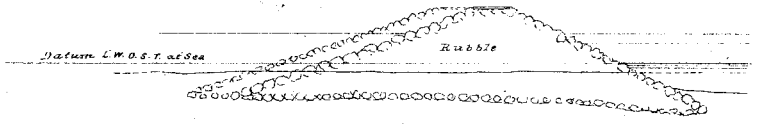


Fig. 9.
Cross Section on South Breakwater

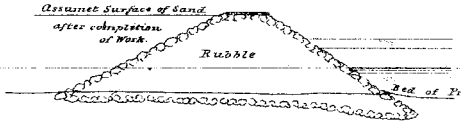


Fig. 8.
Distorted Longitudinal Section of South Breakwater

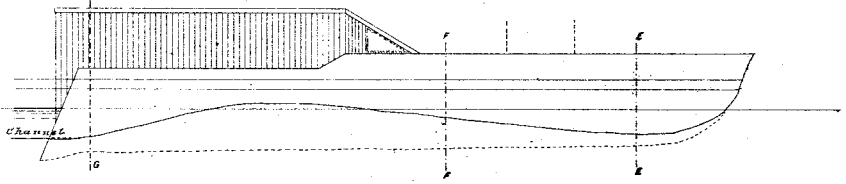


Fig. 13.
Elevation of staging for Outer Works.
North & South Breakwaters.

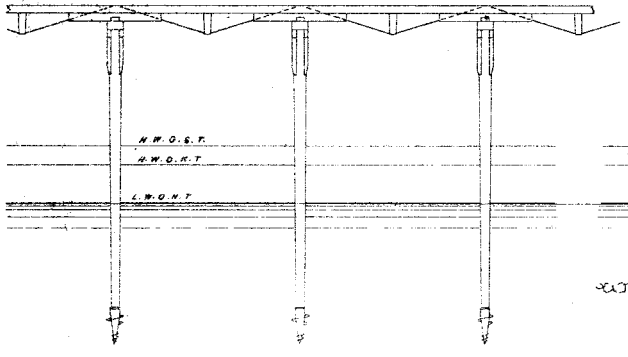


Fig 12.
Cross Section of staging for Outer Works.
North & South Breakwaters

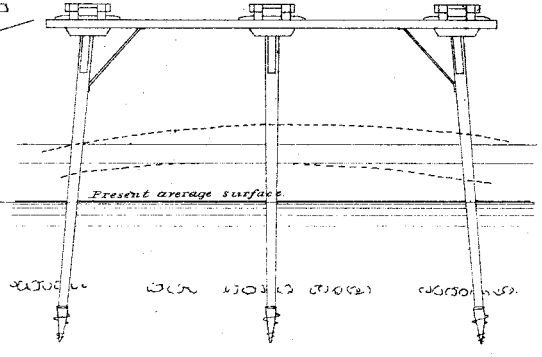
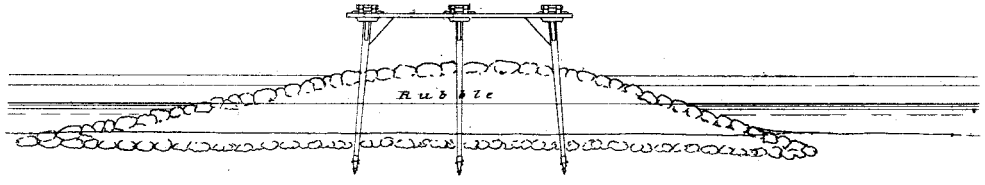
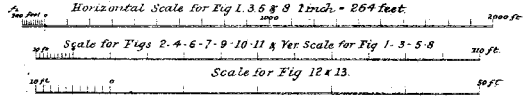


Fig 11.
Cross Section of South Breakwater
on line G.G. Fig 8.



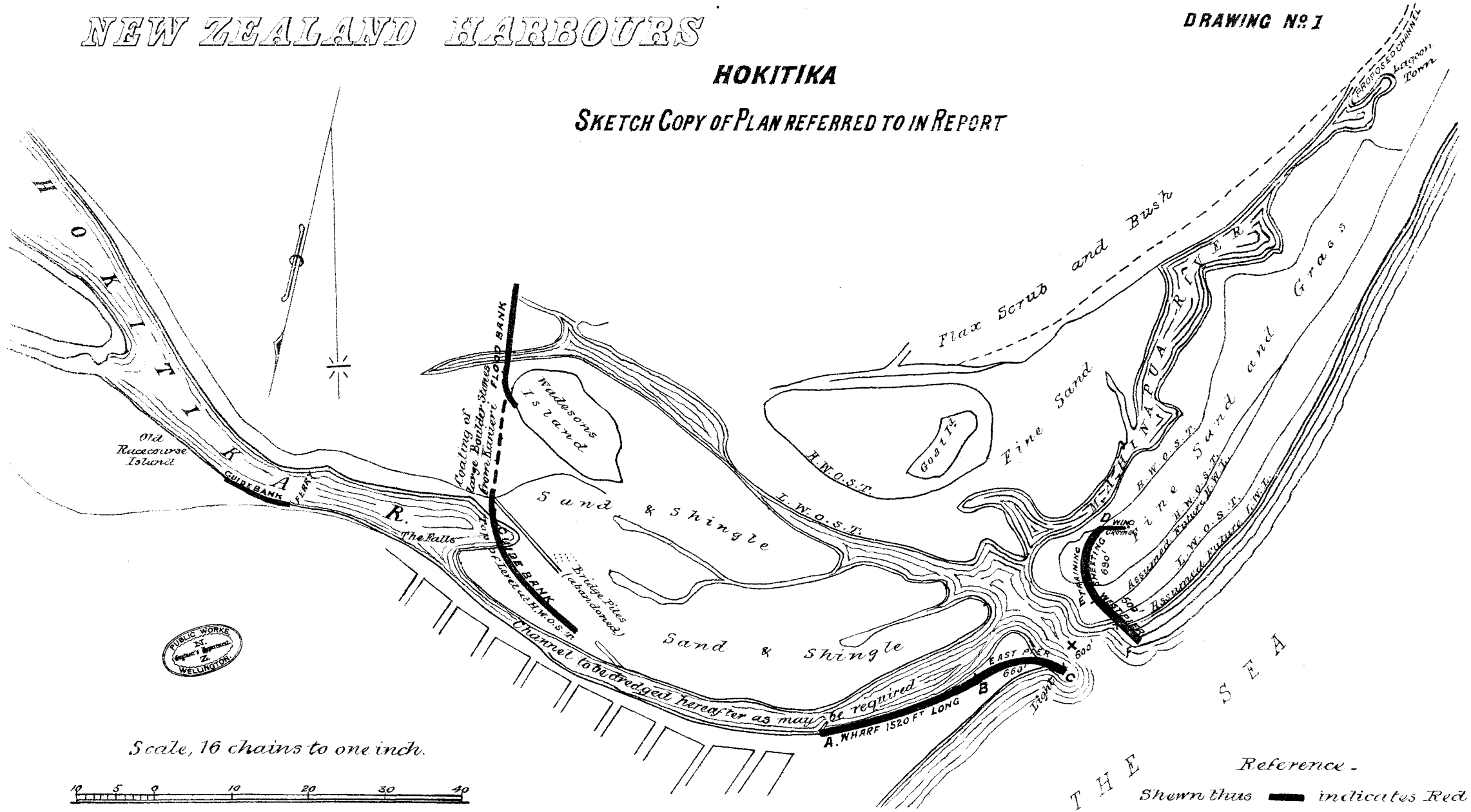


NEW ZEALAND HARBOURS

DRAWING No. 1

HOKITIKA

SKETCH COPY OF PLAN REFERRED TO IN REPORT



Scale, 16 chains to one inch.

10 5 0 10 20 30 40

Reference.

Shewn thus ▬ indicates Red

NEW ZEALAND HARBOURS

HOKITIKA

Plan & Sections of Mahinapua River and Lake.

Note – Where the Channel is to be diverted, the existing river course will be filled with dredgings & embanked to the extent shown by Red crossed lines.

Reference
Red colour shown thus ▬
Red crossed lines ▨

SKETCH COPY OF PLAN REFERRED TO IN REPORT

DRAWING No 2.

Plan of the Southern Portion of the Mahinapua River

Scale

Fig 1

MAHINAPUA LAKE

Cross Sections of Mahinapua River looking up stream

Cross Section No 1

Cross Section No 2

Cross Section

where entirely new Channel is made

Cross Section No 3

Cross Section No 4

Horizontal Scale

Vertical Scale

PUBLIC WORKS
Engineer's Department
WELLINGTON

MAHINAPUA LAKE

3.10 Acres area at Ordinary Water Level

Fig 2

Plan of Mahinapua Lake

SCALE

Fig 3.

