(No. 2.)

1898.

PARLIAMENT OF TASMANIA.

MACQUARIE HARBOUR:

REPORT ON PROPOSED WORKS FOR DEEPENING THE BAR, BY C. NAPIER BELL, M. INST. C. E.

Presented to both Houses of Parliament by His Excellency's Command.

Cost of printing—£18 19s.

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MACQUARIE HARBOUR.

REPORT ON PROPOSED WORKS FOR DEEPENING THE BAR.

November, 1897.

Sir,

I have the honour to submit the following Report on the works required for the proposed deepening of the bar of Macquarie Harbour.

I arrived at Strahan on the 23rd of October, and at once proceeded to the Heads, where I stayed over five weeks, during which time I made observations on the tides and currents, and tested the rock which is to be used in the construction of the works. I also took a number of soundings outside the bar, and took borings on the site of the proposed bridge. While I was staying at the Heads there was some very stormy weather, with heavy westerly gales, and I had the advantage of attentively observing the character of the exposure to which the proposed works would be subject, and the direction of the heavy waves which come into the bay within the shelter of Cape Sorell.

Former visit.

On the occasion of my former visit to this harbour in 1890 the only plan I could get of the locality of the bar and entrance was a very small chart surveyed in 1819, which showed a not very extensive set of soundings on the bar and over the shoals which for four miles inside the bar obstruct the navigation.

Since my last visit Messrs. Hardy and Ellis, employed by Mr. A. W. Lauder, have made a very complete chart of these shoals, and including some soundings over the bar and the sandspits on either side of it. Mr. Pilot Chaplin also took soundings outside the bar, which, being fixed by compass bearings, are not so exact as to position as those taken by Messrs. Hardy and Ellis. I also took a large number of soundings all round outside the bar and along the beach towards the north.

Mr. A. W. Lauder caused several bores to be taken on the sandbanks inside, as well as on the bar, to a depth of 22 feet below low-water mark, but there appears to be no possibility of there being any rock on the bar at a depth of less than 25 feet below low water; in fact there is every appearance of the rock being at a great depth.

Chart of 1819.

By comparing the chart of 1819 with that by Messrs. Hardy and Ellis, there is little or no change apparent between that time and the present. I notice, however, that part of the north channel near River Point has 8 feet 6 inches of water where in 1819 the depth is given as 12 feet, and it would appear as if the width between the nearest part of the south shore to the sandy point on the north shore is now about 400 feet wider than in 1819. Both the shoaling of the north channel and the widening of the entrance is very likely due to the destruction of the vegetation which formerly covered the north point, as the result of which some millions of cubic yards of sand have been blown into the harbour.

The bar and surrounding spits are the same now as shown in the chart of 1819; there is the same depth of water on it. The line of beacons which now indicates the centre of the bar is also shown on the old chart, and the bar is now the same distance from Entrance Island as it was in 1819.

The bar.

The bar is situated 4200 feet outside Entrance Island; it is a narrow ridge of sand connecting the great sandspits on either side of it, which spits extend to the opposite beaches. The bar varies in depth from 8 feet 6 inches in summer and fine weather, to 9 feet 6 inches and 10 feet in winter or when rough weather prevails, at low water. Immediately outside the bar the water deepens from 25 to 48 feet. Inside the bar there is a channel between the two spits, with water increasing in depth from 12 to 31 feet, until Entrance Island is reached, when the channel between the island and the south shore is 84 feet deep. On the west side of the island there is also a channel with depths from 12 to 18 feet, shoaling rapidly to the beach on the west side. The width of the main channel between the island and the south shore is 320 feet, and between the island and the north shore 2200 feet.

All the south side of the harbour consists of rocky hills of quartzite and sandstone; but the projecting point extending from Strahan to the north side of the entrance is all sand covered with bush, except the extreme end of the point, which is bare sand.

Two channels.

One mile inside Entrance Island is Bonnet Island, and the navigable channel between these Islands is of ample width and depth, varying from 30 to over 42 feet. As soon as Bonnet Island is passed, the navigable channel is divided into two, one passing close along the winding rocky shore of the south side as far as Spur Point, and this channel carries a least depth of 10 feet at low water.

The north channel.

The other, or north channel, takes a more direct course from Bonnet Island to the beacons at River Point, where the first-mentioned channel joins it. This north channel carries a least depth of 8 feet 6 inches. In both these channels the depths vary greatly from 24 feet to the least depth above stated, and there is a long bank of sand, with 1 or 2 feet of water on it, which divides these two channels.

After passing through either of these channels, with more or less of shallow water, for a length of 3 miles from Bonnet Island, the water of the harbour suddenly deepens to about 50 feet, which is the normal depth up to Strahan.

The distance from Entrance Island to Strahan is 12 miles. From Strahan the harbour extends to the mouth of the Gordon River, a distance of 20 miles, and the general depth of the harbour between Strahan and the Gordon is from 80 to 120 feet.

Macquarie Harbour.

Macquarie Harbour is a great lagoon, with an area of 112 square miles, or 72,000 scres, Two rivers, the King and Gordon, discharge into it with a united drainage area of 25·25 square miles, and the average rainfall on this watershed is over 100 inches yearly. As the climate is wet and stormy these rivers are frequently in flood, and they bring a great body of water into the harbour; thus a rainstorm of 2½ inches in 24 hours, which is not uncommon, is capable of raising the level of the water in the harbour 3 feet. Of course, the lagoon being open to the sea the level of the water is never raised to this height from the floods of the rivers only, but by northerly gales and floods combined, the level of the lagoon is frequently raised from 3 feet 6 inches to 4 feet 6 inches above low-water mark, and occasionally even higher. Mr. Hales, District Engineer, has seen the water at Strahan rise to 5 feet during a gale, and this without any floods in the rivers; and on the 25th November I saw the tide rise at the Heads 6 feet above low-water mark.

Tides.

The tides at Macquarie Harbour are observed to be very irregular, but this may be partly owing to their being disturbed by the winds, which have an extraordinary influence on the height of the water in the Harbour. The extreme range of the tide seems to vary from 1 foot 6 inches to 3 feet, but this is so irregular that it is impossible to predict anything about the tides, except that in fine weather and south-westerly winds the tides are low, but in windy weather and northerly winds the tides are highest. An on-shore gale, or even a fresh breeze, may raise the level of the lagoon to the extent of completely masking the tides. At the Heads there is usually only one tide in the 24 hours, but a false tide often follows a short time after high water, the effect of which is that after the water has begun to ebb strongly the tide again rises, the ebb slackens for an hour or more, then finally the tide begins to fall, and the strong ebb sets in again.

Sea tide obstructed.

The extensive shoals which obstruct the entrance prevent the full effect of the sea-tide reaching into the lagoon; thus, in fine weather, with a range of tide varying from 1 inch to 2 feet, there is a strong flood and ebb tide into and out of the harbour, the effect of which extends even 20 miles up the Gordon River; but this range of 18 inches or 2 feet causes a range of only 9 inches to 15 inches at Strahan, and the same at the mouth of the Gordon, as the harbour is so deep between Strahan and the Gordon that there is no difference in its level between Strahan and the Gordon mouth.

According to all the information I could collect, the ordinary average tide at the Heads is 2 feet, but any change in the weather increases it, and a gale will usually cause a rise of tide of from 3 feet to 4 feet 6 inches above low water, while a tidal range of 1 foot 6 inches is confined to very fine weather and neap tides.

Observations of the Pilot.

Pilot Haik observes as follows:—"The tides are higher in winter than in summer to the extent of nearly one foot; this seems quite likely, as the same effect is observed at Fremantle, where the conditions affecting the tides are very similar to those at Macquarie Heads. About the time of high and low water the tide is 'slack' for more than an hour, that is, it neither runs in nor out for that time, while the water slowly rises for some time before flood tide sets in; this phenomenon is said to account for the extraordinary difference observed in the length of the ebb as compared with the flood tide, the ebb being frequently 18 hours and the flood only 6. When a northerly gale is coming on the tide flows into the harbour very strongly, and often for 24 hours continuously; the harbour then fills up from 3 feet 6 inches to 4 feet, and even occasionally to 5 feet above low water. As soon as the gale begins to abate, or even during its height, if it shifts round to the westward the water of the harbour ebbs out with great force, the length of the ebb being often 18 hours, and only checked for 5 or 6 hours as the tide rises at sea. In fine weather there are often days when there are no tidal currents either in or out; on the other hand, the flood tide is longer and the ebb shorter in fine weather. In fine weather, undisturbed by approaching bad weather or by floods in the rivers, the flood and ebb tides are of nearly equal duration; occasionally the flood tide attains a velocity of 6 feet a second, and this generally indicates the approach of bad weather." I was able to observe these tides during an unusually heavy gale from the west, which lasted a whole week, and the phenomena then observed are characteristic of all gales, which, on this coast, are frequent enough.

Heavy gale.

On the 24th, 25th, and 26th of October the wind blew fresh from N. to N.N.W., with rain and floods in the rivers. The sea-water flowed into the harbour very strongly and almost continuously, but with short periods of slack water and feeble short ebbs; the tide stood very high at Strahan all this time.

On the 27th it was blowing a heavy gale at N.W.; the tide was slack in the forenoon, but ebbed very strongly in the afternoon and part of the night.

On the 28th, blowing hard at W.; tide slack in the early morning, but ebbed powerfully in the afternoon and part of the night; a very heavy sea outside.

On the 29th, hard gale at W.; mountainous waves outside; tide flowed in from 1 A.M. till 7·30 A.M., then ebbed, increasing in strength till afternoon, when there was a very strong ebb.

Violent ebb.

On the 30th, heavy gale at W., with tremendous waves breaking in water that must be 10 to 12 fathoms deep a long way outside the bar; flood tide in the night, but commenced to ebb at 7·30 A.M., and in the afternoon there was the most furious ebb tide I ever saw; the velocity was estimated at 6 miles an hour, but in the narrow channel between Entrance Island and the rocky shore it was like a cataract, and the velocity must have been 10 miles. The water was thick, with sand flowing out off all the sandbanks for miles up the harbour.

On the 31st, fresh gale at W. Sea somewhat reduced, tide slack during the night and early morning, but began to ebb after 7 A.M., and in the afternoon very strong ebb, but not so strong as on the 30th; velocity of ebb between Bonnet and Entrance Islands 6 feet a second, streams of sand flowing out of the harbour.

