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OFFICIAL PAPERS

CONNECTED WITH THE

CONSTRUCTION OF THE MADRAS HARBOUR.

Appendix. *S. R.*

P. W. D. S.

Pros. G. W. M. March 1902

Nº 7-9 A.

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OFFICIAL PAPERS

CONCERNING THE

CONSTRUCTION OF THE MADRAS HARBOUR.

ARRANGED BY

A. T. MACKENZIE, M.INST.C.E.,

Local Consulting Engineer to the Madras Harbour Trust.



Madras:

PRINTED BY THE SUPERINTENDENT, GOVERNMENT PRESS.

1902.

[PRICE, 4 rupees.]

[6 shillings.]

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OFFICIAL PAPERS

CONCERNING THE

CONSTRUCTION OF THE MADRAS HARBOUR.

THE first printed definite proposal now on record for a harbour at Madras emanates from the Chamber of Commerce and is dated 31st July 1868. That this is not the first mention of it is shown by a minute on the above proposal by the then Governor, Lord Napier, dated 23rd August of the same year, in which

Inception of the Madras Harbour in 1868.

he alludes to the project as often suggested, abandoned, and revived. It is however always difficult to discover the exact date of inception of large schemes, nor is it in the present case material; and for the purposes of this account the representation of the Madras Chamber of Commerce in 1868 may be taken as the origin of the Madras Harbour.

The Government of the day accorded its cordial support and in its order dated 28th August 1868 appointed a Committee of investigation

Local Committee of 1868.

consisting of Colonel J. Carpendale, R.E., Colonel J. C. Anderson, R.E., Major J. H. M. Shaw-Stewart, R.E., Mr. H. D. E. Dalrymple, Mr. R. B. Elwin, M.C.S., and a representative of the Chamber of Commerce, who nominated Mr. P. Macfadyen.

This Committee presented its report on 16th January 1869. It considered the alternative project of improving Blackwood's Harbour at Arneghon sheal, 45 miles north of Madras, but dismissed the idea on

Report of Committee of 1868.

the ground of the futility of expecting to divert the trade of an old-established city to a new port. It then discussed the condition of the port and its disabilities, which were (1) the open roadstead, (2) delay in loading and unloading owing to the use of masulah boats, (3) cost of landing and shipping cargo and extortion of boatmen, (4) damage to goods. All these disabilities it would be the object of a breakwater to remove, while also furnishing a harbour of refuge.

The Committee then considered the question of a close harbour in preference to a breakwater and decided against it, on the ground that "stone dykes running out at any angle with the shore would result

Report of Committee of 1868 (continued).

in the eventual extension of the beach, the closure of the mouth, and the shoaling up of the harbour itself." Finally after examining several plans submitted to it the Committee recommended a detached structure of rough stone on the principle of Plymouth breakwater, as proposed by Colonel Orr, R.E., and Mr. deClosets, and advocated previously by Sir Arthur Cotton and by Colonel deHavilland, R.E., as far back as 1836. This breakwater was to be placed parallel to and at a distance of 1,200 yards from the beach, that is, in a little over 7 fathoms at ordinary low water, and was to be 2,000 yards in length, with ends slightly splayed. The Committee believed that such a structure would cause no silting, since as far out as 6 fathoms only was there shifting sand (varying in depth as much as 8 feet) but beyond that stiff blue clay with an unvarying depth of firm sand over it; and it argued from the analogy of the Armeghon shoal that the breakwater would form no obstruction to the travel of sand either along the bottom or in suspension and would thus cause no appreciable alteration in the beach. The cost was estimated at Rs. 1,06,20,325.

In discussing the financial aspect of the scheme the views of the Committee bear a striking resemblance to those which still govern the situation, viz., that improved facilities will attract trade that now finds other outlets, that the yearly increasing extension of the railway system in this presidency will tap new fields of commerce for the benefit of the best and safest seaport on this or the other coast, and that the trade of the country which has the alternative railway systems of Bombay and Madras to choose from will select that port which is easiest and cheapest; while even at that date Bombay and Calcutta imported a great part of the goods required for Madras. With these factors there must be included the difficulties with boatmen, the increase in insurance, and the expense due to delay. The figures showing the tonnage then visiting Madras on the average may here be quoted—

	TONS
Steamers	146,000
Ships	119,000
Native craft	39,000

the aggregate annual value* being about Rs. 3,00,00,000. This tonnage might, it was considered, produce an annual income of Rs. 2,21,250 from harbour dues, and of Rs. 5,07,500 from port dues.

The report concludes by furnishing particulars of the damage from storms since the year 1746. On October 3rd of that year three large

* Presumably of imports and exports.

French ships in the roads foundered with the loss of 1,200 men and three others were dismantled. Two other ships, prizes, were wrecked and of 20 other vessels in the roads not one escaped. On 13th April 1749 two men-of-war, one a 74-gun ship, were wrecked with the loss of 850 men off Cuddalore, and two other ships and all the small vessels that were near Fort St. David were wrecked. Hurricanes occurred in 1752 and 1761, and in the last 3 of the ships of the British Squadron came ashore and three others were lost with about 1,100 men. On 21st October 1773 all the vessels that remained at anchor were lost with their crews and upwards of 100 country vessels were stranded on the beach. There were heavy gales on 27th October 1797, on 4th December 1803, on 10th December 1807, and on 2nd May 1811. In the last the "Dover" frigate and a store ship were lost in the roads and 90 country vessels went down at their anchors. Other hurricanes occurred on 24th October 1818, 9th October 1820, and 30th October 1836. In 1842 in a heavy gale, but hardly a hurricane, seven vessels with 17 lives were lost. Hurricanes occurred on 22nd May 1843, on 25th November 1846, in March 1853, May 1858, and on 25th November 1865. The number of vessels wrecked since 1842 amounted to 42, average tonnage 480, loss of life to 196, and of property to 38 lakhs of rupees, excluding country craft and vessels wrecked off other parts.

Colonel Carpendale, R.E., submitted a minute of dissent from the above report, expressing his opinion in favour of a close harbour.

The Madras Government in its order dated 17th March 1869 accepted the view of the majority of the Committee as to the superiority of a breakwater over a close harbour, and resolved to submit the whole subject to the Government of India, in the hope that it might meet with the support of the Governor-General in Council, and that the Secretary of State might be moved to send out a thoroughly qualified marine and harbour Engineer to examine and report on the measures to be adopted.

The question was submitted to Mr. G. Robertson, M.I.C.E., who about that time was examining ports on the Indian Coast line for the Government of India.

That gentleman submitted a report in 1871, in which he stated that after examining the report of the Committee, and the large number of schemes submitted, he had come to the decided opinion that before any works could be safely commenced more must be known regarding the most important points in connection either with a close harbour or a breakwater, viz., the currents close in shore and the amount of sand in motion at the coast line. He pointed out

Views of the Madras Government in 1869.

Report of Mr. Robertson, M.I.C.E.

that the travel of sand was due to the oblique action of the surf as well as the currents, and that if the latter were not strong enough of itself to carry the sand either up or down the coast the withdrawal of the other agent, the surf, at any rate would cause the sand to be deposited there; and that consequently a breakwater would cause an accumulation as certainly as an arm projecting from the shore. With this proviso he agreed with the committee in preferring a breakwater to a close harbour, in case one or the other were essential, on the grounds however of more deep water shelter at an equal cost. He estimated the cost of a breakwater such as recommended by the Committee but slightly altered in section at Rs. 1,31,10,000.

In 1872 a note on the subject was submitted by Mr. W. Parkes, M.I.C.E., after study of Mr. Robertson's report and with immediate reference to the cyclone of that year. From his experience on the Karachi Harbour Mr. W. Parkes argued that a breakwater in the form of a rubble mound was unnecessarily expensive and that a submerged rubble mound with a wall of concrete blocks with vertical sides was much more economical and quite strong enough. Such a wall would cost but little over 65 lakhs of rupees and could be much sooner completed. Mr. Parkes went on to argue that the littoral currents at Madras must be so insignificant as to be negligible, and further that if a close harbour were built the quantity of sand accumulated could not be so great as to envelope the pier heads for at any rate generations to come: such a close harbour could, he maintained, be constructed for half Mr. Robertson's estimate and in little more than half the time.