Longitudinal Section of Mahinapua River and Lake

Note This Section has been taken along the centre line of the existing & proposed Channel

Mahinapua Lake

Horizontal Scale

Vertical Scale

NEW ZEALAND HARBOURS

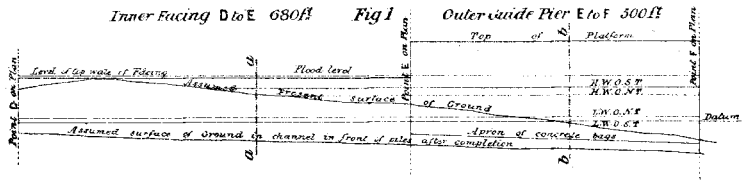
SKETCH COPY OF PLAN REFERRED TO IN REPORT

HOKITIKA

DRAWING No3.

Distorted Elevation of Works on West side of Entrance.

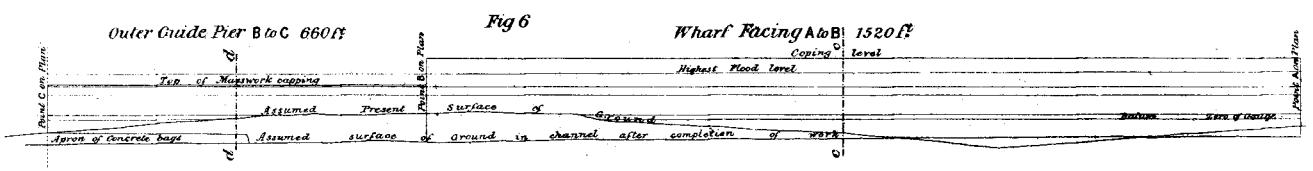
Inner Facing D to E 680ft. Fig 1 Outer Guide Pier E to F 300ft.



Distorted Elevation of Works on East side of Entrance.

Fig 6

Outer Guide Pier B to C 660ft. Wharf Facing A to B 1520ft.



Details of Inner Facing D to E West side.

Fig 2 Average Cross Section on line a a

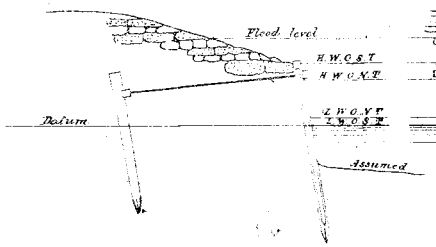
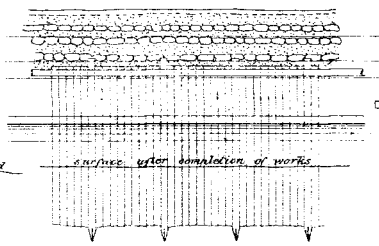


Fig 3 Part Elevation



Details of Groynes

Fig 12 Cross Section

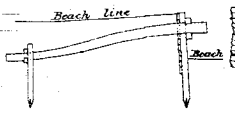
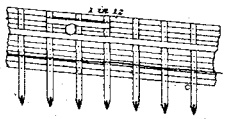


Fig 13 Part Elevation



Details of Wharf Facing A to B East side

Fig 7 Part Elevation

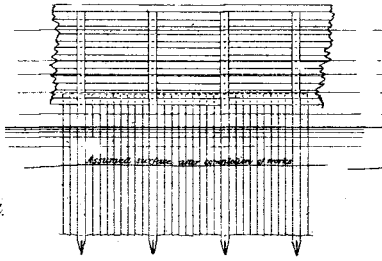
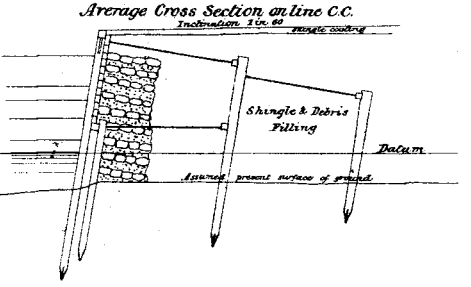
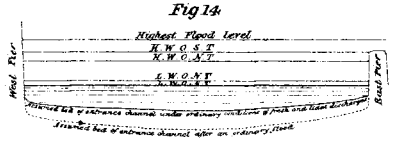


Fig 8 Average Cross Section on line C.C.



Distorted Cross Section of Entrance Channel.

Fig 14



Details of Outer Guide Pier E to F West side.

Fig 4 Average Cross Section on line b b

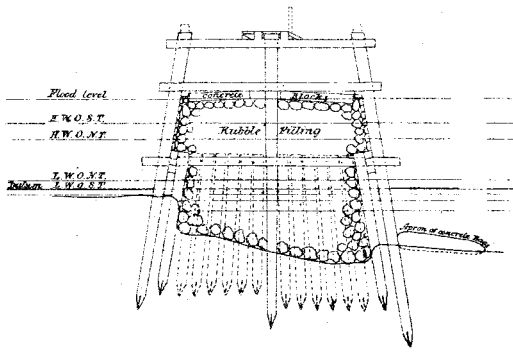
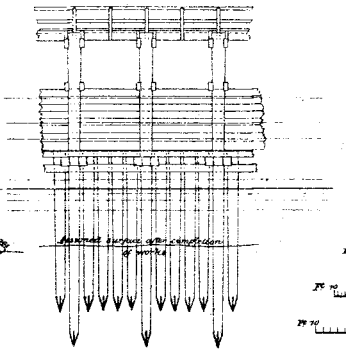
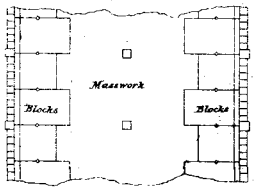


Fig 5 Part Elevation

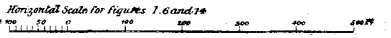


Part Plan of Capping

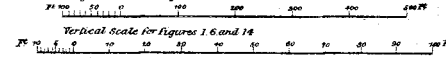
Fig 11



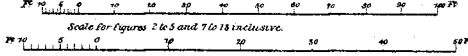
Horizontal Scale for Figures 1, 6 and 14



Vertical Scale for figures 1, 6 and 14



Scale for figures 2 to 5 and 7 to 13 inclusive.



Details of Outer Guide Pier B to C East side.

Fig 9 Part Elevation.

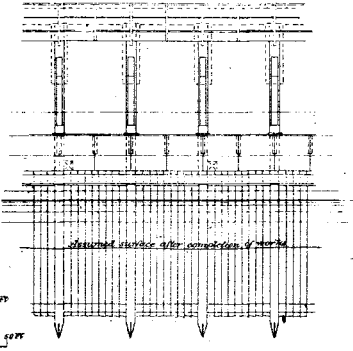
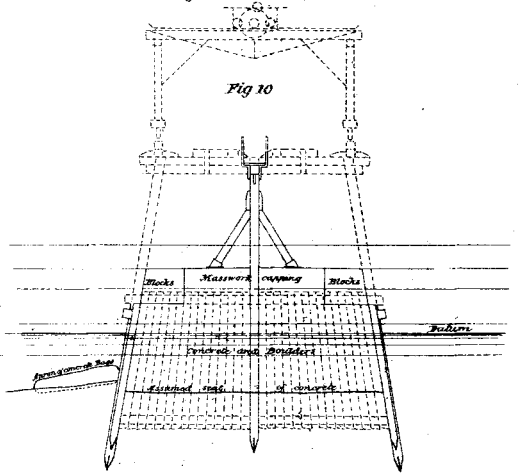


Fig 10 Average Cross Section on line d d.