November 1st, calm, and sea moderate, flood-tide at night, but ebbed at 8 A.M., very high tide, equal to 13 feet on the bar. Ebb gradually increased in strength till the afternoon, when the velocity was 5 feet a second, or $3\frac{1}{2}$ miles an hour. Thus the tide ebbed and flowed all through this gale with very short flood-tide and long ebb, say, about 7 hours flood and 17 hours ebb; and the range of the tide varied from 10 feet to 13 feet 6 inches on the bar.

The above details may seem tedious, and foreign to a Report; but I think they are useful, to show the nature of the forces which are relied on to deepen the bar and maintain the depth when the breakwaters are constructed; and I may thus summarise all the information on this subject which I have collected.

The great tidal basin of Macquarie Harbour is not nearly so effective in generating tidal currents as it would be if the tides were normal; for the tidal range being on an average 2 feet, and the duration of the ebb varying from 12 to 18 hours, these currents are much less intense than they would be with the usual tides of 5 or 6 feet, and ebb of 7 or 8 hours. Small as is the range of tide at Macquarie Heads, yet the tidal area of 72,000 acres is so large that there are almost always powerful tidal currents passing in and out: the ebb current especially is usually so strong and regular as to be quite capable of keeping open a deep channel when it is confined and fixed in direction between the breakwaters.

Velocity of tide.

The ordinary velocity of the ebb is about 3 feet a second, when not disturbed by the weather; but very often the velocity is $4\frac{1}{2}$ to 5 feet a second; and when the water of the lagoon is raised by gales, the velocity of the ebb is 7 feet a second, or about 5 miles an hour.

Bar not rough in bad weather.

I have often observed at Westport and Greymouth that during a heavy storm the breakwaters are safe from the violence of high waves: the reason is that the heavy waves are broken in the shallow water outside of the works, and only small waves reach the breakwaters. In the recent heavy gale which I witnessed here, I observed the same thing on Macquarie Bar: the heavy rollers broke a long way outside, but on the bar there were only small breakers, about 8 feet high. The seas which affect the works most at Westport are the short chopping seas of a N.W. gale, which strike the breakwaters with considerable force, though, fortunately, without the tremendous violence of the great ocean waves; and this is precisely the effect which similar works at Macquarie will be subject to.

Harbour accessible to small steamers in any weather.

In the height of the gale mentioned above, the steamer *Australia*, drawing 9 feet 6 inches, entered the port with ease and safety; but in such a gale no steamer would venture to go near Greymouth, and I doubt whether one would attempt to enter Westport.

Coast drift.

The greatest danger to which harbours in New Zealand are subject, is from the sand or shingle drifted along the beaches from S. to W. This phenomenon is common enough in various parts of the world, and is the thing most feared by harbour engineers. The drift of the beaches is caused by the oblique impact of the waves on the shore, and the current excited by this action.

On the E. and W. coast of the South Island of New Zealand about 75 per cent. of all waves strike the shore obliquely from the southward, and about 25 per cent. strike it either square on or obliquely from the northward.

There are places in the colonies where one would expect to find the sand and gravel of the beaches drifting from the same cause, but where I have not been able to detect any such effect. Thus the New South Wales coast south of Sydney shows no drift of the beaches, and I could perceive no such action on the N.W. coast of Tasmania.

No drift observed here.

On the West Coast of Tasmania the most usual direction of the waves is south of west, and these strike the coast very nearly square on. This should not cause any general drift of the beaches, and from Port Davey to Macquarie Heads the shore is very rocky, with headlands and outlying islands and no rivers to bring down sand to supply the beaches. The rocks are hard quartzites, the wear and tear of which by the waves must be very slight. I do not, therefore, think that works at Macquarie Heads are likely to be troubled by any drift along the coast from the south.

From the Heads towards the north for many miles, as far at least as the Pieman River, the beach is all sand, but from observations made by me on the beach to the north some miles from the Heads I found that, with light S.W. winds and moderate sea, there was a decided drift towards the N., while with a strong gale at W.N.W. and very rough sea I could not detect the evidence of any drift in the currents among the breakers.

There is, however, other evidence showing a very decided tendency of the currents close in shore to flow towards the north, as shown by all sorts of articles out of the harbour which are stranded on the beach for miles north of the entrance; also, the black waters of the harbour colours all the sea along the beach to the north for many miles; floats twelve feet deep which I put in the channel at Entrace Island drifted towards the N.E., and one was found stranded on the beach three miles north of the entrance.

Seeing that it is doubtful whether there is any drift of the sand of the beach south of the harbour, and that there is distinct evidence of a drift towards the north on the north beach, I am of opinion that there is not much fear of the entrance being troubled with this source of danger to any works that may be undertaken; but even if there were as much drift as is found in New Zealand, the strong currents which flow out of the lagoon are sufficient when directed by the breakwaters to maintain a deep channel over the bar, and to disperse any detritus that may be brought within their influence. The force and effect of these currents are sufficiently proved by the fact that they are able to scour the bottom at and above Entrance Island to the extraordinary depth of 84 feet, which is the evidence of the force of the current and the ease with which sand is shifted.

Capacity of tidal basins.

It is a well known principle in designing harbours like this, which depend on tidal action to maintain a deep channel out to sea, that other conditions being equal, the depth of the channel will depend on the capacity of the enclosed space which is filled and emptied by each tide, and in this respect Macquarie Harbour exceeds, in tidal capacity, most harbours of the kind.

Area of the bar.

The discharge of the Harbour is over the bar and the sandspits, the effective width of the opening being 7800 feet, with a waterway of 58,000 square feet. Inside Entrance Island the waterway is much smaller, various sections showing areas of 30,000, 27,000, and 25,000 square feet, and in these sections the depths are from 28 to 50 feet.

Sand carried in and out.

The flood and ebb tides cause a circulation of the sand of the north beach; thus, during strong flood tides the sand of the spits which enclose the bar, and of the shoals adjacent to the beach, is carried in vast quantities into the harbour, when, meeting with still water, it settles down and has formed the extensive shoals and sandbanks which obstruct the navigable channel for several miles up the harbour. With strong ebb tides the sand is carried off the same sandbanks out to sea, where it settles on the bar and the neighbouring spits.

North beach denuded of vegetation.

The sandhills on the north beach were formerly to all appearances covered with vegetation nearly to the water's edge, as is seen by a number of knolls of sand covered with bush, which still remain to mark the original condition. The vegetation has been disturbed at some time, with the result that about 180 acres of the north shore is now bare sand, and in high winds vast quantities are blown into the harbour, where it is carried back and forward by the currents and finally is deposited on the bar and sandspits. If the East breakwater as shewn on the plan were constructed, this circulation of sand would cease, and in that case the ebb tides would continue to carry sand out of the harbour, but little or none would come in again, as the end of the breakwater being in deep water, the waves would drive the sand behind it and on to the north beach a mile and a half to leeward.

The improvement of Macquarie Harbour seems to present less difficulties, and to offer more assurance of favourable results, than is usually found in works of this nature; the mouth of the harbour is very much sheltered from the heaviest waves, the sand of the bar is easily moved by scours; the tides, gales, and floods in the rivers give rise to powerful currents flowing out of the harbour, and there is abundance of rock on the spot to construct the necessary works. Improvement of bar.

If it is true, as appears evident to me, that there is no drift of material along the sea beach, and seeing that the rivers bring no sand or detritus of any kind to the bar, then the problem of deepening the entrance assumes a different character to that of the usual harbours which depend on the tidal action to keep open a channel to the sea, such as Greymouth or Westport in New Zealand, or Newcastle in New South Wales; for in this case the depth of the entrance would depend only on the depth into which the breakwaters are carried. For instance, if the breakwaters were carried into 35 feet of water, the present bar would then be inside of them, and could be dredged to any required depth, and the depth thus acquired would be permanent, as it is in such harbours as Kingston, Dover, Marseilles. Rivers bring no sand to bar.

This problem, however, must be left to the future, as the cost at present would be prohibitive of taking the breakwaters out into 35 feet of water. The work as laid down on plan is designed on the supposition that the bar will be deepened by the scour of the tidal currents, and the depth maintained by the same, as it is in harbours like Westport (New Zealand), Newcastle (New South Wales), and the many harbours of this description in other parts of the world. If on the completion of the works it is found that there is no coastal drift, the question of securing still deeper water at the entrance becomes a matter of extending the breakwaters out further into deeper waters; and then the depth of the sea entrance becomes subordinate to the depths that can be obtained by dredging through the sandbanks inside the harbour between Bonnet Island and River Point.

To enable the tidal current to maintain a deep channel out to sea, its force, which at present is spread over the great width of the bar and the North and South Spits, must be confined in one narrow channel and its direction fixed. To effect this object two moles or breakwaters are required as shown on the plan herewith, the width between them at low-water mark being 1200 feet, and the depth being taken at 25 feet will give a waterway of 2900 square feet, which is about the same as the waterway on a cross section inside Entrance Island at 400 feet above Bonnet Island, where the greatest depth is over 42 feet. Current to be confined.

This width of entrance should give a velocity to the ebb current varying from $2\frac{1}{2}$ feet a second in fine weather to $3\frac{3}{4}$ feet with a rise of 2 feet in the harbour, and over $8\frac{3}{4}$ feet a second with very high water in the harbour, such as occurs with gales and floods combined.

Besides the concentration of the current by means of the breakwaters, it is necessary to provide for the sand which is swept out of the harbour being carried away clear of the entrance by the waves, and for this purpose the ends of the breakwaters should be in sufficiently deep water and exposed to the action of the waves; in fact, they should act and have the same effect as rocky headlands on a coast, for there is generally deep water at such projecting headlands, due to the turbulence of the waves and the strong currents.

In this respect the east breakwater, as shewn, will be favourably situated, as it projects so far into the sea as to leave a deep bay extending to leeward, into which the waves will drive the sand to accumulate on the north beach, a mile and a half from the end of the works.

The breakwaters will be made of rubble stone tipped into the sea like a railway embankment, the centre part being formed of small stones from a weight of three or four cwt. up to two or three tons, while the slopes and ends will be protected from the violence of the waves by stones from 5 to 20 tons weight.