Mr. Parkes' views were supported by a note by Captain A. D. Taylor, R.N.R., on the nautical aspects of the question, in which that officer showed the inefficacy of a breakwater in case of a cyclone, the further superiority of a close harbour in providing smooth water for landing and shipping cargo. He also instanced Port Said to prove the slowness of the operations of nature in accumulating silt.

These reports induced Colonel Walker, R.E., then Chief Engineer to the Madras Government, in a memorandum of the year 1873, to recommend a visit by Mr. Parkes to Madras for the study of local conditions. Mr. Parkes accordingly visited Madras and on 4th November 1873 submitted a complete report and estimate in which after reviewing previous opinions he gave his opinion in favour of a close harbour, reiterating its advantages over a detached breakwater and the groundlessness of a fear of shoaling. His estimate came to £565,000,

for which accommodation would be provided for 13 ships of from 4,000 to 700 tons at fixed moorings, able to swing clear, and for three ships alongside the screw pile pier. The section of arm proposed was a submerged mound of rubble up to a depth of $22\frac{1}{2}$ feet below low water surmounted by a solid wall of two rows of concrete blocks laid close together 24 feet wide, 6 feet above high water. He assessed the saving in landing and shipping operations at a rupee per ton of goods, applying which to the number of tons handled in the previous year, viz., 275,000, he deduced a revenue from savings only of £27,500, which would pay the interest on a sum sufficient to construct the harbour. Mr. Parkes also considered the alternatives of a single eastern entrance and two entrances near the outer angles, and decided in favour of a single entrance, on the ground that the double entrance would mean a sacrifice of one-fifth or one-sixth of the capacity of the harbour, while the single entrance would be disadvantageous to sailing ships only and only at certain times. In estimating the danger from heavy seas rolling into the eastern entrance Mr. Parkes' views are given *verbatim* :—

“ *For protection from seas with one entrance.*—More importance has probably been attached to another objection, which, however, I cannot admit as undisputed, viz., the danger from heavy seas from the eastward rolling into the harbour. Those who urge this objection or probably not fully aware of the effect produced upon such seas when they enter a harbour. They are immediately dispersed, and the extent of reduction is not, as in the case of an open breakwater, a matter of speculation, but it is one of exact calculation.* Captain Biden, the former Master Attendant, estimates the maximum height of wave at Madras at 10 feet. Such a wave entering the harbour would be reduced to 1 foot 9 inches before it reached the piers or the beach. A wave 15 feet high (the maximum measured at Kurrachee) would be reduced to 2 feet 7 inches—neither very formidable.

“ *With two entrances.*—Whether the two entrances would admit more or less swell with an easterly sea would depend on their width and form. If equally accessible to vessels as the eastern entrance, they would, I believe, together admit more sea, and the reductive power of the harbour would be less, as each wave would spread over only one right angle instead of two right angles.

“ *Effect on seas from different directions.*—With the north-east monsoon swell the eastern and northern entrances would be about on a par, but the former would have more reductive power. If the tranquillity of the harbour were inversely proportioned to the duration and force of the wind to which the entrances are respectively exposed, the easterly one would have a marked advantage over either of the others separately, and of course

* Stevenson on Harbours.

in a far greater degree over the two together, but the easterly seas are the heaviest and most dangerous, and go far to counterbalance this advantage. On the whole, however, I am of opinion that the balance of advantage is on the side of the single entrance facing east by south."

Plate I shows a plan of this harbour as proposed by Mr. Parkes. These proposals were generally approved by the Chief Engineer to the Madras Government, Colonel Walker, R.E., and by the Chamber of Commerce, the latter pointing out that "the many considerable advantages which the Government would derive from the harbour—whether as a refuge for ships in distress, as an anchorage for men-of-war, as a secure port for landing at all times and seasons troops or military stores, or as a means of improving the defences of the port—are an undoubted claim for a portion of its cost being borne by Imperial funds." They were also approved as a whole by the

Views of the Government
of India in 1874.

Government of India, which forwarded them to the Secretary of State with a letter of which the following extract will bear reproduction.

* * * *

"The advantages of giving protection to the shipping at Madras, and of affording facilities for the landing of goods and passengers, are undeniable, but the scheme involves three questions, which appear to us to demand consideration and discussion before coming to a final conclusion on the subject.

"There is first the soundness or otherwise of providing a close harbour instead of an open breakwater. As your Lordship is aware, there is some difference of opinion on this important point, but it is to be remarked, *first*, that a breakwater has been estimated to cost a sum so large that, in the opinion of the Madras Chamber of Commerce, it would be entirely beyond the power of the Port Trust to provide even the interest on the outlay, irrespective of the cost of future maintenance and repairs; and, *secondly*, that, on the whole, the balance of the professional and nautical opinions obtainable is in favour of a close harbour rather than an open breakwater. Neither scheme is likely to afford complete, or probably even material, protection from the effect of very severe cyclones, but a close harbour would undoubtedly afford great accommodation to shipping in ordinary bad weather.

"We believe that considerable uncertainty must always attend conjectures as to the effect of harbour works upon the movement of sand on an open foreshore like that at Madras, but we do not consider that the possibility of the proposed harbour being liable to silt up is a conclusive objection to the projected scheme, unless, indeed, the objection be considered sufficiently strong to negative any attempt to provide shelter for the port of Madras. Your Lordship has the means of consulting higher

PLATE. I.
PLAN. A.

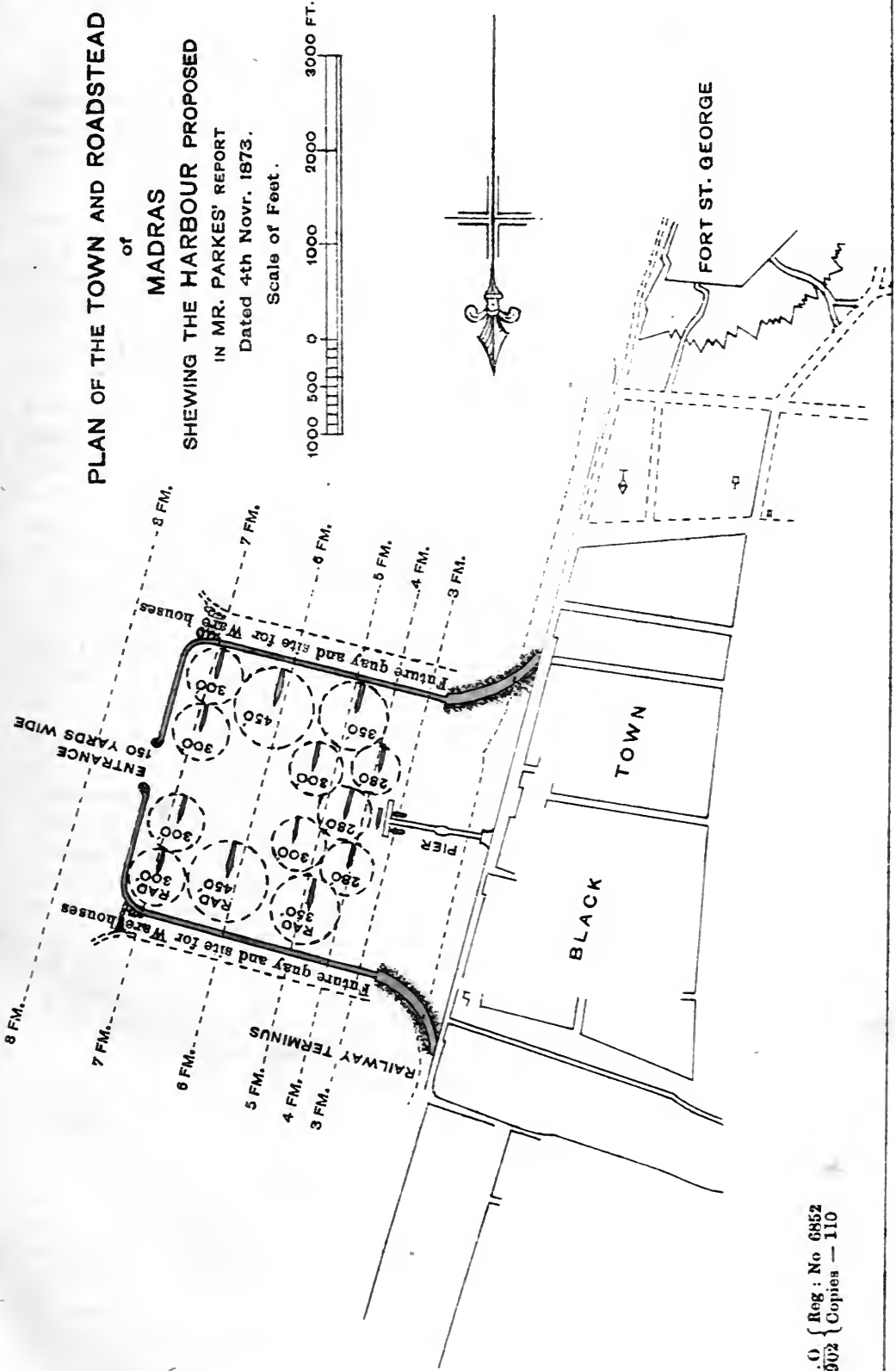
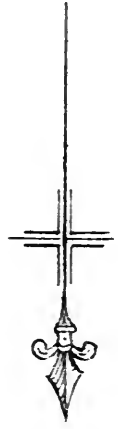
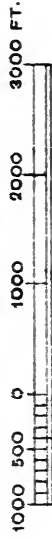
PLAN OF THE TOWN AND ROADSTEAD
of
MADRAS