NEW ZEALAND HARBOURS — MILFORD LAGOON

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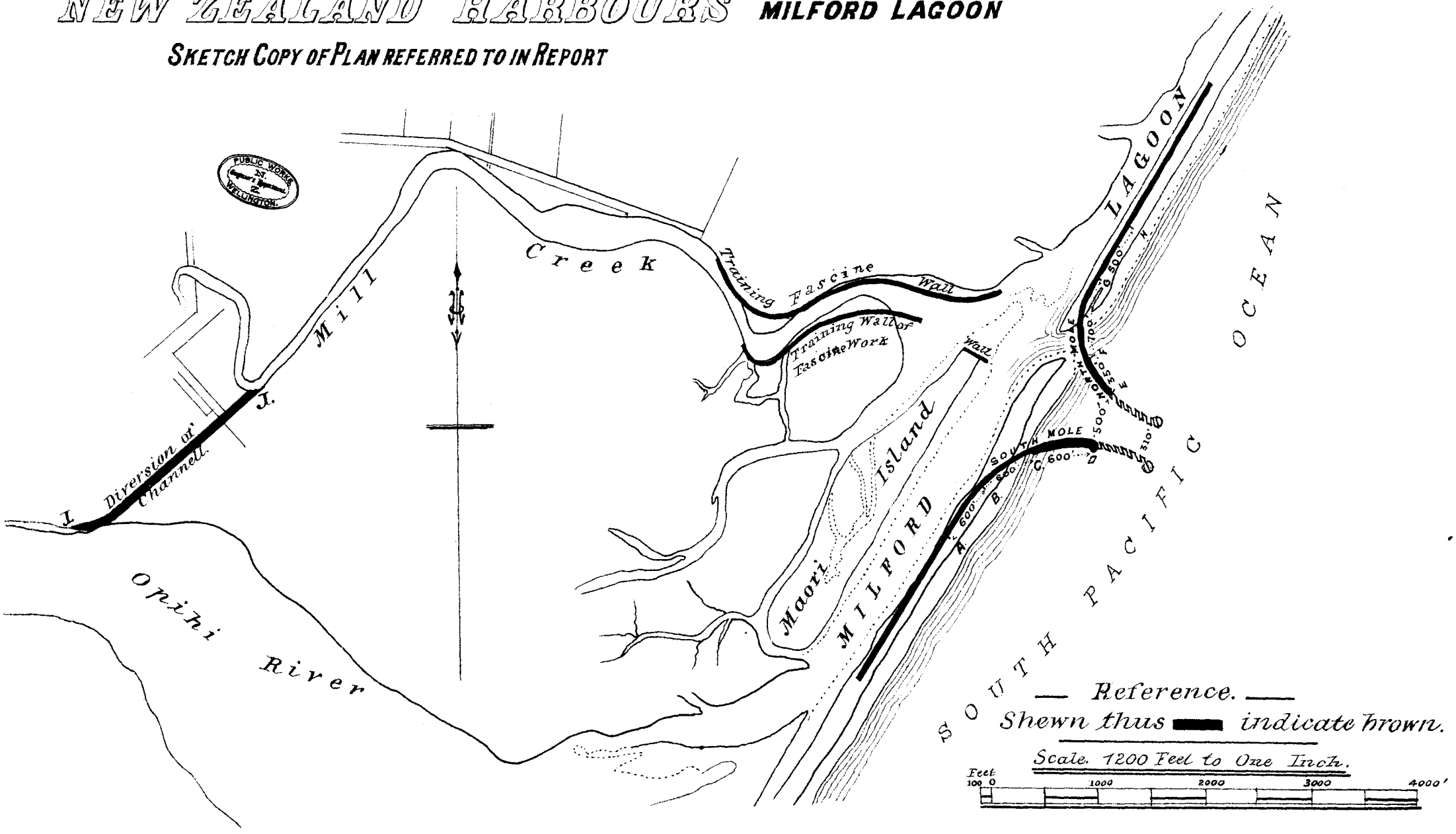
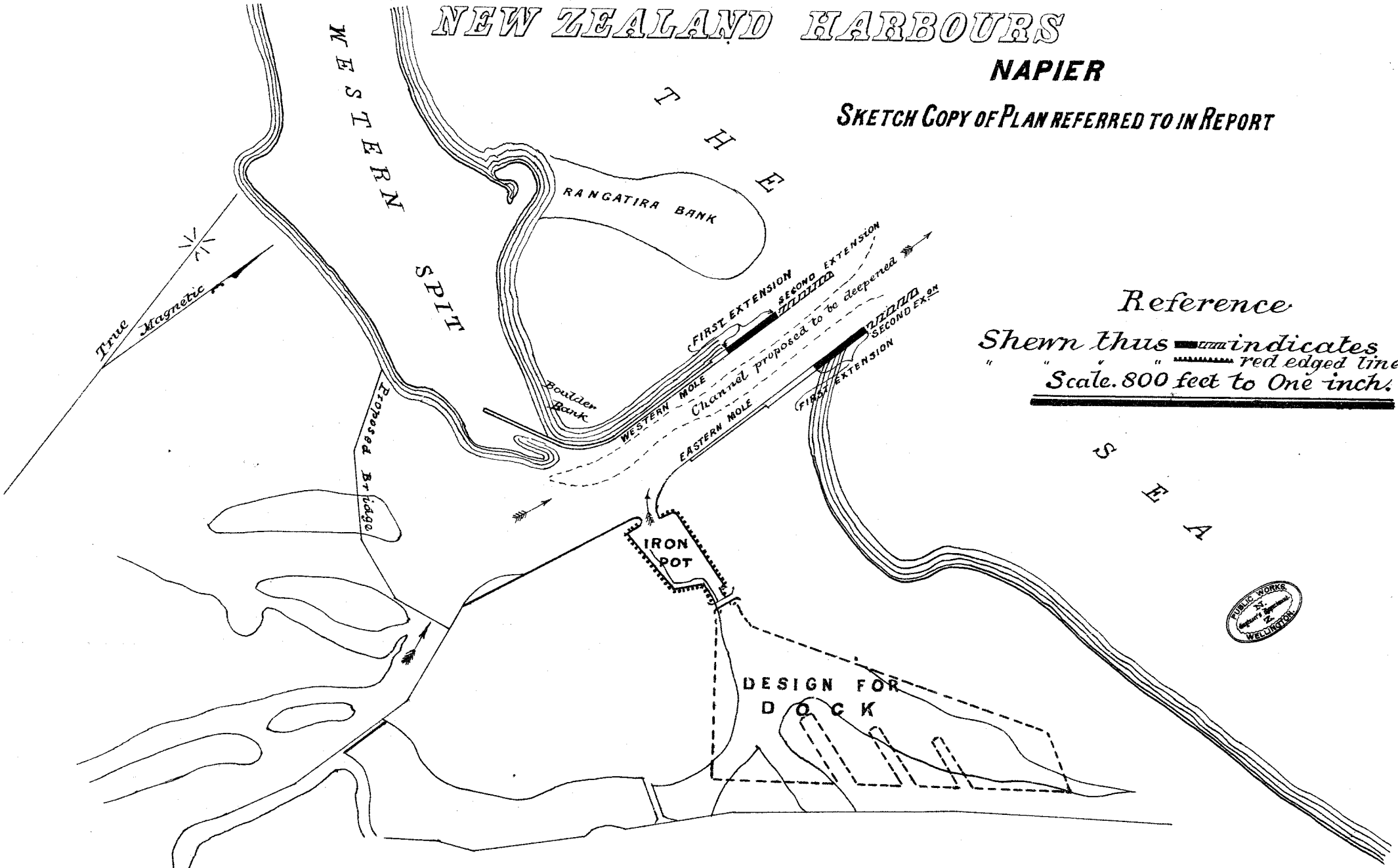


NEW ZEALAND HARBOURS

NAPIER

SKETCH COPY OF PLAN REFERRED TO IN REPORT



Reference.

Shewn thus ▬▬ indicates red

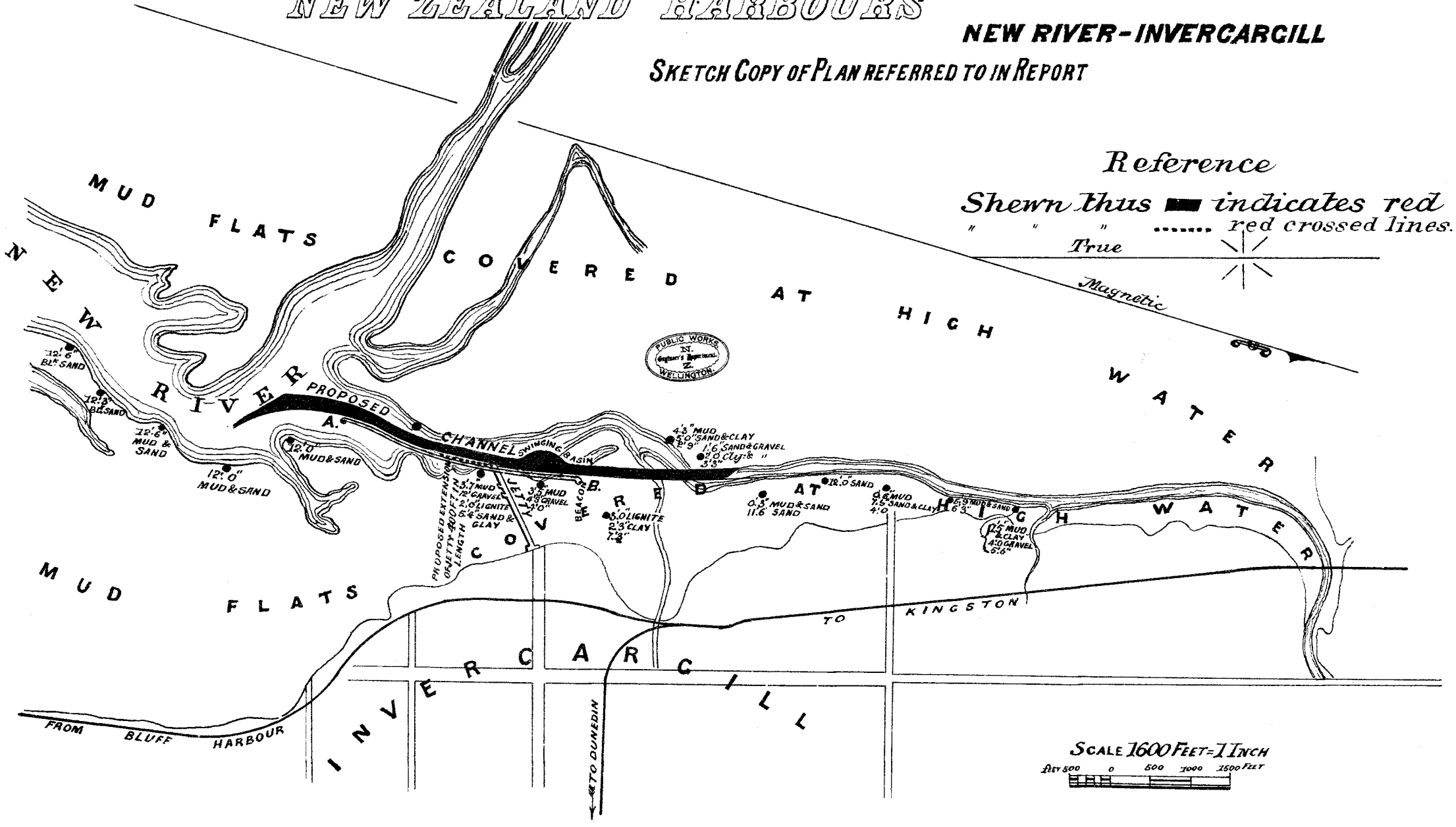
" " " ▬ ▬ ▬ red edged lines.