The great merit of a breakwater made of rubble stones of sufficient weight is that it is indestructible and gives no further trouble; the mass and weight are so great that no seas can disturb it; waves of unusual violence have the effect only of dragging the stones down to a flatter slope, which makes the work all the stronger. There is no fear about the foundations (which is such a source of anxiety in concrete breakwaters); the waves dashing against the stones plough out a deep trench in the sand at the foot of the slopes, and into this the stones sink down till they get so deep that the waves have no further effect, and then the foundations are secure for all time. In such breakwaters the stones may continue to sink into the sand for some time, especially during bad weather, and a supply of rock is usually kept on hand during construction and for some time afterwards to make up settlement of this kind with the least possible delay. Advantages of rubble breakwaters.

The cost and the stability of a breakwater of this construction will depend very much on the size of the stones with which the slopes and ends are covered: if the stones are so small as to be rolled about by the waves they will rapidly break up, and the work will require continual repairs; but if the rock is of suitable size no repairs will be required after the work is consolidated. Importance of large rock.

The stone will be procured from the rocky hills of the south side. This is a hard brittle quartzite. In some places there are beds of hard sandstone, and in the high bluff opposite the "detached rock" there is a thick bed of coarse conglomerate which seems to be very good stone. Quarries.

Trial quarries.

I have had the rock quarried in two places, one near the root of the intended west breakwater, and the other under Mount Wellington, opposite the bridge which is proposed to be erected across the harbour to convey stone for the east breakwater. The stone is hard, brittle, and full of joints, but from the appearances shown by the explosion of two tunnels excavated into the rock it is evident that stone of the requisite size can be got, and that it will not be necessary to employ concrete blocks to protect the slopes and ends of the breakwaters.

The expense incurred in quarrying the stone on trial was considered necessary, because if the stone had been found unsuitable it would have been necessary to include about £20,000 in the estimate to provide concrete blocks. In case the rock at the root of the west mole should be unfavourable to quarry, I have provided in the estimate for the cost of a railway round to the high bluff opposite the "detached rock," where there is abundance of rock with a face of about 100 feet. The length from the root of the breakwater to this place is 6400 feet, and there is no difficulty in laying a line along the shore.

The quarry at Mount Wellington is hard quartz, and a face over 100 feet high is available, the line to carry the stone being laid round the rocks and extended as the rock is quarried.

Stone for the east breakwater must be carried across the harbour, unless it should be found that stone can be got at a cheaper rate from some place on the Zeehan line. I do not think this can be the case, as the distance to Strahan is seven miles in a direct line, along which a line of railway must be laid, and it would be necessary to go many miles up the Zeehan line before good stone could be got. Assuming, therefore, that the stone must be carried across the harbour, this may be done either by a bridge with a swing opening to let vessels through, or it may be conveyed across on punts, the trucks of stone running on to the deck of the punt, from which they would be hauled off on the other side by the shunting engine. The bridge would be the most costly, but, notwithstanding this, I would recommend it in preference to punting, as being quicker, safer, more handy, and simpler in management. I have made sketch drawings for a swing-bridge which, when open, would leave two passages of 70 feet wide for vessels to pass. The bridge would be opened for vessels to pass, and be left open all night.

Swing-bridge.

The swing span would be iron girders on pile piers, in about 18 feet of water, but the rest of the bridge, which is altogether 1830 feet long, would be simple trussed beams on piles; a length of 700 feet on the south side, and a length of 1300 feet on the north shore, is shown to be formed by an embankment of rubble stones. This will have the effect of shutting the current out of a secondary or blind channel on the north shore, and keeping all the water to the centre. It will also protect the loose sand of the north point from being scoured away.

When the breakwater is completed the centre part of this bridge would be taken up, if at that time it were thought fit to do so.

The breakwaters.

The greater part of both breakwaters passes over the shallow sandspits which enclose the bar. This part of the work will be exposed to no rough seas, and being end on to all waves, the work may be of a light form of construction, without incurring any risk of damage. It is also probable that the sand will accumulate against this part and form a beach. This part is shown carried out at the height of 7 feet above high-water mark, the top width being 10 feet.

The parts of the breakwaters which are in deeper water and more exposed to the seas must be made higher so as to preserve the roadway from being washed away by high waves. On the west breakwater this height is shown as fifteen feet above high-water mark, and this breakwater is carried out at this level on account of the necessity which I think there is of showing a light at its end.

Advantage of staging.

The outer part of the east breakwater has no occasion to show a light; it is much longer and more exposed; for economy in construction I have therefore shown this outer part of the north breakwater as built from staging. There are many advantages in building from staging; in the first place the roadway is always secure for working in all weathers, and is not liable to be interrupted by being washed down and having to be made up again, as may frequently happen with a "tip end;" also, provided the staging is built well ahead of the stone, more work can be done from staging than from a "tip end," as there are two or three roads on the former and only one on the latter, unless the "tip end" is made for a double line of rails, in which case the breakwater is unnecessarily wide and costly; thirdly, with staging almost all the stone got out of the quarry can be used up in the work, as the entire base and central part of the embankment can be made of small stones, and the large rock is available for the sides and top. With a "tip end" (this means the embankment carried forward at 15 feet above high-water), it is very difficult to use up the small stone, because the bank is continually liable to be washed down, seeing that the small stone must be placed before the large rock can be put on top of it to protect it, and the general result is that without staging more large rock must be used than with staging, and the larger the rock the more it costs. However, the cost per running foot is the best test to apply in this case, and in 13 feet of water the cost with staging is £26 per foot, but with a high tip the cost is £32 per foot. In 20 feet of water the cost with staging is £36 per foot, without staging, £43 per foot; and in 26 feet of water with staging the cost is £46 per foot, and, without staging, £57 per foot run.

Economy of stone.

It may be that when the work is being carried out, the character of the rock and the cost of it may be found more favourable for carrying the work forward at the height of 15 feet above high-water than I have shown in my estimate, and this consideration at that time will determine whether staging is to be used or not. It must be remembered, however, that the rock placed above high-water does no good, as the work built to high-water mark is high enough for all purposes required to be served by the breakwaters.

Piles eaten by sea worms.

There is one circumstance connected with the use of staging which must not be lost sight of, which is, that the piles are liable to be eaten by sea-worms, and when the work is completed the staging may be so damaged that the necessary repairs incident to new work of this kind cannot be done, as the piles have given way; and it may even happen that the piles are damaged before the work is finished. In Westport and Greymouth, New Zealand, ironbark piles were used, and they began to fail just as the work was completed, and had to be propped up from the stonework.

This inconvenience affects the bridge also. I have therefore in the estimate provided for jarrah piles, which would not cost much more than ironbark. In Fremantle the jetties in the sea are built with round jarrah piles, which are not damaged by sea-worms—at any rate, they resist longer than any other timbers.

Subsidence of the stonework.

It is commonly the case in work of this description that the waves plough out the sand in front of the toe of the stonework, with the result that the work has to be built in deeper water than the soundings show, and this consumes a great quantity of stone. According to my experience I have allowed what I think the subsidence will be, as shown on plan, and included in the estimate; but it will be well to remember, in carrying out the construction from staging, that if the staging is carried on well ahead of the work the sand may be all covered over with two or three feet of stone over the entire base of the central part. This will confine the sand, and prevent its being washed out, and so a great quantity of stone may be saved.

Apart from these inconveniences, I anticipate no trouble in the construction of the breakwaters.

The channel over the shoals.

Having provided the means for deepening the bar, there remains to be considered the long shallow flats which intervene between the deep water at Bonnet Island and the main deep water in the harbour, which commences at the black buoy at River Point, which is a distance of three miles.

To improve this part of the navigation it is necessary to compel the flood and ebb tides to flow through the same channel, which at present they do not, as a great part of the water in ebb tides follows the channel close along the rocky bay between Round Hill and Mount Wellington, while the flood tide mostly keeps to the north channel, and the effect of both tidal streams to maintain a deep channel is thus materially weakened.

The survey of these shoals and channels shows that the north channel is the proper one to improve; to do this it is necessary to close the channel by Round Hill, and then cause both flood and ebb tides to flow through the north channel.

Training walls.

For this purpose I have shown on the plans a training wall of rubble stone, which, starting from Mount Wellington, crosses the deep channel leading to Round Hill, and then follows the shallow sandbank which I have mentioned above as dividing the two channels, till within a short distance of the place where at present the two channels divide. This wall is shown with a curve of very large radius, which will have the effect of keeping both the flood and ebb current to the side next the wall, and prevent any fretting of the opposite convex side, which is all sand. It will not be necessary to consider the width of this new channel, as the scour of the current will enlarge and deepen the channel till a waterway is established that exactly suits the volume and velocity of the water that passes through it, after which all scour will cease and the channel will be permanent.

Effect of training walls.

As soon as the wall is constructed the channel will deepen at once several feet, but no one can tell exactly how long it will take to scour out the channel to a depth of over 20 feet, which is the depth required to suit the contemplated deepening of the bar. I have no doubt that in time the natural scour will produce the required depth, but if it is required to hasten the operation of nature, then, of course, dredging must be done to assist it. I have not included any dredging in my estimate, because I am inclined to think that the natural scour will deepen the channel in time to suit the wants of navigation, as it will probably take some time after the works are commenced before large vessels frequent the port.

This training-wall is shown on the sections as built only up to low-water mark, which is high enough for the purpose it has to serve, and the wall must be built by depositing the stone from punts. The stone to be used in its construction will be quarry rubble which is too small for the breakwaters; consequently the wall should be carried on at the same time as the breakwaters, and thus use up the spoil from the quarries.

This wall is shown to be built mostly in very shallow water, but when scour begins to take effect the toe of the slope on the side next the channel will be undermined and the stone will slip down into the continually deepening waters. The wall must therefore continually be made up by fresh stone placed on the top, and in this way, when the final depth is reached, the wall will have assumed the form of a sloping bank pitched or faced with stone.

Walls cannot be dispensed with.

It might be suggested to close the deep opening at Mount Wellington by a bank of stone, and then leave the long shallow sandspit to act in the place of the wall. This would be a very easy way of obtaining the object sought, but the channel would not be permanent; the soft sand would yield to the impetus of the current on the concave side, and in a few years new cross channels would be cut out which would entirely defeat the purpose in view. On the other hand the convex side is all sand, but there is no fear of that side being worn away any further than will give the width required by the body of water, which will adjust itself to depth and width suitable.