SHEWING THE HARBOUR PROPOSED

IN MR. PARKES' REPORT

Dated 4th Novr. 1873.

Scale of Feet.



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professional authority than is obtainable in this country, if you should consider it desirable to obtain further opinions on this point.

“So far as we can form an opinion, we agree with the Government of Madras in recommending Mr. Parkes' scheme of a close harbour as the best that has yet been devised, having regard to all the conditions of the case.

“The next point for consideration is, whether the details of the mode of construction advocated by Mr. Parkes are satisfactory, and whether the estimates of cost are likely to be sufficient. It is to be observed here that the proposed harbour is to consist of sea-walls or breakwaters, composed of loose rubble-stone at the base, and of solid concrete blocks resting thereupon, in the same manner as the breakwater recently constructed at Kurrachee. We should have been glad had we been able to show from further experience in this country what is the effect of heavy seas and severe storms upon this method of construction, for there is no question but that it will be very severely tested at Madras, but so far as we know there are no grounds for questioning its stability. Here, again, Her Majesty's Government may have better advice available than is at the disposal of this Government.

“Mr. Parkes' estimate amounts to £565,000, and from a report enclosed it will be seen that the experience obtained from the works at Kurrachee shows that the rates for concrete blocks may be accepted as sufficient, but that some additions should be made to the estimate which raises the probable cost to £710,000; and if interest is to be charged upon this sum during the period of construction, then the amount of capital debt on the completion of the works will rise to £776,465, on the assumption that the time occupied will be four years, and that the advances are evenly distributed. It should also be noted that the scheme projected by Mr. Parkes does not provide accommodation for the landing of cargoes along the sea-walls forming the harbour and that additional outlay on this count will ultimately be required. Cargoes may, however, be landed, meanwhile, at the existing pier.

“The third and last point for consideration is, how to meet the interest of the money to be lent to the Government of Madras, and provide a sinking fund for extinguishing the capital debt, without causing serious injury to the trade of Madras. The calculations of the estimates of charge and revenue are as follows:—

“The Madras Government have taken a payment of 6 per cent. per annum on £600,000 or £36,000, as representing the annual charge for interest and sinking fund, and has proposed to raise the money as follows:—

	£
A rate of As. 8 (1s.) per ton on foreign steamers and ships, and	
As. 4 (6d.) a ton on coasting steamers and native craft ...	20,000
As. 14 (1s. 9d.) per ton on all goods landed and shipped ...	16,000
Total ...	36,000

“But it will be seen that higher dues will be required if the cost of the work rises as high as we have thought it prudent to estimate. Taking the calculations given in Colonel Dickens’ note, it will be necessary to obtain £42,196 per annum to cover interest at 4½ per cent., and provide for the repayment of capital in 40 years. To this we add £10,650 per annum, on the average, taking one year with another, for repairs and maintenance, and £4,000 for the port charges as at present. The result is that a sum of £56,846 is required to be provided annually.

“The following are the very highest dues we can expect to be paid, calculated on the existing trade :—

	£	
440,000 tons of shipping, at As. 8, or 1s. per ton	...	22,000
220,000 tons of goods at Rs. 1½ or 3s. per ton	... ..	33,000
		55,000
Total	... ..	55,000

“We consider that the nature of the trade at Madras makes it evident that from steamers calling at the port, but a very moderate amount can be levied without running serious risk of driving them away altogether, and we agree with the Madras Government that the returns from tonnage dues cannot well be taken at a higher figure than £20,000 a year, leaving £36,846 to be annually provided for by a charge upon the goods landed in such manner as the Government of Madras, after further consultation with the Government of India, may consider proper.

“We think it desirable to record our opinion that, if this loan be granted, there cannot fail to be considerable risk of loss to the revenues of India, both on account of the uncertainty of all harbour works, and also on account of the probability of pressure being put upon the Government of India to relieve the trade of Madras from the burden of paying the interest if the harbour dues not prove to be a success, or if the port-dues operate injuriously, and it is for Her Majesty’s Government to consider whether these risks are, or are not counterbalanced by the undoubted advantages that will accrue should the undertaking prove to be a successful one.”

The Secretary of State in accordance with this despatch submitted to Mr. J. F. Bateman, C.E., the following three questions to which the answers attached were given—

Questions.

“(1) Whether the proposed method of constructing the breakwater, as described in the Report dated the 4th November 1873, affords promise of stability.

Answers.

(1) I am of opinion, after the full information I have received of the mode of construction adopted at Kurrachee and the success and stability of the breakwater there, exposed, as it is alleged to be, to as heavy or a heavier sea than the breakwater at Madras can be, that the mode of

Questions.

"(2) Whether the obstruction to the littoral currents offered by the breakwater is likely to cause an accumulation of sand; and, if so, within what period such accumulation is likely to impede the entrance to the harbour.

"(3) Whether the proposed harbour, being enclosed by breakwaters only 3 feet 6 inches above high water mark, and having an opening 150 yards wide exposed to the sea, would afford sufficient protection to the shipping moored within it during the prevalence of high winds blowing inshore.

Answers.

constructing the breakwater, as described in Mr. Parkes' report of 4th November 1873, does afford promise of stability. It is, however, very probable that, both during construction and subsequent to completion, very severe storms may disturb and injure the work; but this contingency is not, in my opinion, sufficient to prevent the execution of the breakwaters in the manner proposed by Mr. Parkes.

(2) A breakwater or pier projecting at right angles from the coast must of necessity obstruct littoral currents and arrest travelling sand or shingle, but I have no information as to the quantity of sand which would be thus arrested in a year, and cannot therefore make any calculation of the period within which the accumulation would extend as far out as the points of the piers, or impede the entrance to the channel.

The piers or sides of the enclosed harbour are proposed to be extended nearly two-thirds of a mile from shore, and I am of opinion that, whatever may be the quantity of sand which will be arrested, a very long period will elapse before the accumulation behind the walls can have an injurious effect, so long, indeed, that it may be disregarded.

(3) The breakwater, though the top be only 3 feet 6 inches above high water, will very effectually stop the progress of driving waves, and will afford material shelter within the harbour. It will not prevent water rolling over in heavy seas, but the destructive effect of such water will be destroyed, and no injurious wave

*Questions.**Answers.*

can be propagated within the space of the harbour.

I consider an opening of 150 yards will afford easy ingress and egress to vessels, and that any waves entering this space from high winds blowing inshore will, as soon as they have entered, spread out in all directions with such rapidity as to be wholly dissipated as objectionable waves within a short distance of the entrance.

The water within the harbour in all winds, however high, will be comparatively quiet."

Sanction by the
Secretary of State for
India.