Scale. 800 feet to One inch.

NEW ZEALAND HARBOURS

NEW RIVER - INVERCARGILL

SKETCH COPY OF PLAN REFERRED TO IN REPORT

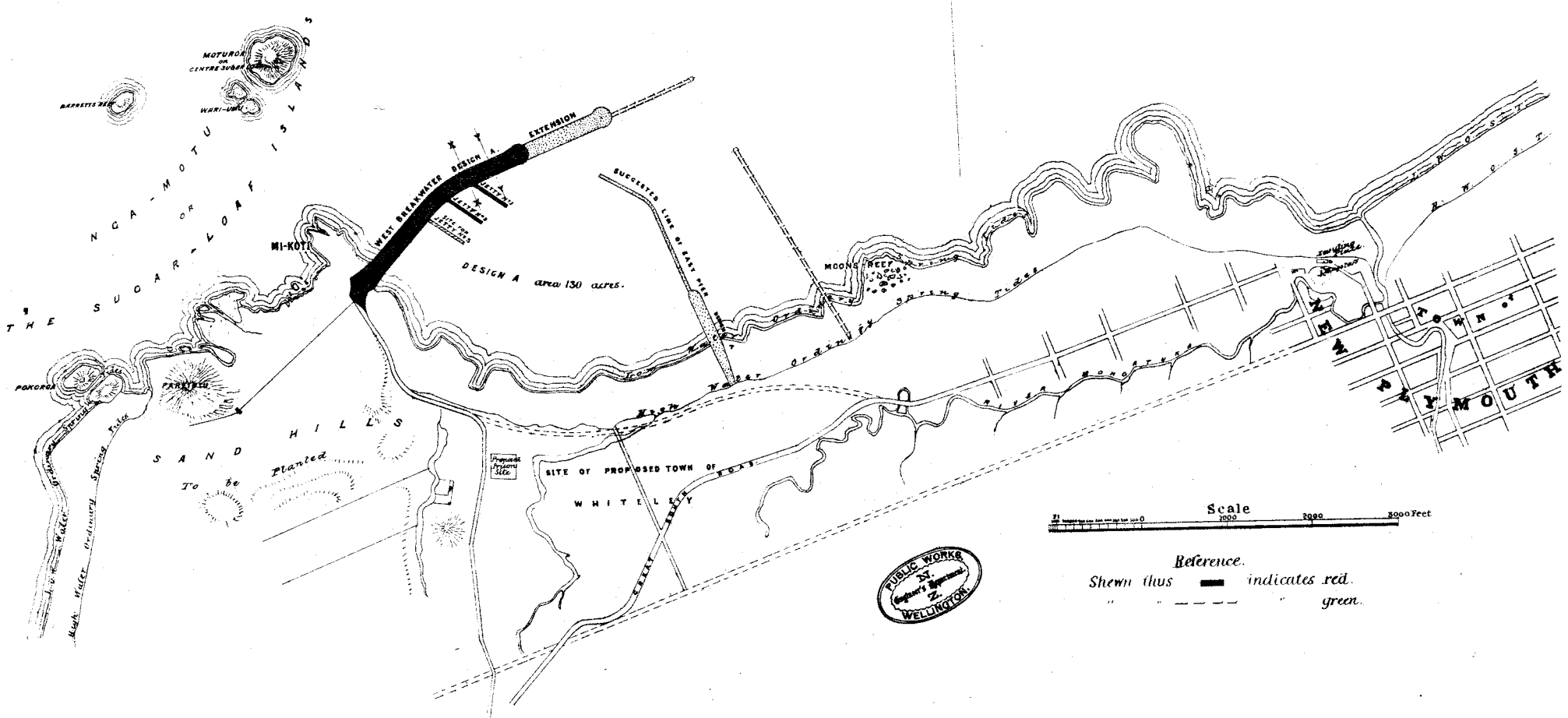


NEW ZEALAND HARBOURS

DRAWING No. 1.

SKETCH COPY OF PLAN REFERRED TO IN REPORT

NEW PLYMOUTH

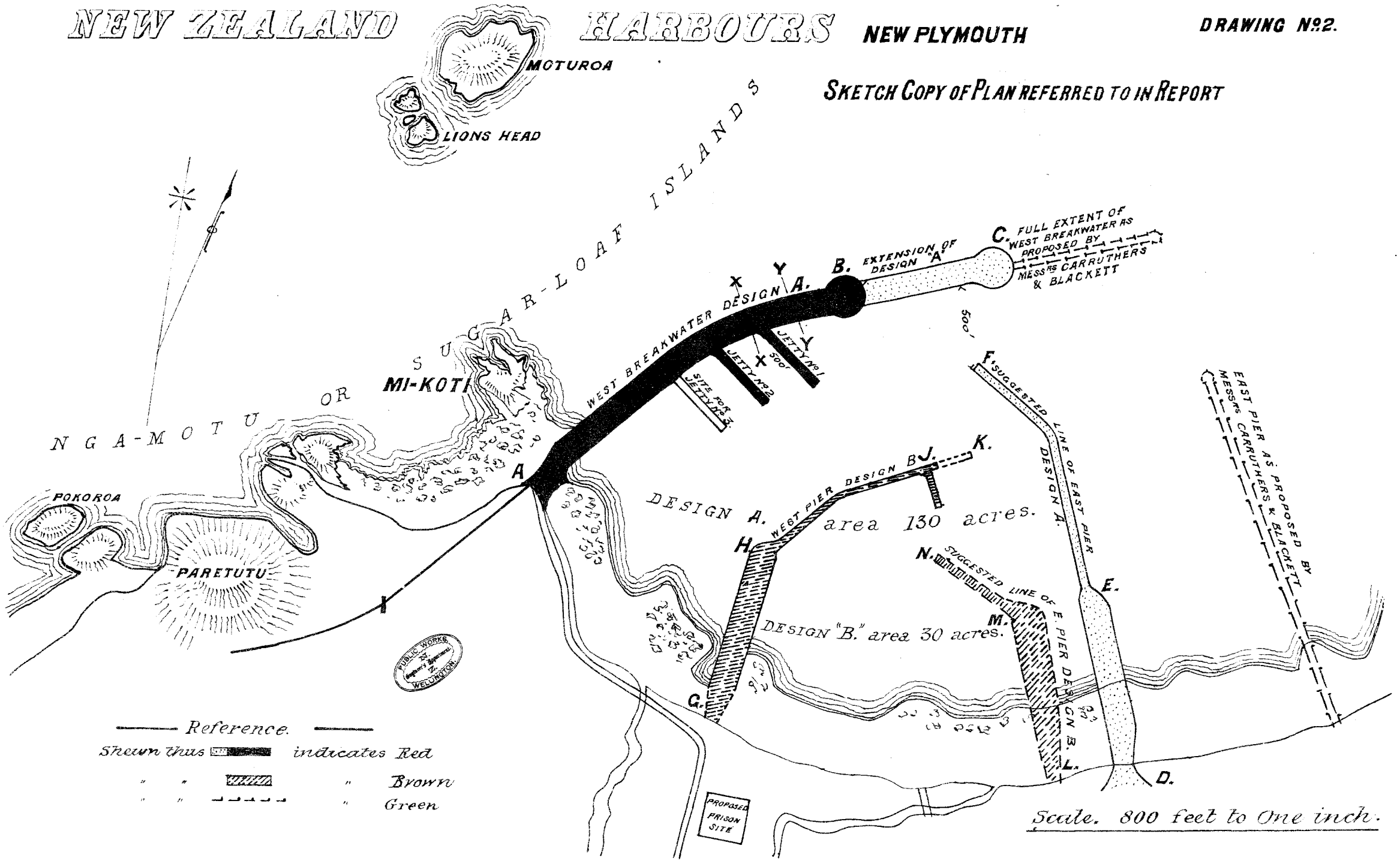


NEW ZEALAND HARBOURS

NEW PLYMOUTH

DRAWING No. 2.