It is absolutely necessary that the construction of the wall be commenced at the upper end near River Point, and be carried on down stream towards Mount Wellington; because, if it were attempted to build it from Mount Wellington up stream, the ebb current would continually cut across the end of the advancing wall, scouring out channels which would give no end of trouble and expense.

By this way of proceeding the wall will have no effect until the deep part of the Mount Wellington channel is reached; but as soon as the stone begins to contract this deep opening the effect of the wall will be evident in the increased body of water which will be forced through the north channel.

I am aware that many people entertain great distrust of the result of attempting to construct works for the improvement of Macquarie Harbour; by them it is thought that it will be a costly work of unusual magnitude and risk. My inspection of the place convinces me that the necessary works are not by any means of unusual magnitude, nor likely to be attended by any risk, neither to the works, nor as regards the results expected to follow their completion.

Importance of works.

The importance of deepening the bar to the extent of admitting vessels of 2000 to 3000 tons is admitted by all who are acquainted with the development that is rapidly taking place in the trade and population of this rich mineral district; and it may be useful and reassuring if I may be permitted in this report to cite some cases of harbours like this which have been improved by works, which have also been the making of the ports as the result of their construction.

The Kilia, mouth of the Danube, is fully exposed to the waves of the Black Sea, which is frequently visited by furious storms. Originally, the depth was 11 to 12 feet; since the construction of breakwaters of rubble stone there has been a uniform depth of 22 feet.

The mouth of the Liffey, at Dublin, had originally a bar with about 9 feet at low water. The construction of two rubble breakwaters has caused the bar to entirely disappear, and now the largest vessels enter Dublin Harbour.

The mouth of the Mississippi was, not long ago, too shallow for the vessels which sought the trade of New Orleans. The entrance was narrowed and straightened by breakwaters made of stone and fascines, and the success attending this work is well known.

The harbour of Galveston, Texas, has recently had its bar greatly improved by the construction of breakwaters, one of which is over four miles long, the stone for which was brought from a distance of 150 miles.

The harbour of Bilbao is exposed to the full force of the Bay of Biscay; the bar was formerly shallow and very dangerous; the depth having been improved by the construction of breakwaters, a vast trade developed in hematite iron ore, carried in the largest vessels.

The harbour of Newcastle-on-Tyne had formerly a shallow and dangerous bar, which was considered as the graveyard of vessels. By the construction of breakwaters, and dredging away the hard boulders and clay, the bar is so much improved that the largest vessels now enter in safety.

The entrance to the harbour of Newcastle, N.S.W., had 50 years ago a bar with 11 or 12 feet of water. By the construction of a long breakwater the depth is now increased to 21 feet at low water, and the Government of New South Wales has authorised the construction of a north breakwater to reduce the width of the entrance and secure a greater depth of water.

In New South Wales there are seven rivers which have works under construction for the improvement of their bars. None of these are yet finished, but I am informed that already the works have effected great improvement in the depth of the channels.

The entrance to the Gippsland Lakes has had a new mouth cut through a neck of land, the opening being controlled by breakwaters, and the result is a great improvement in the depth of the channel over the old original entrance.

In New Zealand the entrance to Port Chalmers had a shifting bar with 16 feet of water. A breakwater more than 4000 feet long has been constructed, with the result that there is now a constant depth of 24 feet at low water. This harbour has a tidal basin of about 16,000 acres, with a mean tide of six feet and an ebb of about seven hours' duration. It has therefore a larger tidal capacity than Macquarie, but its ebb current is not so strong.

The entrance of the Grey River, West Coast of New Zealand, is exposed to the full force of the Pacific from south to north, and I could not imagine a more unpromising place to try to improve. It has a tidal basin of 400 acres, and must depend for its scouring power on the Grey River, with 1600 square miles of drainage area. Originally it had a shifting bar of six to nine feet. Two breakwaters of rubble stone have had the effect of maintaining for the last eight year a mean depth of about 18 feet.

The mouth of the Buller River, at Westport, N.Z., had a bar of 9 to 11 feet, fully exposed from north east to west. It has a tidal basin of 650 acres, range of tide six feet, and the river has a drainage area of 2300 square miles, with a yearly rainfall of 90 inches. Floods are frequent and of great violence. Two rubble breakwaters, one 6000 and 4400 feet long, have maintained for the last seven years a depth varying from 18 to 24 feet, the variations chiefly resulting in dry weather from the great quantities of sand and shingle which drift along the coast from south to north.

The estimate here given for the cost of work for Macquarie Harbour includes everything which I can think of as likely to be incurred, including the construction of jetties at Strahan suitable for large vessels. The estimate for the breakwaters exceeds my original estimate of 1890, the reason being that the new survey shows features which have increased the cost. I have shown the breakwaters the same length as in my sketch plan of 1890, but the new survey shows deeper water at the outer end of the west one. If necessary, this mole may be shortened 600 feet, and save £20,000 in cost; but it is to be observed that if deep water is wanted the works must be carried into deep water, and hugging the shallow water is often false economy.

I have also shown a training-wall just inside Entrance Island, the object of which may not be obvious; but the object is not to allow the waterway too great width for fear of its getting correspondingly shallow. The sandbank formed by the outside waves driving in the sand has contracted the present channel, forcing it to pass through the narrow channel of Entrance Island; but when the east breakwater is built this sandbank would be all swept to sea if it were not retained by this training-wall.

Berthage for large vessels.

There are two sites shown as suitable for future jetties to be constructed as the traffic requires them.

One site at West Strahan has the advantage of ground being already available for the necessary railway sidings which will give access to the jetties. It has the disadvantage of being fully exposed to gales from the south, in which direction there is a "fetch" of 11 miles, with deep water all the way. I have not had an opportunity of seeing the effect of a gale in this direction in the height of the waves rolled in, but in ordinary cases a "fetch" of 11 miles over deep water would be a very serious objection to the security of vessels lying at a wharf. It has also the disadvantage in being separated from the present wharf with the custom house and railway station.

There is another inconvenience attached to the West Strahan site, which is the great depth of the water, and in the position most suitable for jetties for long vessels the depth is from 28 to 59 feet.

Besides the cost of building a jetty in such deep water, the structure would be very unsteady unless the piles were either braced with chains, or the foot of them were filled up with rubble stone to a height reaching from the bottom to, say 30 feet below low water, and either method would be costly. If, to avoid the inconvenience of the deep water, a wharf is substituted for the jetties, this is probably still more costly, and not so economical of space for berthage, a jetty having ships on both sides, but a wharf on only one side.

The other site is at East Strahan. This is a well sheltered, land-locked nook, with moderate but sufficient depth of water, and plenty of room for long vessels entering and leaving. It has the advantage of complete shelter, of being alongside the present wharf and close to the proposed terminus ef the Mount Lyell Railway, which would probably be found to be an essential convenience, as large steamers might have cargo for Mount Lyell as well as various other mines on the Zeehan line, in which case the position at East Strahan would be very suitable for distribution each way. It has the disadvantage of requiring ground for the necessary sidings to be taken from the reserve as shown, and also that the present railway must be extended along the shore about 28 chains to reach the sidings provided for working the traffic of the jetties.

In my opinion the site at East Strahan, as shown on the plan, is the best, but this is a matter which the General Manager of Railways can decide with reference to the traffic. Before deciding he must make sure that the exposure of the West Strahan site is not a serious objection.

I have shown on plan on the East Strahan site two jetties and two extra wharves, but as this amount of accommodation is far beyond present requirements, I have included in the estimate only one jetty, with the necessary embankment and railway extension and sidings. No one can tell when more than this will be wanted, but, when it is, the plan shows the most suitable position for future extension.

Plant.

The list given of the necessary plant includes end and side tip-trucks, cranes for lifting stone, and engines for hauling it.

The trucks I would advise to be the spring tip-trucks, designed for the Westport works, and which have proved so satisfactory and durable that no other kind of tip-truck is equal to them; they have been adopted in Western Australia as the most satisfactory. If these trucks can be bought second-hand from Westport and Fremantle it would be well to procure them, and, if the trucks were dismantled and the ironwork only bought, it might be economical in saving freight.

Some of the cranes might be brought from the Wesport works and some from those of Fremantle, at both of which places the cranes are an excellent type, which were got from England for the Westport works; the Westport Harbour Board sold trucks and cranes to Fremantle.

The time which it will take to complete this work will depend on the arrangement made to carry it out: at Westport the output of stone from quarries to the breakwater were from 800 to 1000 tons a day. The Macquarie East breakwater contains about 451,000 tons of stone, and if 500 tons a day are put into it for 264 days in the year it would take $3\frac{1}{2}$ years to finish; but it will take more than a year to complete the bridge and open up the quarries, so it appears that it will be $4\frac{1}{2}$ years before it is finished.

I have no doubt that the bar will be much deepened before the work is finished, as in Westport the bar had greatly improved two years before the work was completed; but if the work is to be hastened, then it becomes a question of putting on more cranes and trucks than I have shown in my estimate. It would cost about £4000 in additional cranes and trucks to reduce the time of completion from $4\frac{1}{2}$ years to $3\frac{1}{4}$ years; but such a calculation is very uncertain, as it is not impossible that the extra plant being provided the estimated extra work might not be accomplished, and it is best to see how the quarries turn out, and how the work can be done, before putting more plant on the ground, especially as the cost of the plant I have provided compared to the extra cost of more plant to shorten the time of completion is nearly the same as the interest that would be saved by thus shortening the time.

To this Report is attached the following plans:—

(1.) General Plan of the Entrance, showing Breakwaters and Training-walls.
(2.) Longitudinal section of the Channel from the Bar to River Point.
Cross section, showing effective width of the Bar.
" at various places inside Entrance Island.
Section along the site of Bridge over Harbour.
(3.) Longitudinal section of the Breakwaters.
Cross " " "
(4.) Drawing showing the Staging for Breakwaters.
(5.) " " Trestles for Bridge.
(5.) " " Swing-bridge.
(3.) Cross Sections of Training-wall from Mount Wellington to Round Hill.
(6.) Plan showing proposed Jetties at Strahan.
(7.) Small Chart of Macquarie Harbour showing Works.

I have the honour to be,
Your obedient Servant,

C. NAPIER BELL, *M. Inst. C.E.*

The Hon. the Minister of Public Works.

MACQUARIE HARBOUR.

GENERAL ESTIMATE, DECEMBER, 1897.