On receipt of these answers the scheme was sanctioned in a despatch dated 11th March 1875, of which the following is an extract:—

"Considering these favourable judgments in conjunction with the experience of Mr. Parkes' mode of construction which has been furnished by the harbour of Kurrachee, I am satisfied that his plans are likely to be suitable for their purpose, and may be safely sanctioned.

"The question of expense is, as might be expected, a matter of some controversy. Your Government is disposed to place it at as high as £776,465; Mr. Parkes' own original estimate did not exceed the sum of £565,000. The Madras Government have adopted an intermediate view, and are of opinion that £628,000 will be amply sufficient. A similar discrepancy exists with respect to the estimate for maintenance, which is placed by your Government and that of Madras at the sums of £10,000 and of £2,000 a year respectively.

"The contingencies upon which the cost of constructing and repairing a harbour depends are so uncertain that it would be hazardous to express a confident opinion in respect to these conflicting estimates. But the question is too large to be dealt with only upon financial grounds. Many human lives are sacrificed in the tempests which annually ravage the Coromandel coast, and it is probable that a large proportion of these might be saved if the vessels which are now surprised in the roadstead could seek the shelter of a harbour. The material interests of the vast population that inhabits the Presidency of Madras are not less deeply affected by the unsheltered condition of the port. It can hardly be doubted that, if a safe and regular access to the sea could be secured to them, their industry and trade would be greatly stimulated. The public utility of a harbour can seldom be measured by the actual return in the shape of dues which it can be made to

pay, and in the Presidency of Madras, where the destitution of shelter upon the seaboard is so remarkable, such a principle of valuation would be specially misleading.

“ I do not, therefore, propose to make the construction of the harbour of Madras depend upon the accuracy of the estimates submitted by the Government of Madras. Those estimates may, however, properly serve as a guide in determining the sum which is to be advanced for the work out of the extraordinary Public Works fund. The principles upon which that fund was constituted, and of which I reminded you in my Financial Despatch of the 23rd July 1874, No. 387, forbid its application to any work except so far as the yield of that work is likely to repay the interest upon its cost.

“ Looking to the tonnage both of the ships which visit the port and of the goods which pass through it, and also to the burdens which are borne without injury to the trade of other ports, I am disposed to concur with the opinion of the Government of Madras, that dues raised upon shipping and upon goods in that port may be trusted to repay interest upon the £628,000 which they estimate as the outlay necessary in addition to the annual sum which, in their opinion, they will have to provide for the maintenance and working expenses of the harbour. I do not conceal from myself that circumstances now unforeseen may render inevitable an excess either upon the capital outlay or the annual expenditure in maintenance. But the imperial character of the undertaking, and the high interests involved in it, do not permit me to look upon the existence of that contingency as an insuperable obstacle to the prosecution of the work. If the excess should arise, it must be borne upon the ordinary budget; but until the probability of its being incurred is ascertained, the necessity for providing for it will not arise. I desire, however, to record the opinion that, if the full amount of the highest estimate formed by your Government should be reached, the expenditure will still have fallen short of the benefits which the work may be confidently expected to confer upon the people of Madras.”

The work was commenced in 1877 with the north arm. The immediate result was a considerable accretion of sand on the south side of that arm. This attracted the attention of the Government of India, who in December 1877 deputed General, Sir A. Clarke, Member of the Viceroy's Council, to inspect the work, without however interfering with its progress. Sir A. Clarke inspected the work in February 1878 and submitted a long report dated 18th February 1879, in which he condemned the scheme on political, financial, nautical, commercial, and engineering grounds, and recommended a design by which the harbour would be detached from the shore, its accommodation increased, its defensive

Commencement of work.

Criticisms and suggestions by General Sir A. Clarke, R.E.

power improved, and egress and ingress facilitated. In this design the two arms were broken at $3\frac{1}{2}$ fathoms, leaving an entrance both north and south, the curved or breakwater portion being longer than hitherto designed, the outermost point being armed with a fort, and the interior divided by wharves. This report was forwarded home and referred by the Secretary of State to Mr. Parkes in September 1879. But in the meantime the progress of the south and north arms had provided new data and Mr. Parkes was able to satisfy the Secretary of State that

Mr. Parkes' reply. sufficient warrant had not been furnished for stopping the works. Mr. Parkes' reply is of such interest as bearing on subsequent developments that part of it is here reproduced *in extenso* :

The Sand Difficulty.

“The point at issue between Sir Andrew Clarke and myself may be expressed in a very few words. My conclusion was from the first, and still is, that supplementary works will at some future time be required to prevent the advance of sand from destroying the harbour, but that the period at which this will become necessary is so distant that it need not at present be taken into account.*

“The area of discussion is very much narrowed by Sir Andrew Clarke's admission of what I consider to be the one great principle, which is the key of the whole question. It is one for which I have contended from the first, though, in consequence of the special circumstances under which I made my original report, it is rather tacitly assumed than positively asserted therein. That principle is that the force by which the sand is disturbed and transported is that of the *waves* and not of the *currents*, and that its movements are confined to a belt bounded by the shore on one side and by a line approximating to the four-fathom contour on the other. Outside this there is no important movement. So far, Sir Andrew Clarke and myself are agreed.

“It is well known that the waves in the two monsoons approach the shore from different directions, approximately north-east and south-east, each obliquely transverse to the general line of the shore. The first and main movement of the particles of sand lifted from the bottom by the waves must obviously be in the same direction as that of the particles of water which have lifted them, and this must be either in the same direction as the wave itself is moving, or the exactly opposite direction, without any tendency to a diversion to the right or the left so long as the wave has an unimpeded onward movement. But when this movement is met by the shelving bottom a portion

* To show that this does not impose any very serious burden on posterity, I may mention that whatever the length of time may be it may be *doubled* by the extension of the South Pier seaward for a length of 1,000 feet, at a cost of 80,000*l.*

of the particles of sand-laden water are diverted right or left according to the direction of the obliquity, and thus an *alongshore* movement is communicated to the sand. At first the proportion of this movement is small, but as the rolling wave advances towards the shore into still shallower water the degree of obstruction increases, and the alongshore component of the movement increases with it, until where the wave make its final break on the beach the onward movement is completely arrested, and the final result upon the particles of sand carried by it is a transport for a certain distance *alongshore*.

“It directly follows from this, *first*, that the alongshore movement is very much greater close to shore than it is further out; and *second*, that the movement in the outer part of the area of disturbance, whether great or small in itself, has a large component of transverse movement, and a small one of alongshore movement. The importance of making a distinction between these two movements arises from the fact that the alongshore movement is directly arrested by the piers, and so far as the movement in one direction in one monsoon is not balanced by that in the other direction in the other monsoon, the effect will be cumulative from year to year. The transverse movement on the other hand will not be interfered with by the piers, and the seasonal changes will continue to balance one another as heretofore.

“The triangular accumulation and its partial removal, as shown on the plan, was, however, a definite addition to our materials for estimating the *amount* of sand movement due to the alternate southerly and northerly alongshore wave action. Its *completeness* as evidence depends on the degree of reliance which may be placed on the first of the two principles enunciated in the previous paragraph, and which as yet rested entirely on hypothetical considerations. My own belief was, and is, that it is a legitimate deduction from admitted principles, and that it might fairly be concluded that the amount of sand which passed the line of the pier, but would have been arrested by the pier itself had it been in existence, was so small in comparison with that actually arrested as to be properly disregarded. A calculation made upon this assumption showed that at the same annual rate of accumulation it would require 50 years for the four-fathom line to reach the sea face of the harbour, and if it were further assumed, as the plan shows, to be well within the mark, that half the accumulation under the southerly seas is removed by the northerly seas, the period would be extended to 100 years. But even if this be not admitted, and a substantial allowance be claimed for sand which passed freely, and is therefore not shown by the area of accumulation, a very considerable one might be made without so reducing the ‘life’ of the harbour as to trench upon my contention that the means of extending it may be left to posterity. Up to 1876, however, my reliance was on a hypothesis based on abstract reasoning. I hope to show that it may now be based on *fact*.”

During this investigation Mr. Parkes had recommended a slight alteration in the form of the seaward side of the harbour and the entrance, which was agreed to, and the work was steadily prosecuted, the only incident being a visit by Colonel Sankey, R.E., and Captain J. H. Taylor, R.N.R. (then respectively Chief Engineer and Master Attendant at Madras), to Colombo, and their remarks after an inspection of the works there on the much more massive section of the arm at Colombo and the extra rubble protection. This was in 1881 and on 4th August of the same year Mr. Parkes wrote a reply to these criticisms defending his design by the example of Kurrachee and declining to consider Madras and Colombo comparable.