SKETCH COPY OF PLAN REFERRED TO IN REPORT

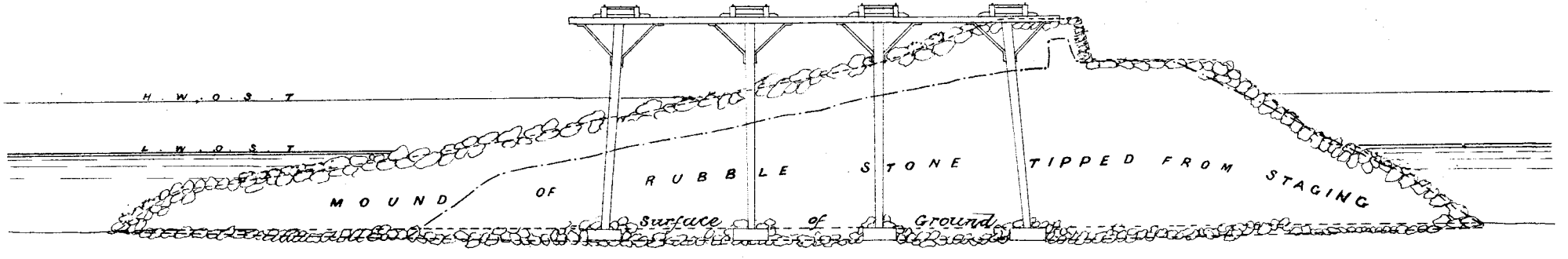


NEW ZEALAND HARBOURS

SKETCH COPY OF PLAN REFERRED TO IN REPORT

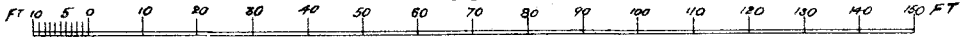
NEW PLYMOUTH

Cross Section of proposed West Breakwater
Design A on line -XX- Drawing No 2



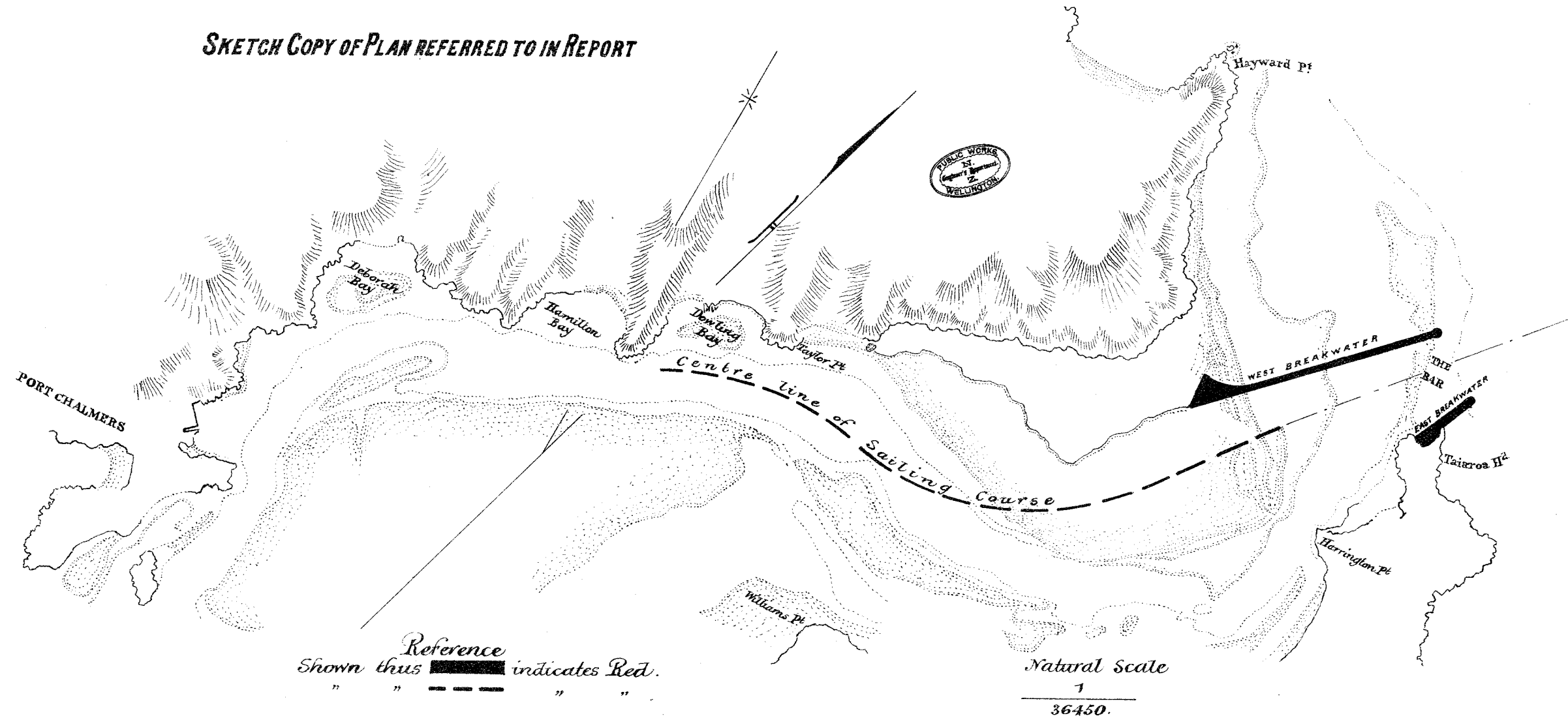
Note! cross section of west Breakwater as proposed by Mess[s] carruthers & Blackett, (green dotted lines) shewn thus — · — · — · — · —