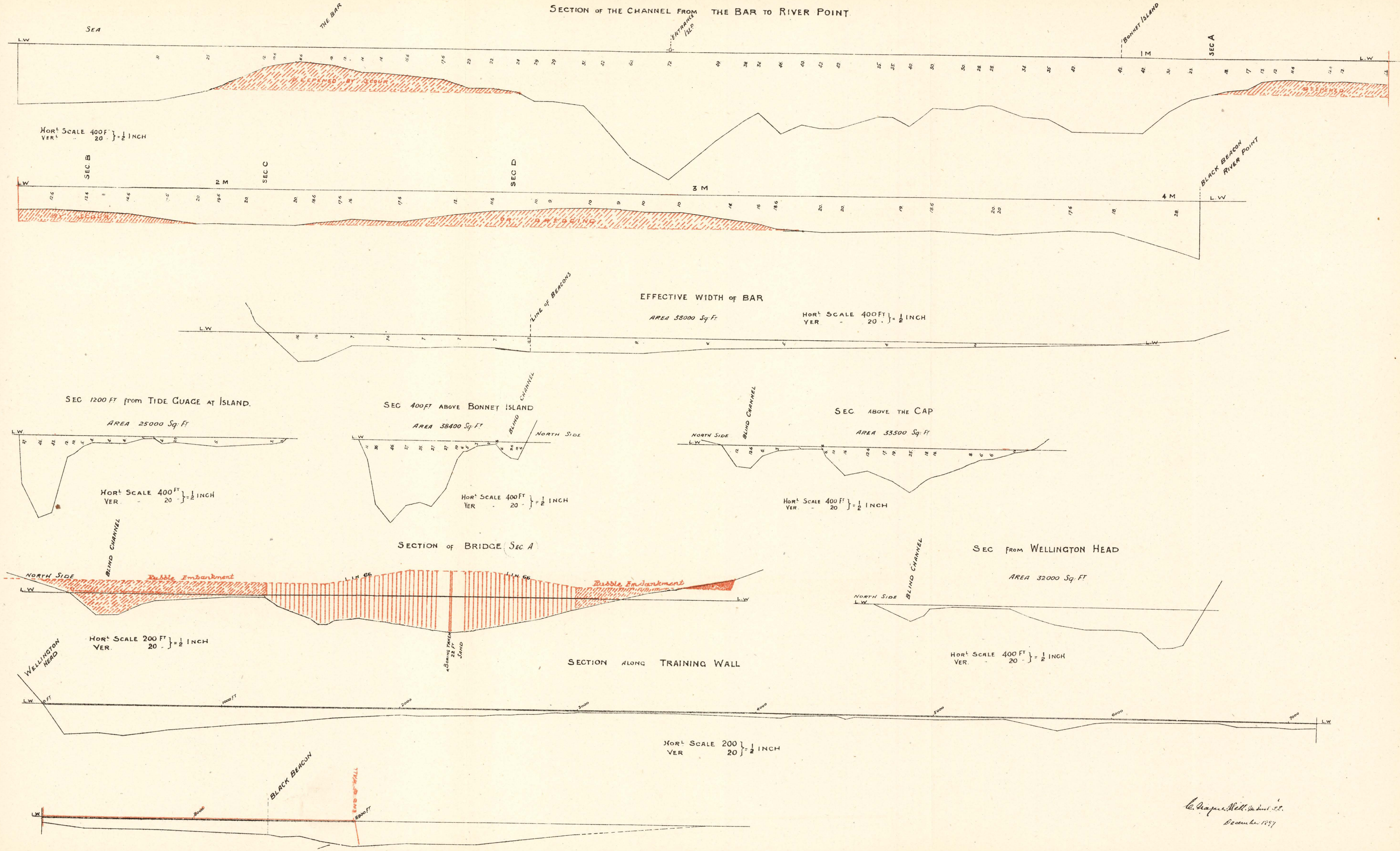
			£	s.	d.	£	s.	d.	£	s.	d.
East Breakwater—											
0 to 4830 ft. Rubble Stone	cub. yds.	156,290	0	4	6	35,165	0	0			
„ 6400 ft. Staging, at average of 13 ft. high	lin. ft.	1570	26	0	0	40,820	0	0			
„ 6800 ft. Staging, at average of 17 ft. high	„	400	31	0	0	12,400	0	0			
„ 7000 ft. Staging, at average of 23 ft. high	„	200	41	0	0	8200	0	0			
„ slope at end of heavy rock	cub. yds.	3000	0	6	0	900	0	0			
									97,485	0	0
West Breakwater—											
Rubble Stone on inner part	„	111,820	0	4	6	25,159	10	0			
Rubble Stone on outer part	„	76,250	0	5	0	19,062	10	0			
Rubble Stone slope at end of heavy rock...	„	2000	0	6	0	600	0	0			
Light at end	...	...	...			600	0	0			
									45,422	0	0
Bridge over Harbour—											
Iron Swing Span, two 70 ft. openings	tons	51	24	0	0	1224	0	0			
Rollers and Roller Frames, &c.	...	...	...			380	0	0			
Centre and End Piers, Winches, Wire Ropes	...	...	...			882	0	0			
Trestle Bridge	feet	1700	...			4560	0	0			
Stone Embankment (2000 feet)	cub. yds.	18,996	0	3	0	2850	0	0			
									9896	0	0
Training Walls—											
Wellington Head to Round Hill	cub. yds.	49,700	0	3	6	8697	0	0			
Near Entrance Island	„	5650	0	3	6	989	0	0			
Piles as Beacons	...	9	11	0	0	99	0	0			
									9785	0	0
Railways, Material, and Plant—											
Railway Formation	chains	170	10	0	0	1700	0	0			
Permanent Way	„	426	8	2	0	3450	0	0			
Sleepers, Ballast-laying	„	426	5	5	0	2236	0	0			
Points and Crossings	...	20	30	0	0	600	0	0			
									7986	0	0
Taking down centre part of Bridge	...	...	...			...			361	0	0
Locomotives, Class C, 12½ tons	...	5	850	0	0	4250	0	0			
Trucks on springs—side tip, 16; end tip, 16	...	32	45	0	0	1440	0	0			
Cranes	25-ton	2	1450	0	0	2900	0	0			
„	10-ton	7	900	0	0	6300	0	0			
„	5-ton	4	500	0	0	2000	0	0			
Weighbridges and Sheds for ditto, Quarry Tools, Punts, Boats, Anchors, Ropes, Store, Office, Two Dwelling-houses, and Sundries	...	...	...			2350	0	0			
									19,240	0	0
									190,175	0	0
Contingencies not specified	...	...	...			...			14,974	0	0
									205,149	0	0
Less Sale of Plant and Material	...	...	...			...			10,000	0	0
									£195,149	0	0
Wharfage at Strahan—											
One Jetty to berth four large steamers at East Strahan	lin. ft.	800	18	0	0	14,400	0	0			
Necessary Sidings, Embankment, and Filling	cub. yds.	62,600	0	1	6	4695	0	0			
Pitching Slopes	sq. yds.	3300	0	6	0	990	0	0			
Permanent Way of Sidings	chains	200	13	7	0	2670	0	0			
Points and Crossings	...	12	30	0	0	360	0	0			
Signals, &c.		...	...			150	0	0			
Metalling Yards	cub. yds.	660	0	3	0	99	0	0			
Fencing and Gates, Level Crossings, Shed 120′ × 30′	...	...	...			716	0	0			
									24,080	0	0

Note.—With a small amount of dredging at one end, the present existing wharf will accommodate one large steamer of 300 feet long on a draft of 20 feet.

WILLIAM GRAHAME, JUN.,
GOVERNMENT PRINTER, TASMANIA.


GENERAL PLAN
(No. 1.)
GENERAL PLAN
HYDROGRAPHICAL SURVEY,
ENTRANCE TO
MACQUARIE HARBOUR
TASMANIA
SCALE OF FEET
NOTE:
THE DIRECTION OF WAVES WAS OBSERVED
FROM A HIGH HILL DURING A HEAVY GALE
Sand hills clothed with dense Scrub
RIVER POINT
BLIND CHANNEL
DETACHED ROCK
PILOT BAY
ENTRANCE ISLAND
EAST BREAKWATER
WEST BREAKWATER
TRAINING WALL
This bare sand to be planted with grass
Bare shifting drifts of fine sand
BLACK BUOY
BONNET ISLAND
THE CAP
WELLINGTON HEAD
CAMP POINT
BLACK BEACON
WHITE BEACON
ROUND HILL CHANNEL
ROUND HILL SPUR POINT
CHANNEL HILL
ROUND HILL
LAGOON
Bare Hills of Quartzite clothed with low broom, heather, brush
Sand hills and dense
Course of great waves
Course of smaller waves
— MEMORANDA —
6 feet line shewn thus
12 feet line do
Difference of Tide Guages. Outer + 11⁶⁄₁₀ feet on Inner Guage Readings
From Camp Point Shag Island bears 134°28' Round Hill Spur Point, 143°11'
and Round Hill ▲ 150°12' True.
Magnetic Variation 9°25' East.
On Entering Harbour Black Beacons and Buoys kept on Port side
and White Beacons on Starboard throughout to Long Bay Jetties.
⚓ Good sheltered Anchorage with Fresh Water close by.
Soundings in feet & decimals reduced to Low water Spring Tides.
High Water Full & Change 7h 30' Rise of Tide 3 feet.
Rise and Fall also Duration of Tides very subject to direction of Winds affecting
sudden increase of fresh water from Rivers, and other Local Conditions.
With Low Barometer high tides and reverse with High Barometer
Tide appears to run in Channel, Tide and Quarter Tide occasionally.
Note. Datum is Lowest reading Spring Tides Inner 0⁶⁄₁₀ ft Outer 11⁶⁄₁₀ ft
Prevailing Winds are S.E. & N.W. also S.W. the two first most frequent.
PUBLIC WORKS
ENGINEER-IN-CHIEF'S OFFICE
TASMANIA
Surveyed by W. M. Hardy and S. P. Ellis, under direction of A. W. Lawder. June & July 1891.