On November 12, a severe cyclone visited Madras and the seaward portion of the works, which had then progressed nearly to the pier heads, was almost destroyed.

Some of the correspondence that ensued upon this disaster is of sufficient importance to be reproduced. First comes the report of Sir G. Molesworth, then Consulting Engineer to the Government of India for State Railways, of which the following is an extract:—

In conclusion, I may briefly summarise my opinions as follows:—

- 1st.—The proximity of a cyclone is no measure of the intensity of wave action.
- 2nd.—The storm of the 12th of November 1881 was a very severe test, probably almost as severe as any that can occur at Madras.
- 3rd.—Wave action at Madras extends to depths far lower than experience in English and continental harbours has led Engineers to expect.
- 4th.—The pier faces have failed almost entirely by the displacement of the 27-ton blocks.
- 5th.—The elbows have failed, on the sea side from under scour of the rubble base, and on the harbour side by displacement of blocks.
- 6th.—The rubble base has on the sea side of the face and the elbows been pulled down to a flatter slope, while the rubble base on the harbour side has stood well.
- 7th.—The sides have from the shore to the elbows been practically uninjured.
- 8th.—The waves of a dangerous character must always come in broadside on to the shore, or nearly so, whatever the position of the storm.

MADRAS HARBOUR

SKETCH SHEWING SITES OF DAMAGE

In STORM of 12th. Novr. 1881.

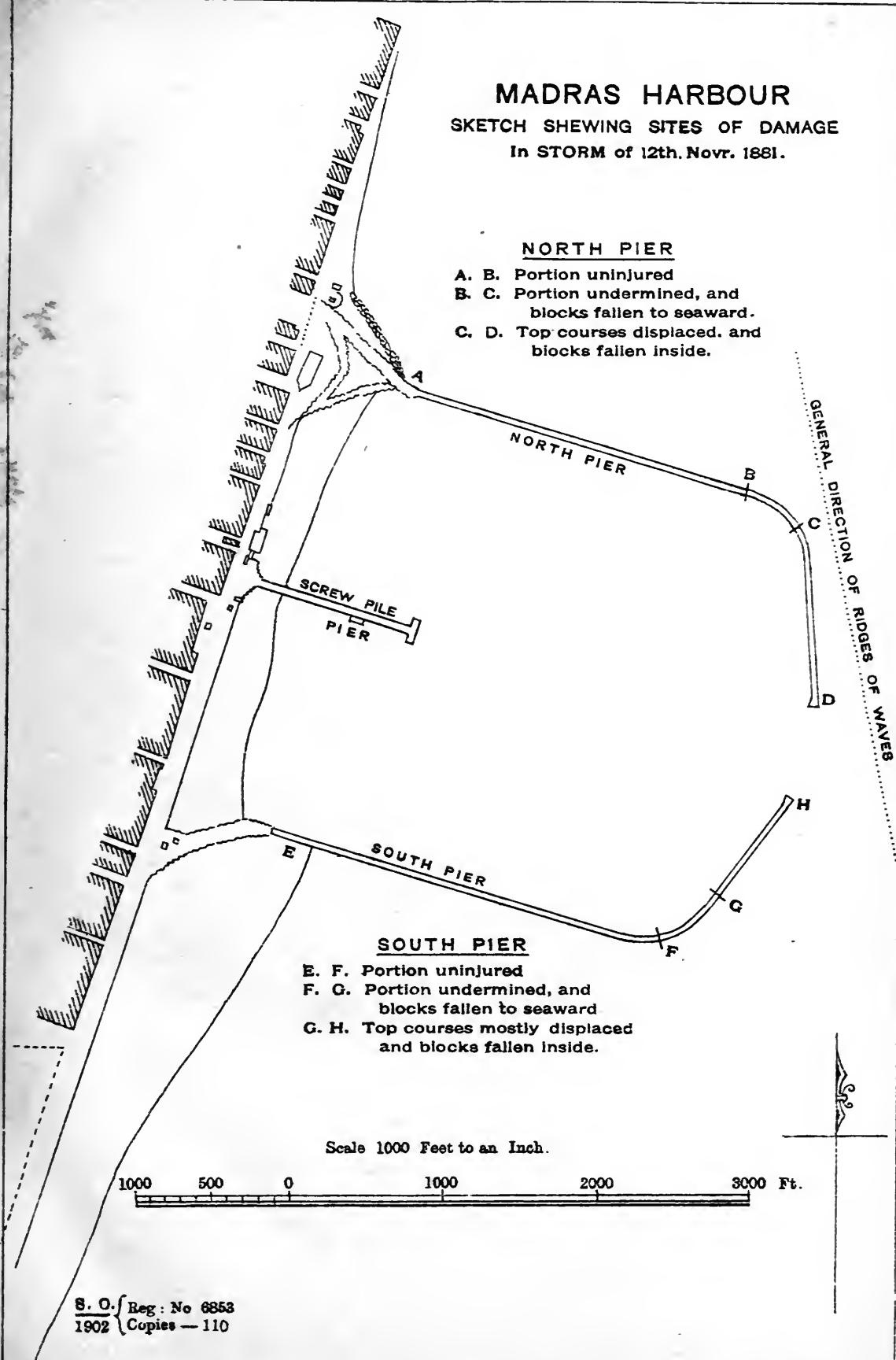
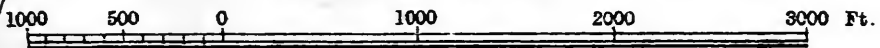
NORTH PIER

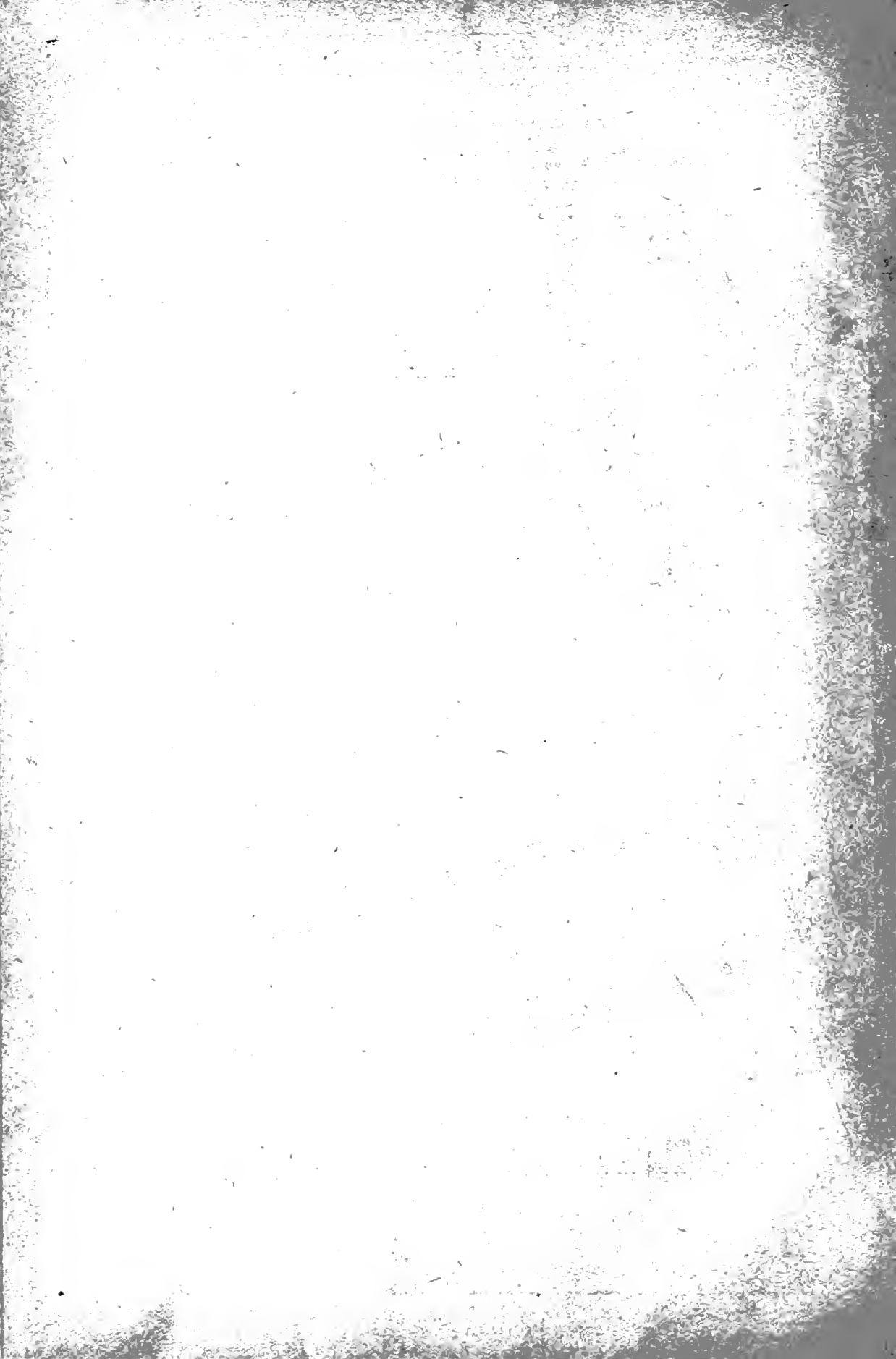
- A. B. Portion uninjured
- B. C. Portion undermined, and blocks fallen to seaward.
- C. D. Top courses displaced, and blocks fallen inside.