Scale



NEW ZEALAND HARBOURS — OTAGO BAR — DRAWING No. 1

SKETCH COPY OF PLAN REFERRED TO IN REPORT

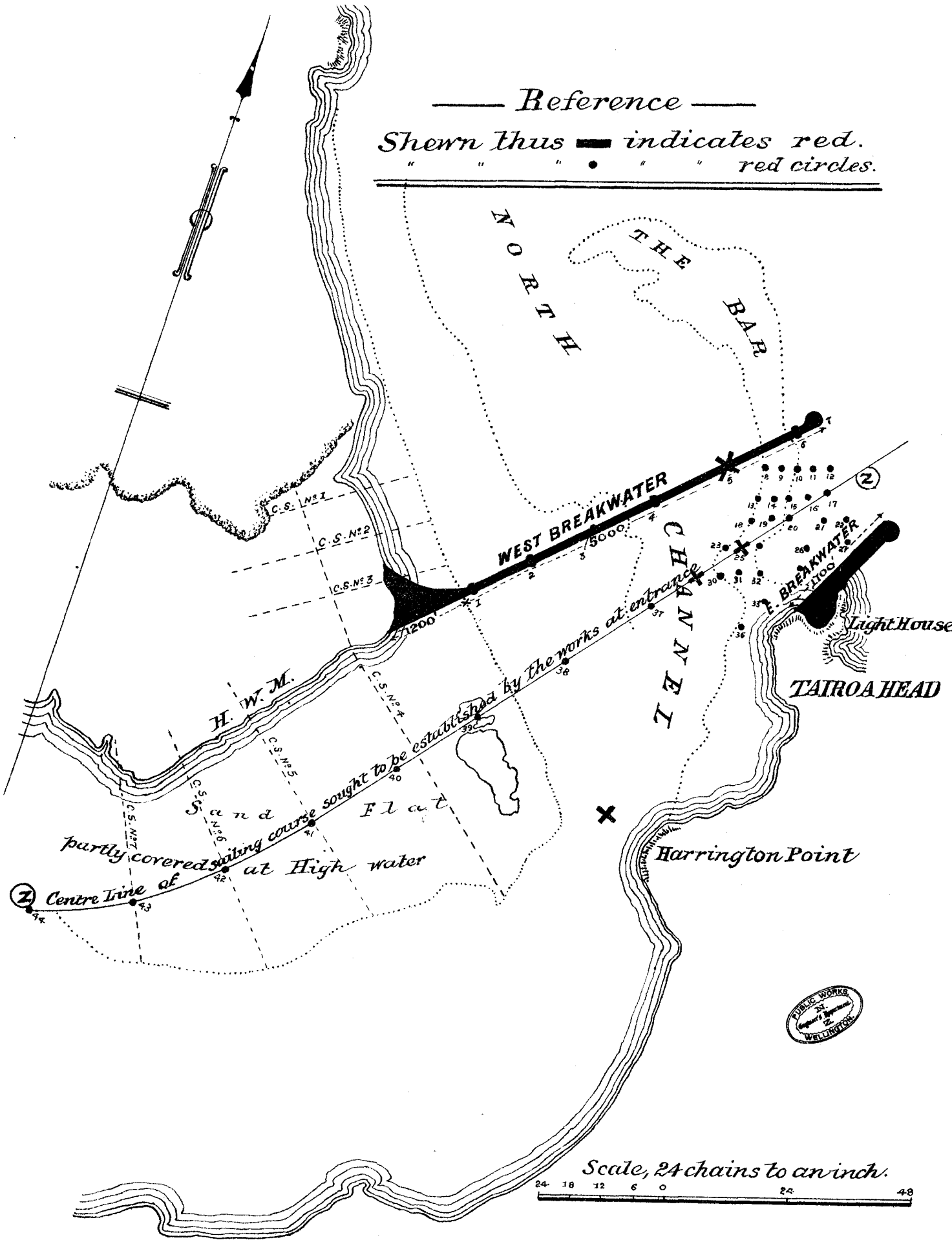


NEW ZEALAND HARBOURS

OTAGO BAR

DRAWING No. 2

SKETCH COPY OF PLAN REFERRED TO IN REPORT



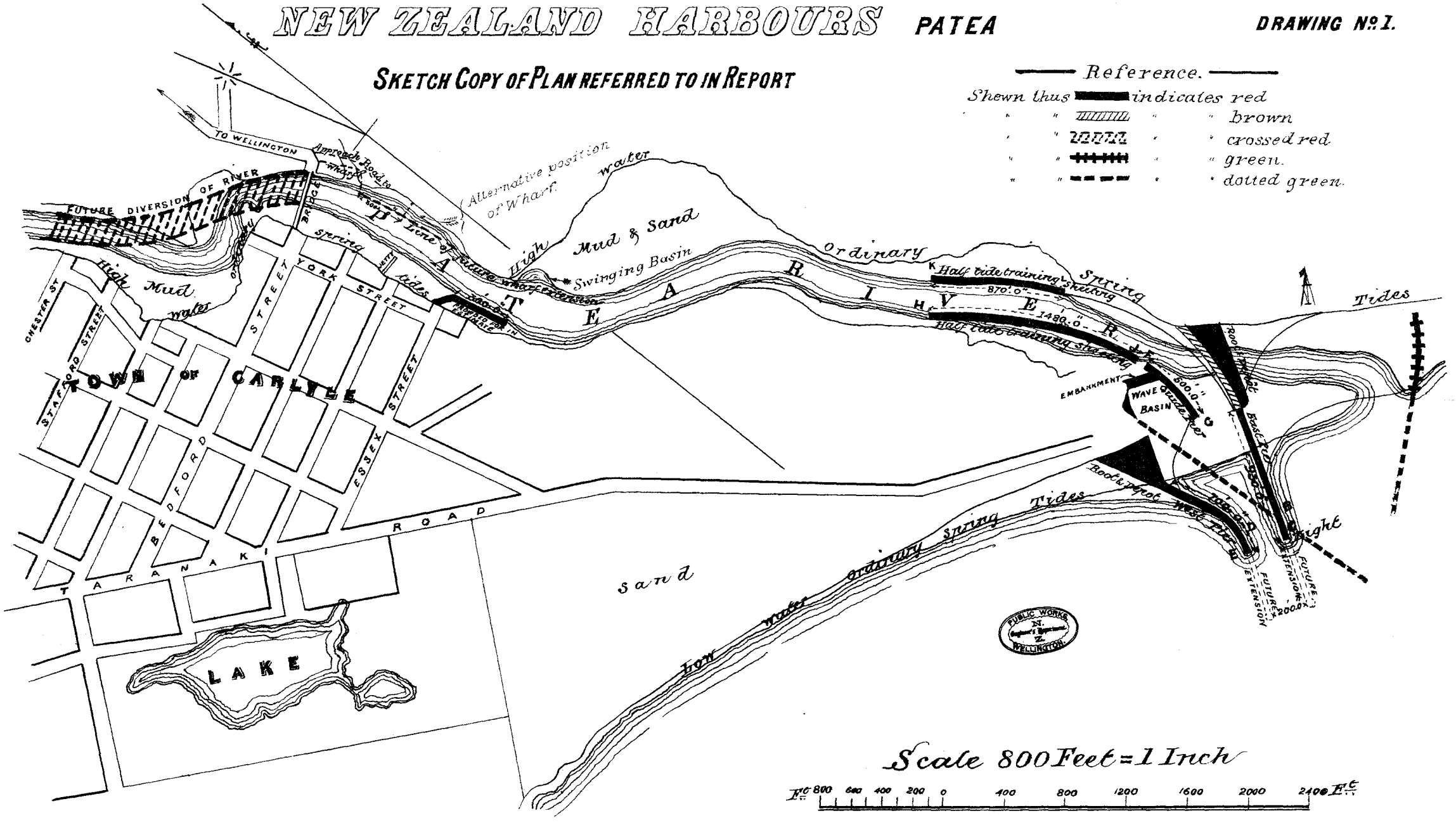
NEW ZEALAND HARBOURS — PATEA

DRAWING No. 1.

SKETCH COPY OF PLAN REFERRED TO IN REPORT

Reference.

Shewn thus ▬ indicates red
" " ▨ " " brown
" " ▩ " " crossed red
" " ▬▬ " " green.
" " - - - " " dotted green.



Scale 800 Feet = 1 Inch

Ft. 800 600 400 200 0 400 800 1200 1600 2000 2400 Ft.