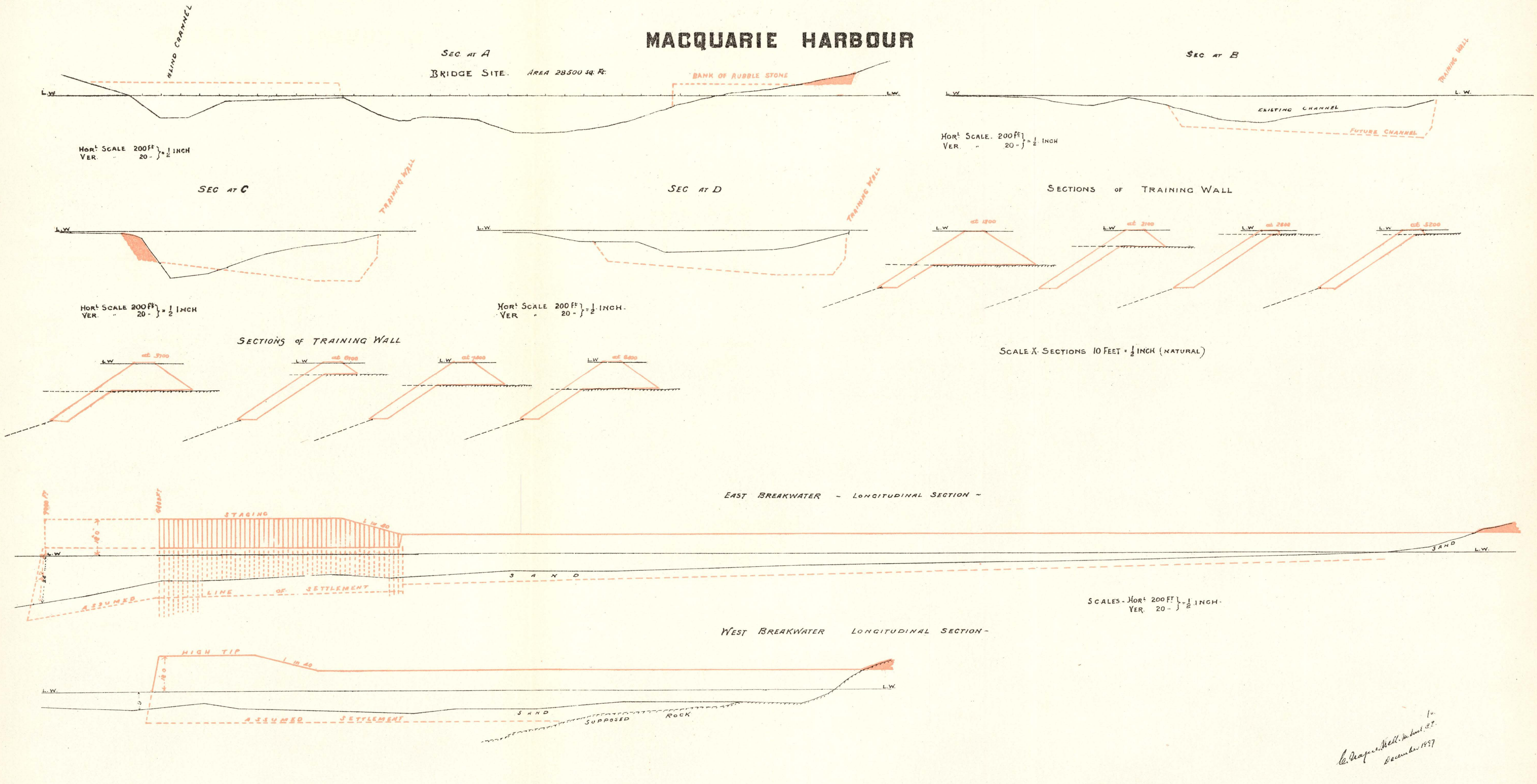
MACQUARIE HARBOUR



C. Napier Bell, M. Inst. C.E.
December 1897

(No. 3.)

MACQUARIE HARBOUR

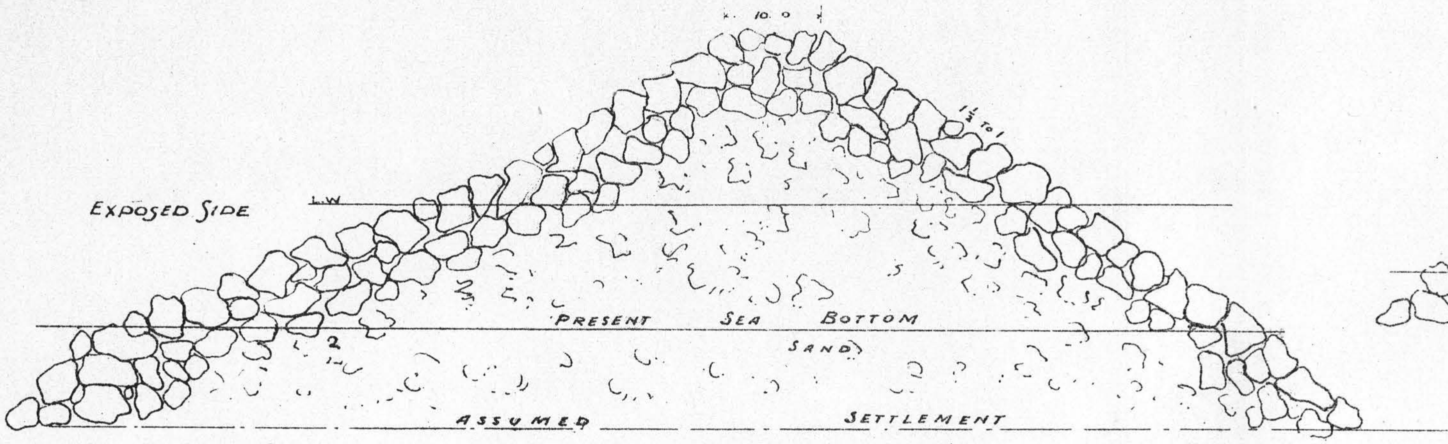


MACQUARIE HARBOUR

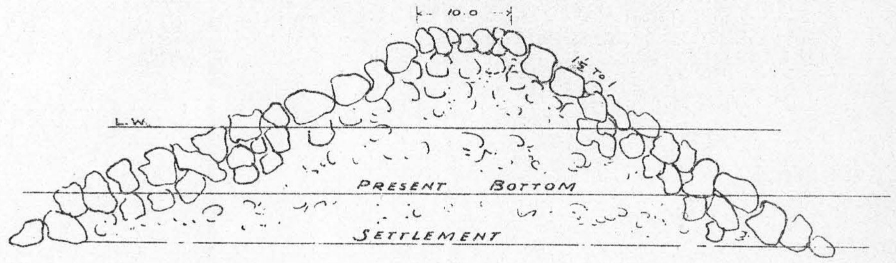
(No. 4.)