SOUTH PIER

- E. F. Portion uninjured
- F. G. Portion undermined, and blocks fallen to seaward
- G. H. Top courses mostly displaced and blocks fallen inside.

Scale 1000 Feet to an Inch.





- 9th.—The sides of the harbour will not probably be exposed to broad-side action of cyclonic waves.
- 10th.—The entrance has been uninjured by the storm.
- 11th.—The storm has not increased the accumulation of sand in the harbour.
- 12th.—The section adopted by Mr. Parkes is the cheapest and most expeditious that could be adopted.
- 13th.—It is probably sufficient for the sides of the harbour, which will not be exposed to the full action of the cyclonic wave, but the rubble base should be supplemented with gneiss.
- 14th.—It is insufficient for the faces and elbows.
- 15th.—The disaster is not serious, as all the materials that have been deposited are available without removal.
- 16th.—The concrete of which the blocks is composed is good and sufficient, but in some instances it has been used too soon after manufacture.
- 17th.—Some of the laterite obtained from the new quarry is unsuitable for the rubble base, and I advise that no laterite be used in reconstruction.
- 18th.—I am of opinion that the failure of the breakwater is not attributable to the character of the concrete or laterite, though in some few parts the catastrophe may have been hastened by broken blocks or unsuitable rubble.
- 19th.—I would only propose to reconstruct the vertical wall where it can be economically used for the distribution of materials.
- 20th.—The blocks that have fallen should remain where they are.
- 21st.—The reconstruction should be on the lines of the present breakwater, but on the random block principle.
- 22nd.—The face should be extended to cover the elbows.
- 23rd.—The sides should be protected by throwing down additional gneiss rubble on the sea side.
- 24th.—The blocks might be rather larger for the outside slopes, say 30 or 35 tons.
- 25th.—An inner breakwater should be formed for the protection of barges during construction.
- 26th.—The blocks should not be used within six months from their manufacture, unless they have a greater portion of cement.
- 27th.—Early action should be taken in the construction of blocks and the quarrying of materials, so as to prevent further demolition of the structure.
- 28th.—A detached breakwater covering the mouth of the harbour is inadmissible.

29th.—The entrance should, if possible, be narrowed, but a decision on this point must be postponed pending further investigation and experience.

30th.—The cost of reconstruction will be about 27 lakhs of rupees.

31st.—The harbour, even with this addition, will, when compared with similar works, have been constructed at a very low rate.

Mr. Parkes' report
and proposals for restor-
ation.

Then follows Mr. Parkes' report dated 9th March 1882 from which a portion is here reprinted.

“ My report has been delayed longer than I could have wished, owing to the great difficulty of obtaining detailed measurements and sections, which require an exceptionally calm state of the sea. Upon the results shown by these depend in a great measure our conclusions as to the particular action of the sea which produced the damage. I have thought it desirable to delay the submission of my report until I had obtained such facts as were necessary, not only to form a basis for my own positive conclusions, but also to test beyond the possibility of doubt the correctness of the conclusions which have been put forward by others upon a more or less imperfect knowledge of the facts. I may here mention once for all that I have given careful consideration to various suggestions that have been made to account for the damage, but I do not think it necessary to notice these as a rule, but rather to submit my own conclusions, with the facts on which they are based.

“ *Previous reports.*—I wish however to explain my position with regard to two documents of very great interest, the first being a report which was made only two days after the storm by the Chief Engineer of the Presidency, who with great promptitude availed himself, in company with the Master Attendant, of a specially favorable opportunity of taking what was necessarily a very general view of the state of the works. This report was forwarded ‘with all reserve’ to the Secretary of State, and I had an opportunity of perusing it before I left London. If I were to comment upon the suggestions made in this report as to the particular action of the sea, it would give them a prominence which the author probably never intended they should possess.

“ The other document is a very excellent report made by Mr. Thorowgood on the 21st November, nine days after the storm, which is especially noteworthy as showing how much information can be obtained in a short time. But this information, though generally confirmed by subsequent observations, was not sufficiently complete to form a basis for practical conclusions, and what was then wanting had to be obtained with considerable difficulty afterwards. It is scarcely possible to make an intelligible statement of facts without conveying some suggestion of conclusions to be

drawn from them, and in some cases such suggested conclusions fail to be confirmed by the facts subsequently ascertained. To a slight extent this is the case with Mr. Thorowgood's report, but it is no disparagement of its merits to ask that it may be considered as superseded, even if generally confirmed in its conclusions, by the present report, and in its facts by the plans and sections which will be submitted to Government, and will, I think, form a very interesting and instructive record.*

"*Mr. Thorowgood.*—I should mention that I had the advantage of five weeks' constant communication with Mr. Thorowgood before he left for England, and during that time, as further materials accumulated, we were able to form more definite conclusions, and those conclusions, independently formed by each of us, were in all essential matters the same. They included, subject to corrections suggested by the further surveys which have since been made, most of the recommendations which I am about to submit.

"*The storm.*—The storm is thus described in the official Meteorological Report issued by the Government Astronomer on November 23rd 1881 :—

'A cyclone visited Madras on Saturday and Sunday the 12th and 13th instant. It appears to have exhausted its greatest force while crossing the Bay before reaching the coast of Southern India, which would account for the high and destructive sea, far beyond what might have been expected from the meteorological indications accompanying its progress. The centre of the storm must have struck the coast considerably southward of Madras. The lowest reduced reading of the barometer was 29.51 at 4 P.M. on Saturday; and the strongest wind was experienced between 11 P.M. and 2 A.M. on Sunday, during which time it averaged 32 miles per hour in velocity, equivalent to a pressure of about $5\frac{1}{4}$ lb. per square foot. Rain commenced at 1 $\frac{1}{2}$ A.M. on Saturday and continued until 8 P.M., amounting in all to 8.19 inches—the twelfth heaviest fall on record at Madras since 1803. No single hour was extraordinarily excessive, but the persistence of both wind and rain was remarkable. The veering of the wind was as usual for cyclones southward of Madras. The records of the anemograph furnish the following mid-times for each principal point of the compass with the corresponding hourly velocities :—

N.W. by W. at 2 $\frac{1}{2}$ P.M.; velocity 20 miles.	|	E.N.E. at 1 $\frac{1}{4}$ A.M.; velocity 33 miles.
N.W. at 3 $\frac{1}{2}$ P.M.; do. 29 do.		East at 2 $\frac{1}{2}$ A.M.; do. 25 do.
N.N.W. at 6 $\frac{1}{2}$ P.M.; do. 23 do.		E.S.E. at 4 $\frac{1}{2}$ A.M.; do. 18 do.
North at 7 $\frac{3}{4}$ P.M.; do. 27 do.		S.E. at 7 $\frac{1}{2}$ A.M.; do. 14 do.
N.N.E. at 8 $\frac{1}{2}$ P.M.; do. 30 do.		S.S.E. at 9 $\frac{1}{2}$ A.M.; do. 14 do.
N.E. at 10 $\frac{1}{2}$ P.M.; do. 31 do.		South at 10 $\frac{1}{2}$ A.M.; do. 13 do.'