NEW ZEALAND HARBOURS

PATEA

SKETCH COPY OF PLAN REFERRED TO IN REPORT

DRAWING No. 2

Fig 1
Longitudinal Section of East Pier

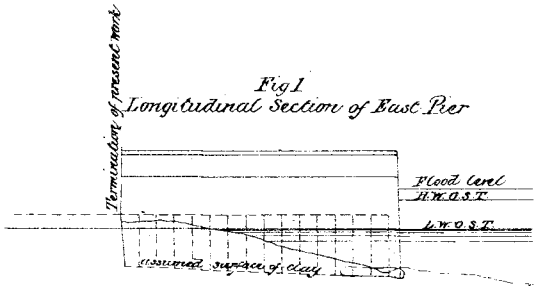


Fig 4
Longitudinal Section of West Pier

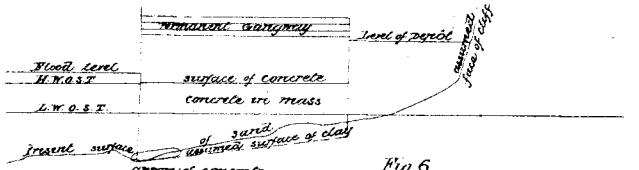


Fig 2
Cross Section on line X X (see Fig 1)
looking seaward

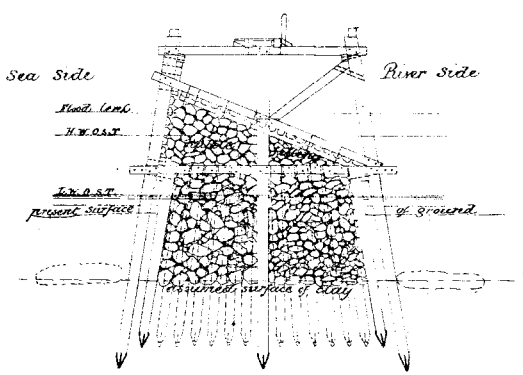


Fig 3
Part Elevation River Side

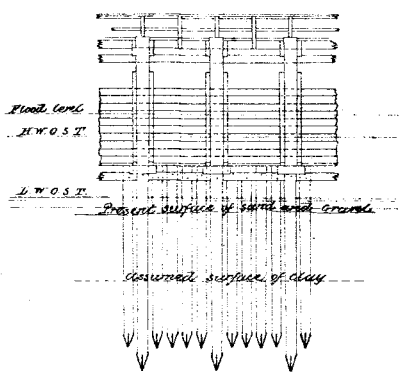


Fig 5
Part Elevation

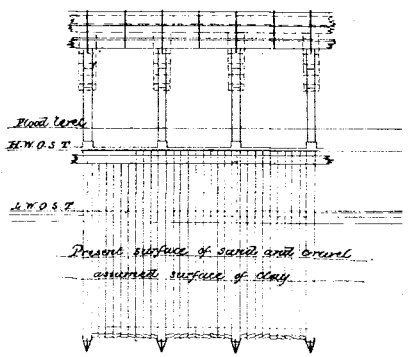
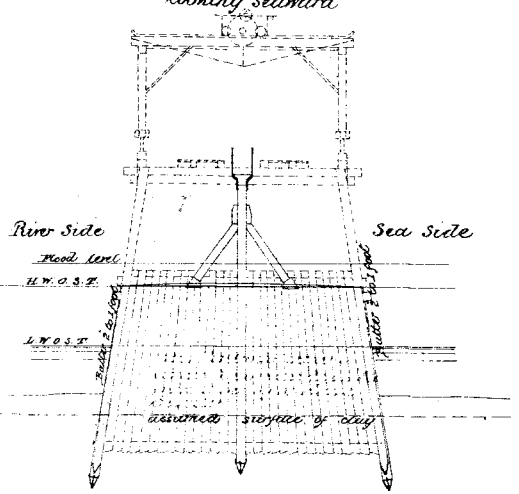


Fig 6
Cross Section on line Y Y (see Fig 4)
looking seaward

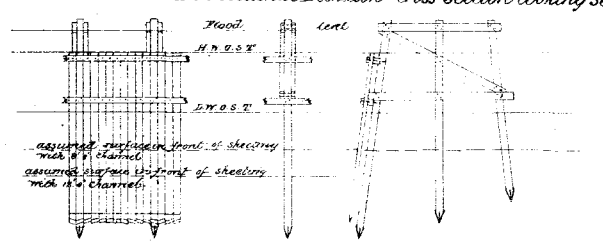


Guide Pier

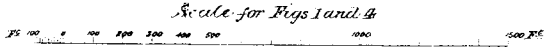
Fig 7
Part Elevation

Fig 8
Part Sectional Elevation

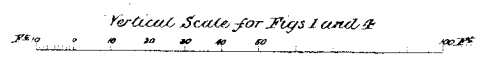
Fig 9
Cross Section looking seaward



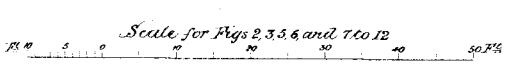
Scale for Figs 1 and 4



Vertical Scale for Figs 1 and 4



Scale for Figs 2, 3, 5, 6 and 7 to 12

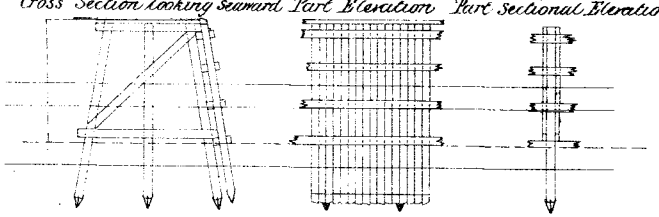


West Pier
Sea Face of Boot

Fig 10
Cross Section looking seaward

Fig 11
Part Elevation

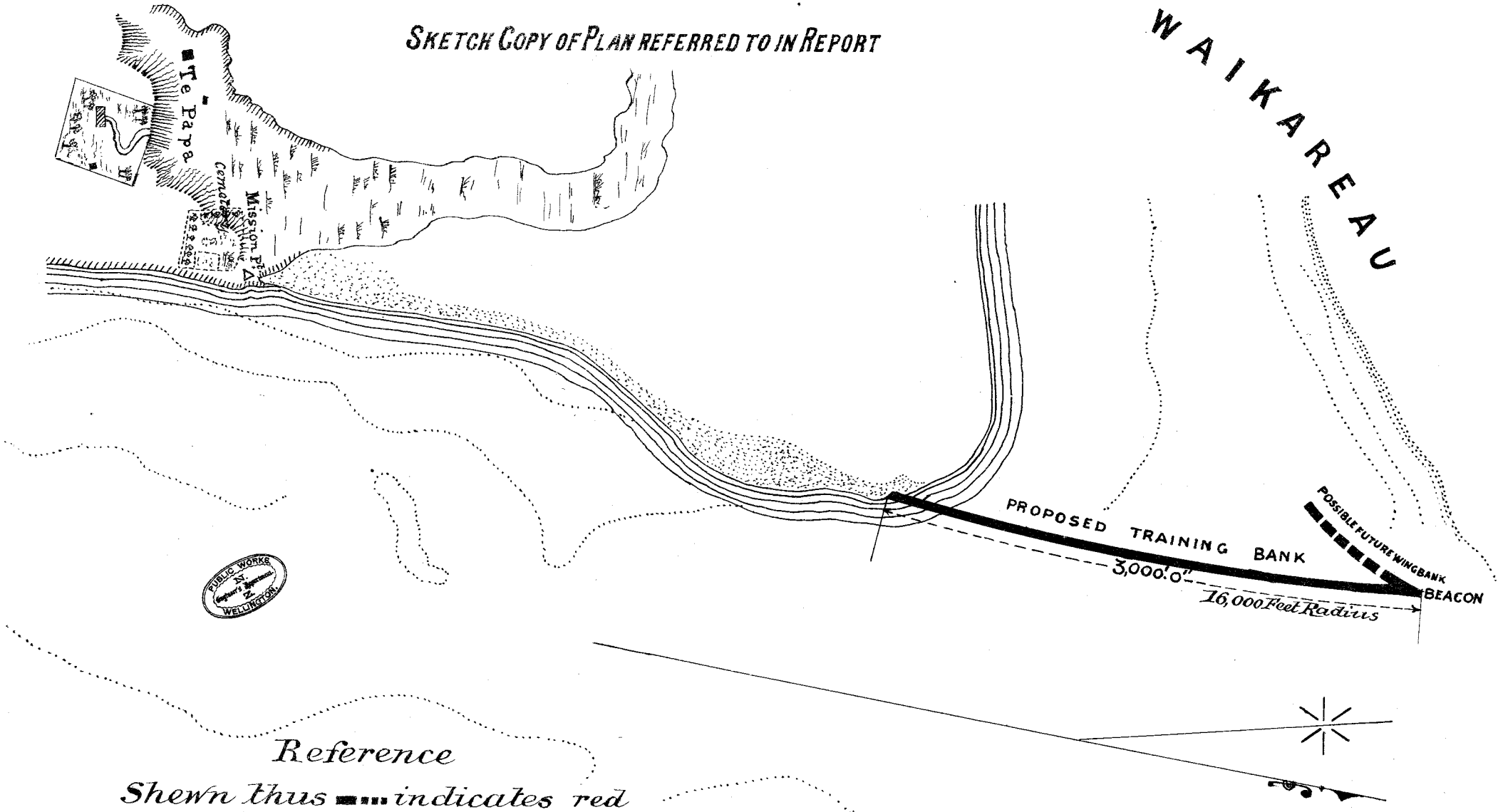
Fig 12
Part Sectional Elevation



NEW ZEALAND HARBOURS — TAURANGA

ACTS FOR DRAWING Nos 1 & 2.