SECTIONS OF BREAKWATERS AND STAGING

WEST BREAKWATER - OUTER END -

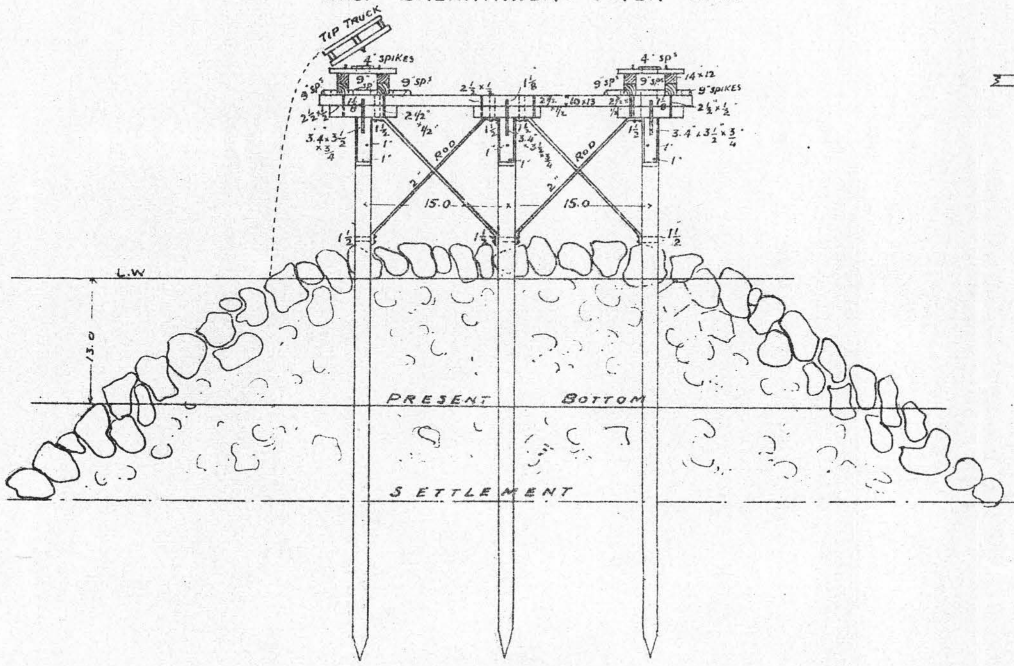


EAST AND WEST BREAKWATERS - INNER PART -

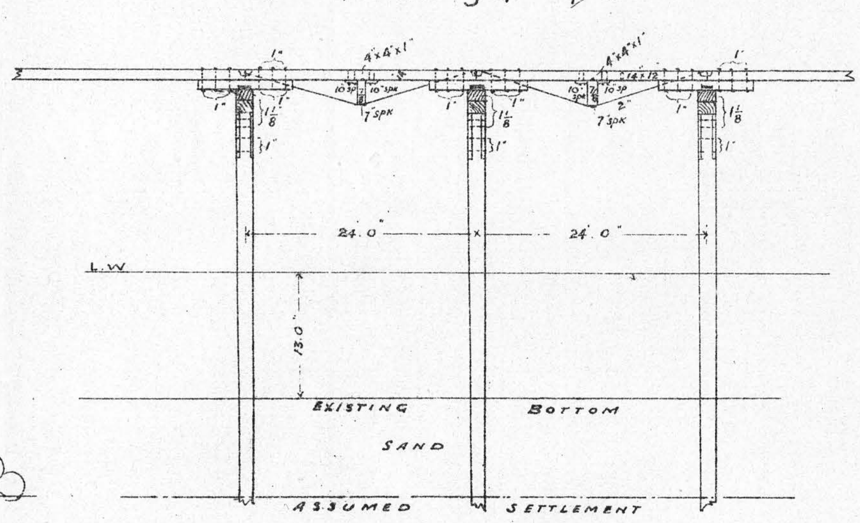


SCALE 10 FT = $\frac{1}{2}$ INCH NATURAL

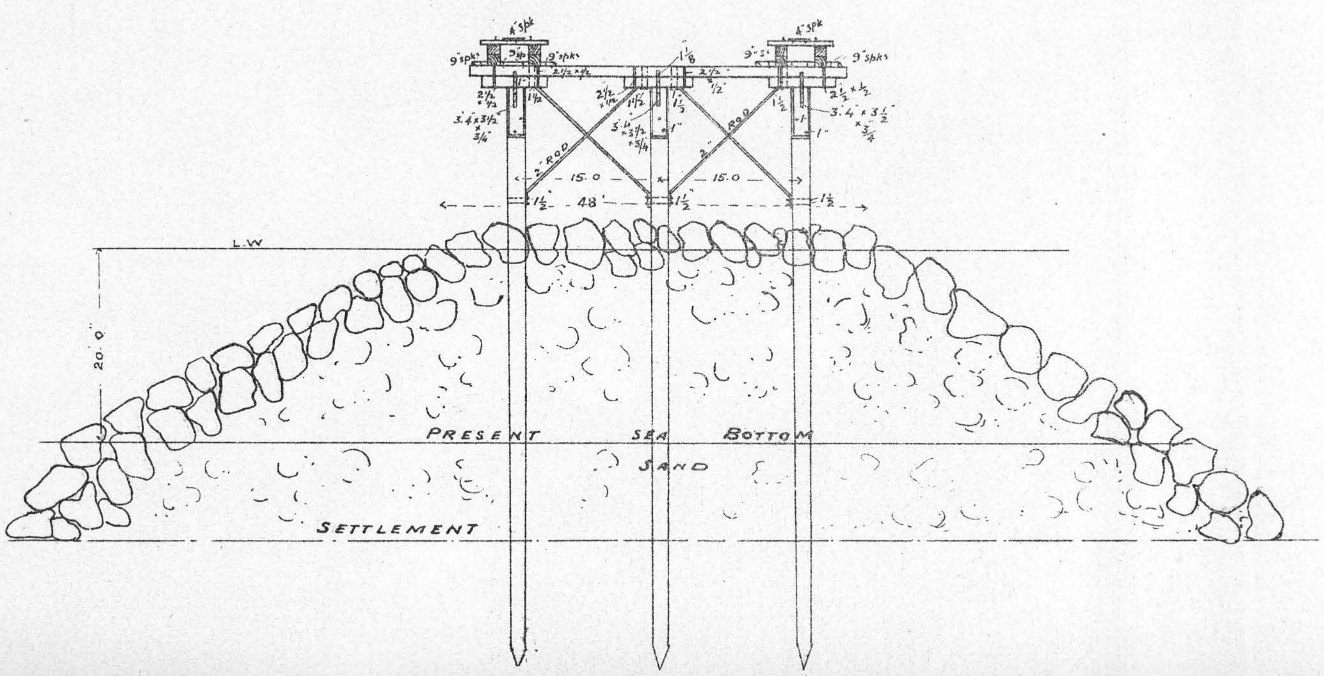
EAST BREAKWATER - OUTER END -



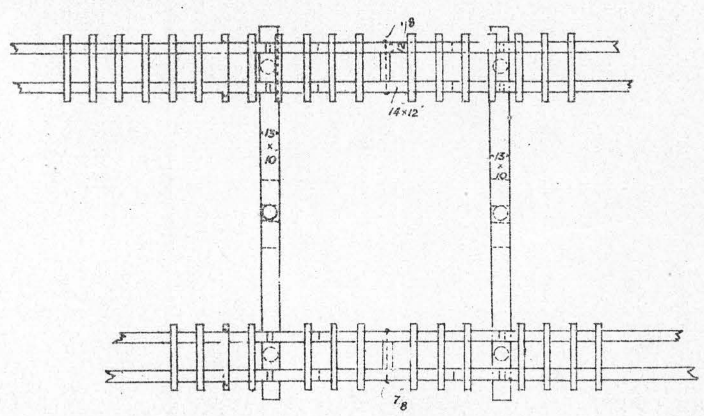
LONGITUDINAL SECTION OF STAGING



EAST BREAKWATER - OUTER END -



PLAN OF STAGING



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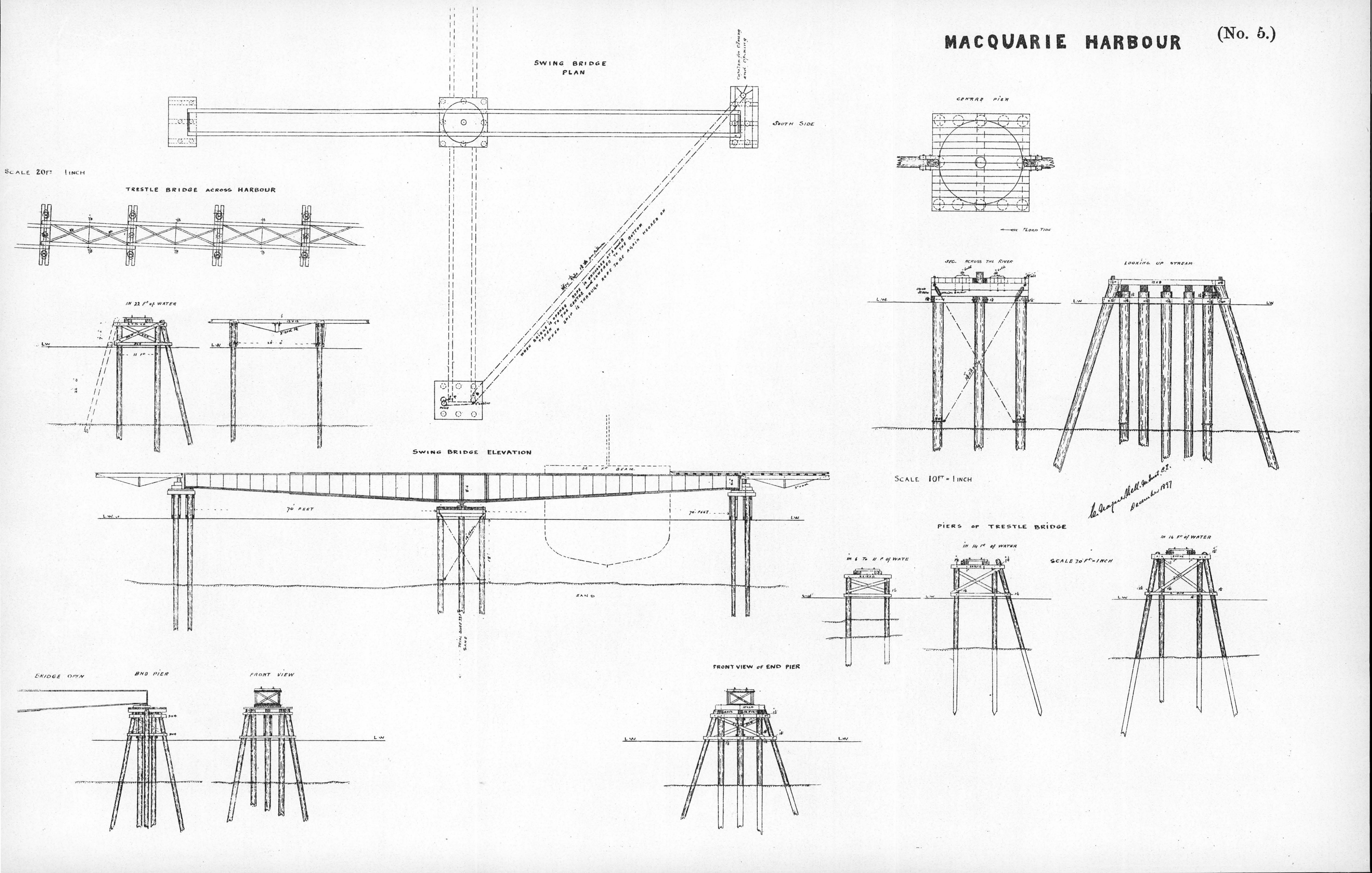
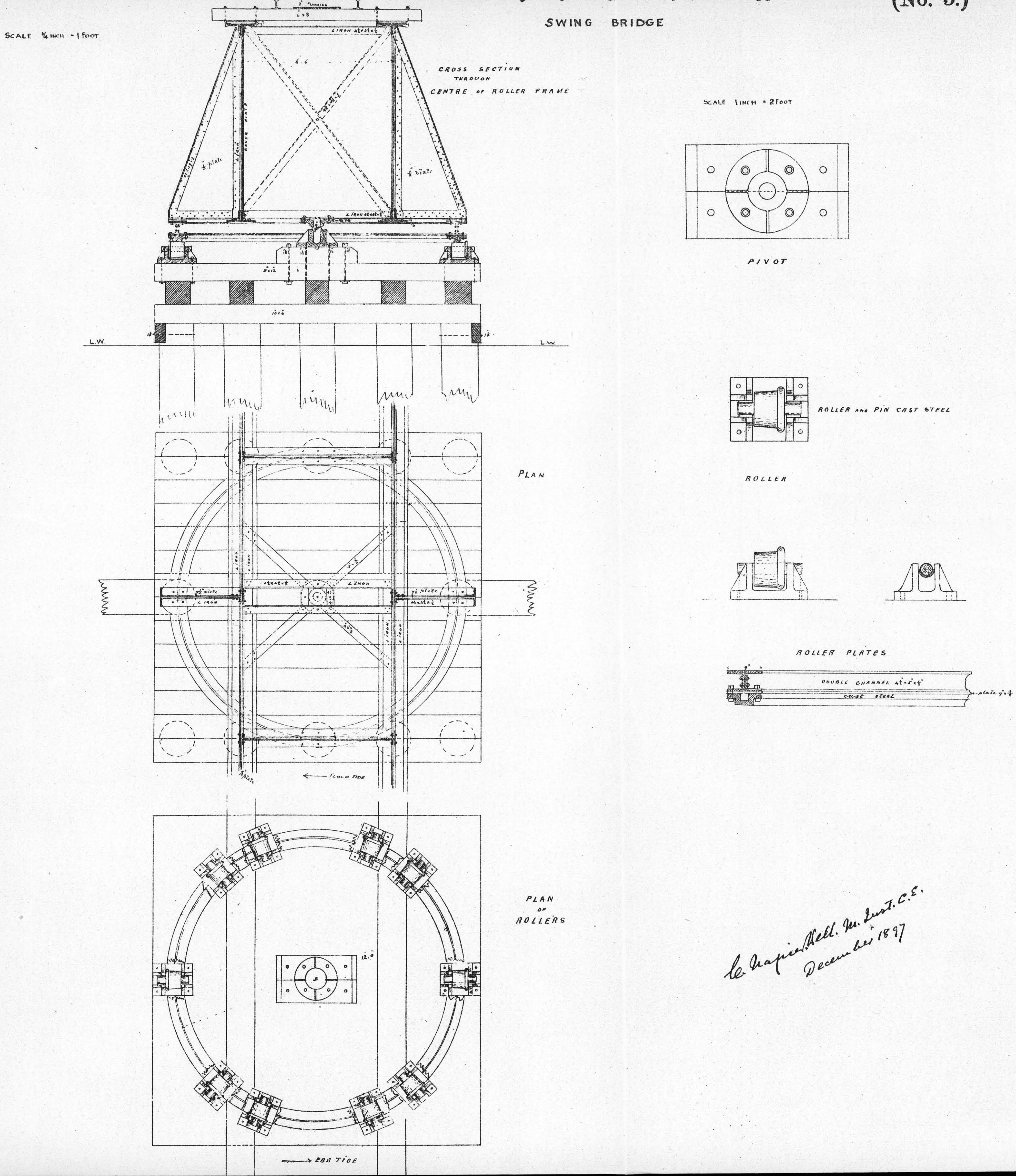
MACQUARIE HARBOUR (No. 5.)