"The Astronomer here alludes to the fact, to which I have myself frequently had occasion to advert, that there is no relation between the force and direction of the wind in the neighbourhood of a cyclone and those

* These are still in progress. At the end of the present fine season so much as is complete will be submitted to Government.

of the sea which may accompany it. The sea is raised, not by the wind which may happen to be blowing at the time at any given spot, but by an intense atmospheric disturbance at a distance, that is in the centre of the cyclone, and from the site of that atmospheric disturbance (which when the wind is from the north-west at any place will lie between north-east and east of that place) the sea disturbance will proceed, propagated by laws which, so far as we know, have no similarity whatever to those by which the atmospheric disturbance itself is propagated. On this occasion the maximum velocity of the wind at Madras was 33 miles per hour; on occasion of the great storm in May 1872 the velocity was 53 miles per hour; in May 1874 it was 49 miles per hour; while in May 1877, when the concrete block work of the north pier had advanced about 300 feet, the sea was nothing like so severe as in last November, though the velocity of the wind was 34 miles per hour.

“The testimony of all observers is to the effect that the sea of 12th November must rank with those of the great historical cyclones, though there is a conflict of evidence as to whether it was actually as heavy or heavier. Mr. Chisholm, the Government Architect, a very intelligent and close observer, speaks confidently as to the recent sea being considerably heavier than that of 1872; but on the other hand, the officers of the Marine Department, who witnessed both storms, give the palm to that of 1872. A rough test is afforded by its action on the planking of the screw pile pier 17 feet above mean sea level. This was torn up in 1872, in 1874, and again in 1881, but it is uncertain whether on the last occasion the effect of the Harbour Works would be to reduce the waves at the site of the pier (as I have no doubt was the case over the area of the harbour generally), or to aggravate them by the confusion which would be caused by their rolling in over the piers as well as through the entrance. The end of the pier is just outside the line in which the first break of the waves occurred, and the height there was no doubt abnormally raised.

“As compared with the force of sea in other places the evidence is also unsatisfactory. Mr. Bhoomya Saenna, Sub-Engineer, is the only person who could compare this sea with that raised by the south-west monsoon at Kurrachee. He considers the waves were not higher, but the succession of them was more rapid. The maximum height measured at Kurrachee was 15 feet. Mr. Chisholm estimated about the same height for the late storm at Madras,* and at both places independent testimony fixed the depth of solid water passing over the breakwaters at about 20 feet.

“Mr. Thorogood did not consider this sea to be so heavy to all appearance as those he had witnessed at the mouth of the Tyne, and he is

* Other estimates give 30 feet, but I do not put any faith on such estimates made by unskilled persons, either in respect of this or any other storm with which they may be compared.

confirmed by Mr. Underdown, the Foreman Diver, who was also engaged on the Tyne works.

“I do not consider however that these comparisons are of much value. I have given them because they are sure to be made by others if not by myself, but my own experience is that the appearance of the sea gives very little indication of its real force.

“*Effects of sea on foundations.*—When we come to compare results however we are led to a more definite conclusion. The best test for practical purposes of the force of sea is its power of undermining foundations. It is proved by the general practice of Engineers at home that a depth of 15 feet below low water is safe. At Alderney, where there is evidence of a power of sea greater in some respects than at any place I know, foundations at that depth have never been disturbed. At Wick, where a mass of concrete and masonry of 2,500 tons was moved bodily by the sea, and the height of the waves was estimated at 42 feet, foundations at 18 feet depth were untouched, and no action was found below 10 feet. The deepest foundations I have ever heard of as being undermined were 11 feet below low water at the Tyne, but at Madras the walls were in two places for a short length *undermined at 22 feet below low water.**

“This is an effect I should never have anticipated, and I can now only account for it by the supposition that there is some peculiarity in the cyclone-raised disturbance to which the apparently heavier seas on the English coast have nothing analogous. There is nothing improbable in the supposition of a difference in the effects produced on the underlying water by a very intense action within a limited area, and by a long continued surface friction over a large space. It is true that the North Atlantic storms are cyclonic in their movements, but the movements extend over a larger area, and have a less intensity, than those in the Bay of Bengal.

“But however this may be, it is certain that the 8 feet extra depth of foundation which I allowed, more for the sake of convenience and economy than for that of security, was really required for the latter purpose. Though the damage actually resulting from undermining on this occasion was not great, the whole length of the eastern face of the piers was *threatened* and a rather heavier sea would have produced a serious amount of damage of a different kind from that which actually was produced. The most important lesson taught by this storm is that *foundations at a depth of 22 feet under water are not proof against a cyclone sea.*

“*Effects of sea on superstructure.*—The great bulk of the damage however is of a totally different kind, and is due to the direct force of the waves on the superstructure. The results produced are precisely what

* It is of course well known that wave action extends and even moves rubble stone to a much greater depth than this, but the instances of such action have little bearing on practical engineering questions.

might have been anticipated on a work of insufficient strength. The impact of the sea was delivered to all appearance just where it was expected, but it was stronger than any we had previously experienced on this description of work, and required a greater resistance than we had provided. The lesson has been very dearly bought, but it is precisely the same kind of lesson that has been taught in almost every case where works have been undertaken exposed to a sea of unknown force. It is only when a sea of nearly maximum force has been experienced that the final precautions are shown to be necessary.

“ I believe the damage produced by this storm on the Madras Harbour Works, the general nature of which is shown on the accompanying sketch, is greater in its extent than that of any similar disaster on record, but it must not be concluded that this is due to an unusual degree of weakness in the work. It is due rather to the fact that at Madras the maximum force of sea is not, as is practically the case on the coasts where most of our experience has been gained, an event of almost annual occurrence, but it occurs only at intervals of several years, and in one such interval of more than usual duration a great extent of work had been completed, and was therefore exposed at once to the previously unknown destructive action of a sea of nearly maximum force.

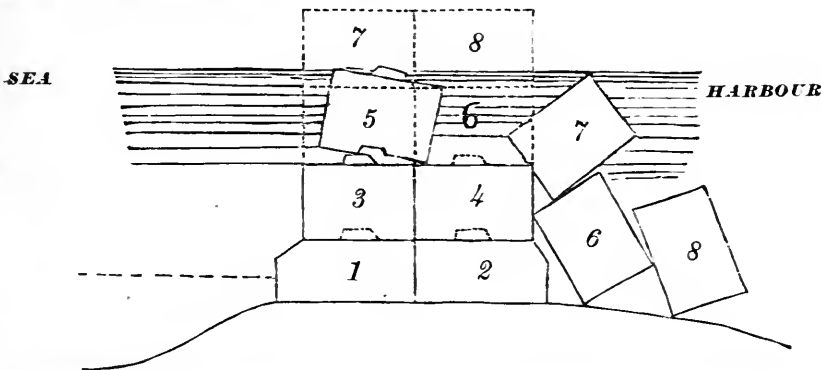
“ The design of the work as executed at Madras was the result of a careful investigation into the causes of damage to previously executed works. Much material that appeared to be superfluous in them was dispensed with, but additional strength was given to the parts that were retained. The latest additions to the section were based on the experience gained at Kurrachee. At that place the first heavy sea showed where the greatest impact of the waves fell, and that part was strengthened in a way that has been quite successful in a subsequent experience of nine years at Kurrachee, and for five years was successful at Madras, but it failed under a sea of greater force than had previously been experienced at either place. To prevent a recurrence of the damage additional strength must be given to the vulnerable part. But it must be understood that all such precautions are necessarily tentative as to their sufficiency. We may feel confident as to their being right in principle, but the force of the sea cannot be estimated in figures, and we are unable to say, when a work has stood successfully, what margin of stability it possessed, or when it has failed, by how much the destructive force was in excess of its stability. The strength of an iron girder or the capacity of a water channel may be definitely calculated in figures, but the stability of a sea barrier is a question to be decided by precedent, guided by judgment and experience.