SKETCH COPY OF PLAN REFERRED TO IN REPORT



Reference

Shewn thus ▬ ▪ ▬ ▪ indicates red

Scale

0 1 2 3 4 5 Cables
½ Sea Mile

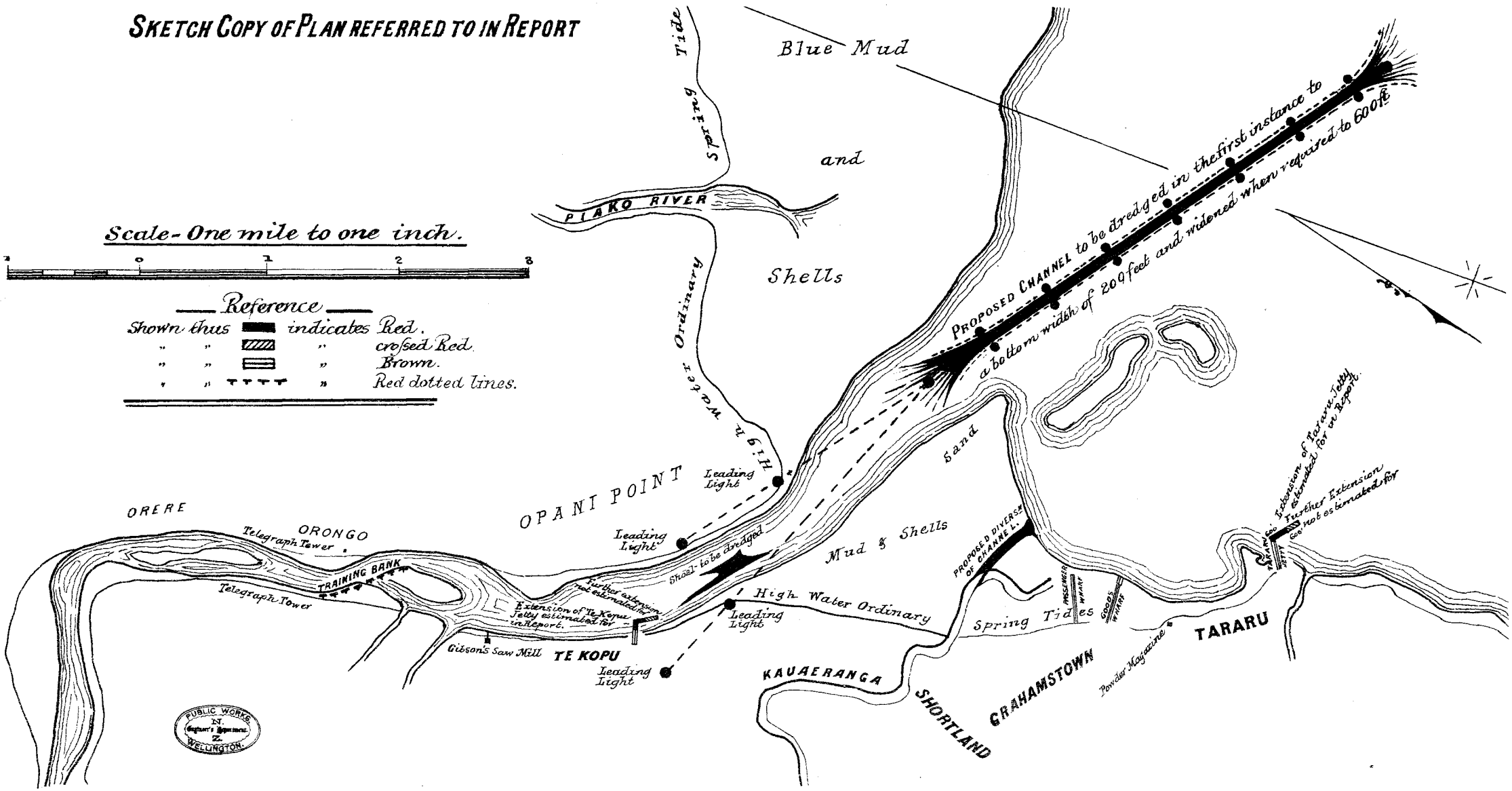
Low Water Ordinary Spring Tides
High Water Ordinary Spring Tides

NEW ZEALAND HARBOURS

THAMES RIVER

DRAWING No. 1.

SKETCH COPY OF PLAN REFERRED TO IN REPORT



NEW ZEALAND HARBOURS

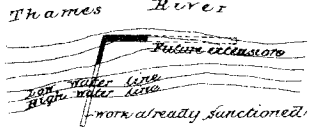
THAMES

DRAWING No. 2

SKETCH COPY OF PLAN REFERRED TO IN REPORT

Plan of proposed Jetty at Te Kopu

Fig 1



The extent of the work provided for in the estimate is indicated by red color.

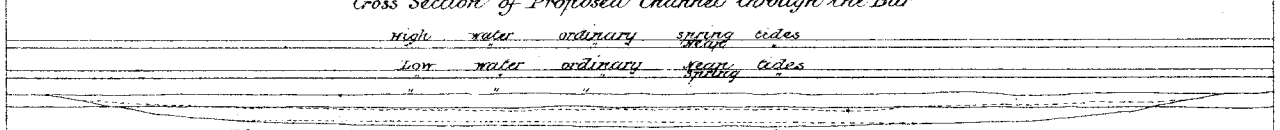
—Reference—

Shewn thus ■ indicates red

Shewn thus ▨ indicates green

Fig 7

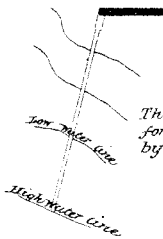
Cross Section of Proposed Channel through the Bar



Note: The estimate provides for the formation of a preliminary channel of not less than 8 feet in depth for a width of 220 feet at low water of spring tides, and also for subsequently deepening this channel to 12 ft at low water for a width of not less than 200 feet

Plan of proposed extension of Tararu Jetty

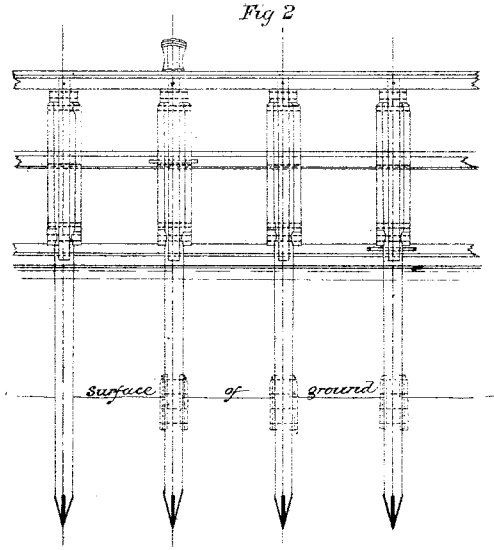
Fig 4



The extent of the work provided for in the estimate is indicated by red color.

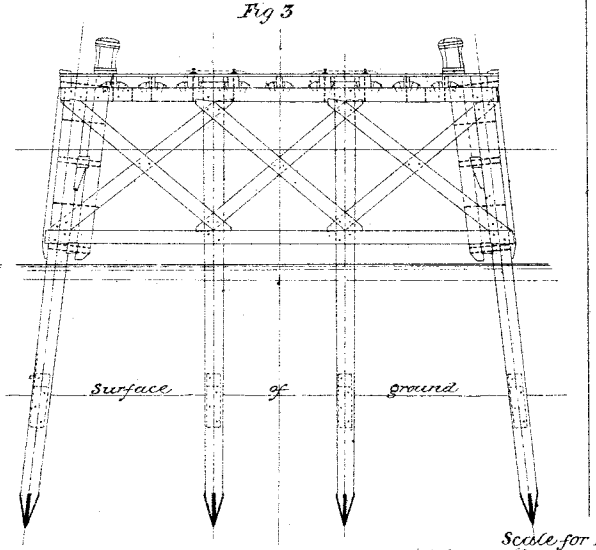
Side Elevation

Fig 2



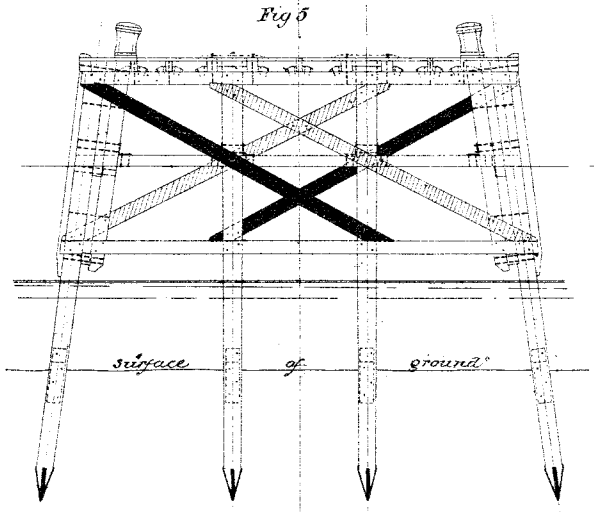
Cross Section

Fig 3



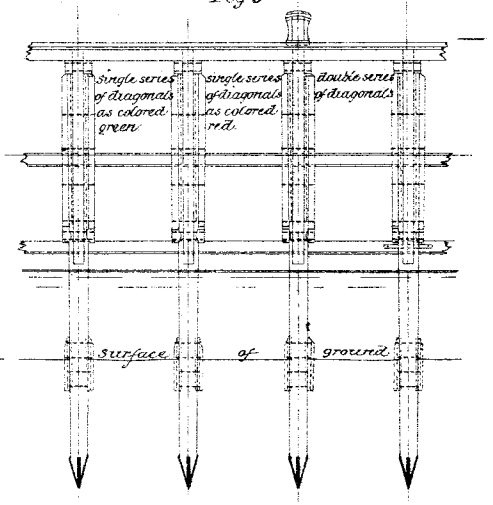
Cross Section

Fig 5



Side Elevation

Fig 6



Scale for Figs 1 & 4

Scale for Fig 7

Scale for Figs 2, 3, 5 & 6

Note: Where the bollards occur at intervals of 60 feet the bay is to be fitted with double braces as coloured red and green in the c.s above, elsewhere the diagonals are to be arranged as a single series varied on alternate bays as explained in the elevation.