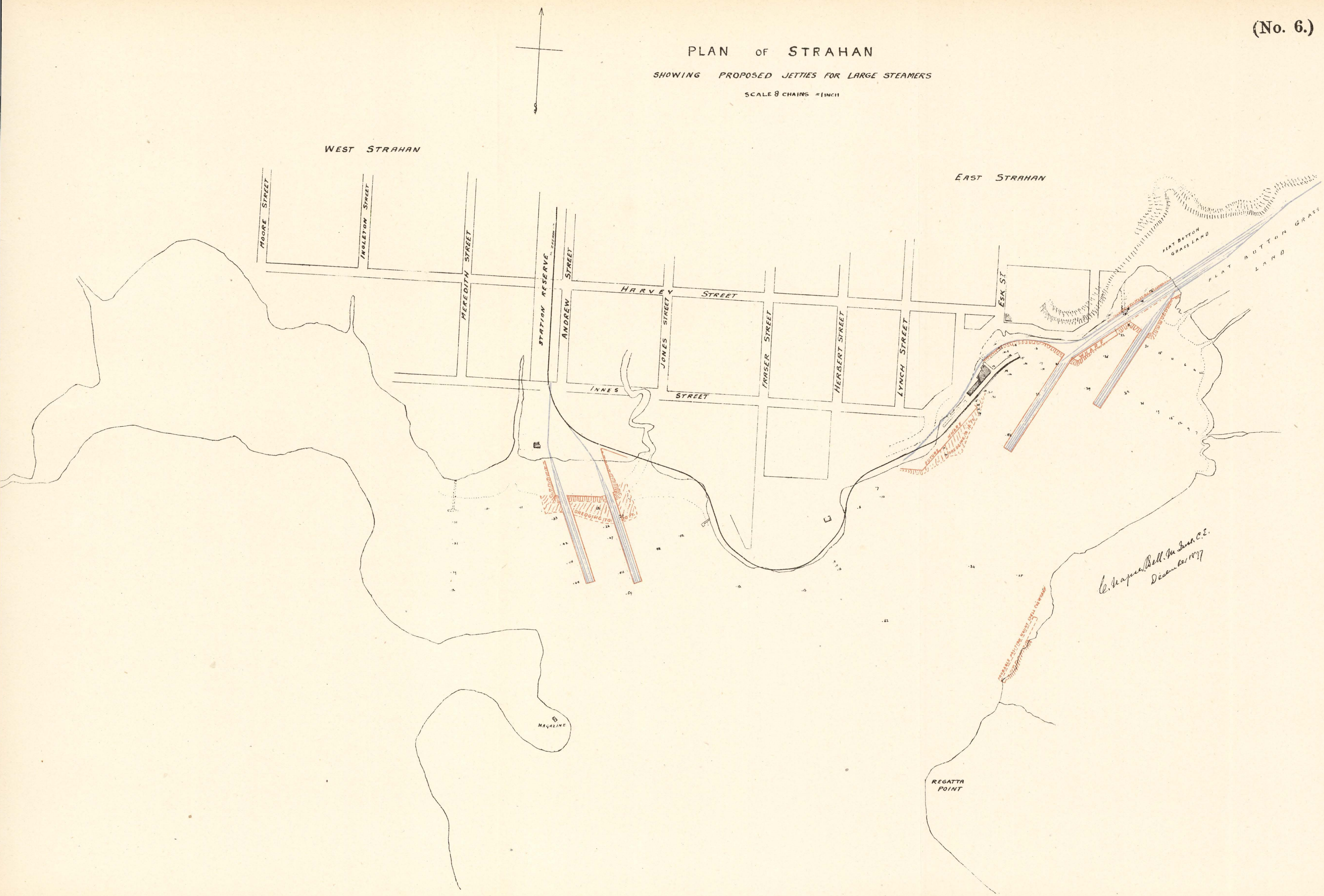


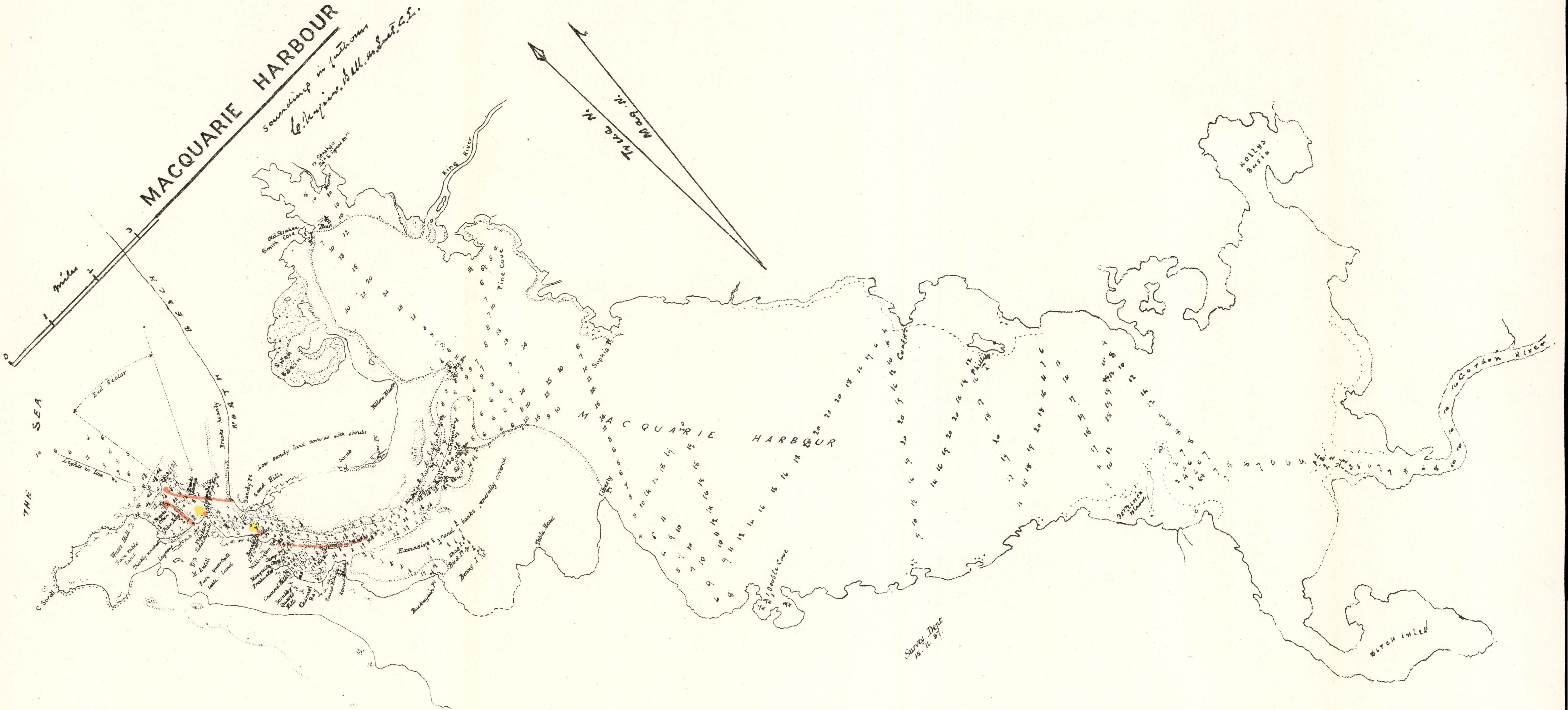
MACQUARIE HARBOUR

(No. 5.)

SWING BRIDGE




PLAN OF STRAHAN
SHOWING PROPOSED JETTIES FOR LARGE STEAMERS
SCALE 8 CHAINS = 1 INCH
WEST STRAHAN
EAST STRAHAN
MOORE STREET
INGLETON STREET
MEREDITH STREET
STATION RESERVE
ANDREW STREET
HARVEY STREET
JONES STREET
INNES STREET
FRASER STREET
HERBERT STREET
LYNCH STREET
ESK ST.
FLAT BUTTON GRASS LAND
FLAT BUTTON GRASS LAND
WHARF
FUTURE WHARF
DREDGING TO 18 FT.
PROBABLE POSITION MOUNT LYELL CO'S WHARF
MAGAZINE
REGATTA POINT
C. Napier Bell. M. Inst. C.E.
December 1897


MACQUARIE HARBOUR
soundings in fathoms
miles
True N.
Mag. N.
King River
Pine Cove
Smith Cove
Swan Basin
Sophia Pt.
M A C Q U A R I E   H A R B O U R
Kellys Basin
Gordon River
Birch Inlet
Double Cove
Table Head
THE SEA
C. Sorell
Low sandy land covered with shrubs
Sand Hills
Extensive sand banks, partially covered
Yellow Bluff
North Beach
Lights in line
Survey Dept 15. 11. 97.