“ The experience gained at Kurrachee was to the effect that the heaviest blow of the sea was delivered on the tops of the blocks on the harbour side of the breakwater, tending to drive them out from the wall into the harbour. Several blocks were forced out in this way, but in no case was

any block forced to seaward. The tendency was met by inserting a stone joggle which locked the top course to the course below, and prevented it from sliding. This precaution was quite successful at Kurrachee, and a contrivance for effecting the same object having been from the first adopted at Madras, the tendency was so completely met that no evidence of its existence was given by the action of the seas which preceded that of the 12th November last.

"A knowledge of this tendency, however, forms a clue to enable us to trace the process of destruction of the Madras piers. The waves rising upon the sea face must have as fallen with terrific force upon the top of the work on the harbour side, and the blocks were tilted off, probably two courses, and possibly, in some cases, three courses, being displaced at once. The sea wall then standing alone yielded to the lateral force of the waves, and generally one course, but sometimes two, and in one or two cases even three courses were driven after the blocks of the harbour wall. Generally speaking there is a course more remaining on the sea side than on the harbour side.

"The following may be taken as a typical section of very much of the work in its present state. Parts of it

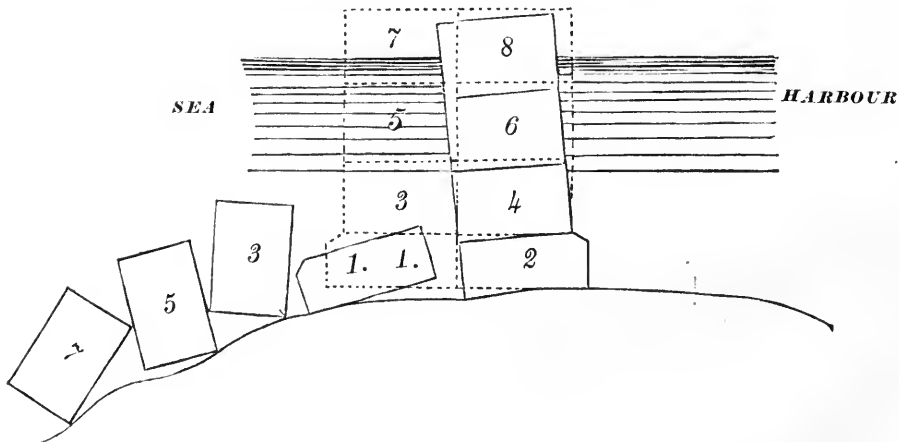


are necessarily hypothetical, but there is enough which is matter of actual observation to justify the assumption of the remainder. For a length of at least two-thirds of the damaged parts blocks 1 and 3 have been traced by the divers and found with slight exceptions to be undisturbed. For the greater part of this length block 5 may be traced from the surface and sometimes from below, generally more or less disturbed somewhat in the way shown. No. 7 is in some cases in its place, but it is then generally tilted by riding on the tenon on the top of No. 5; 6, generally 7, and 8 are represented by an apparently confused heap of blocks which effectually prevent access to 2 and 4. There is, however, sufficient evidence direct and indirect to negative the very improbable supposition of these having been undermined and thus caused the fall of the inner wall towards the harbour. This evidence is, first, that where the inner slope of the rubble is

unencumbered with blocks it is found to be practically unchanged; second, where the sea wall is gone and the harbour wall standing, as is the case for a short length in each pier, the harbour wall leans over to seaward; third, at the spot at which, if anywhere, scour under the harbour wall might be expected, viz., at the extreme end of the north pier, the rubble is 4 feet above the foundations, and the wall is standing exceptionally well, the blocks corresponding to No. 6 being in place. There can therefore be, I think, no doubt that the failure began with No. 8 block, or more probably 6 and 8 together, and worked downwards and towards the harbour. The rubble foreshore on the sea side however presents a marked contrast to that on the harbour side. It is almost everywhere drawn away from the wall and lowered sometimes below the level of the foundation blocks.

“The above description may be taken as a generalization of the effects produced upon about two-thirds of the damaged parts. It comprises the outer portions of the two piers, a length of 1,200 feet of the north and 900 feet of the south pier. The remaining third, comprising 400 feet of the north and 500 feet of the south pier, have been differently affected and the investigation is more difficult, as the blocks are thrown down on both sides of the piers, and a precise examination of the portions which remain standing is for the most part impracticable.

“There is, however, one portion of the north pier, just at the commencement of the curve, which is accessible to the diver, and has been carefully examined. The following section, made from his description, will very clearly exhibit the action to which it has been subjected. In this case the harbour wall is standing, though considerably damaged.



No. 1 block is drawn out to seaward 4 feet from its original position, and its inner end is lifted 9 inches from the rubble bed, the block itself being tilted towards the sea. The upper blocks are lying in confusion on

the sea slope of the rubble. I do not see how it is possible to attribute these results to any other action than undermining of the foundation blocks. The portion of the pier where this is evident is a length of something under 100 feet, but it is probable that whenever the upper blocks have fallen to seaward it is due to the same cause, although the foundation blocks themselves are inaccessible. The action of the sea appears to have been exceptionally severe at this spot, for the original sandy bottom is scoured away 6 or 7 feet outside the rubble.

“There is a portion of the south pier, also on the curve, which appears to have been acted upon in a very similar manner. At these two places the breakwaters form about the same angle, one on the right and the other on the left, with the prevailing line of the waves, and here the scouring action on the bottom appears to have been more violent than where the waves fell more directly on the face of the work.

“*Remedies.*—The whole of the actual damage to the works is due to one or other of the above causes, and I think that if the original section were amended so as to give increased strength to the two weak places shown to exist, every confidence might be placed in its stability under even a much heavier sea than the recent one. The section as carried out was a perfectly good one to withstand a moderate sea, and the effects of the heavier sea show no grounds for any radical alteration. Such material as there was good in quality and properly disposed, but there was not enough of it; or perhaps it would be more correct to say the principles of the design were good, but not carried far enough. There is not the slightest justification for re-opening the worn-out questions of the relative merits of random and placed blocks, or of bonded and unbonded work. Breakwaters of random blocks or of bonded masonry might have stood if very much more massive than those which have partially failed, but their security would have been due to their greater massiveness, not to the different principles of their construction.

“*Quality of materials.*—I have said that the materials were good. I am aware that a great deal has been said about the unsuitableness of laterite for the rubble base, and some doubts have been expressed about the quality of the concrete owing to many of the blocks having been broken. Now laterite is undoubtedly a *troublesome* material, and I am glad to think that no more of it will be required, but there is not the slightest ground for thinking that it contributed in any way to the late disaster. The trouble it occasions is that, being friable, it is very quickly compressed by the weight of the blocks laid upon it, so that to allow for subsidence the latter have to be set a higher level than is ultimately required. This is troublesome in execution, and it has the still greater evil of subjecting the blocks to excessive and irregular strains in the process of subsidence, in consequence of which many were broken. But when once consolidated, the laterite forms as good a bed as the granite rubble. This is proved by the comparison of the amount of settlement of the standing portions of the two.

piers, one being built on laterite and the other on granite. There is no appreciable difference between the two. It is right to add that the laterite was used, not from choice, but because it was not practicable to obtain the granite rubble in sufficient quantity to carry on the work at the speed for which all other parts of the work were organized. It would of course have been right to sacrifice speed of execution if ultimate stability were endangered, but after full consideration it was decided that this was not the case.

“Breaking of blocks.—The breaking of the blocks is undoubtedly a blemish, and though it occurred over both the granite and laterite bases, it occurred, I have no doubt, more over the latter for the reason I have given above, though it is impossible to determine the proportions accurately. The evil, however, is really greater in appearance than in reality, for the force which broke the blocks at the same time jammed them so closely together that the broken pieces are really as effective for the stability of the work as many unbroken blocks which have not been subjected to the same amount of pressure. I doubt whether it would have been possible by any means entirely to prevent these breakages, but the number would have been reduced if it had been possible to keep the blocks longer before subjecting them to these severe strains. Be this as it may, however, the concrete is undoubtedly of excellent quality, as even the fractured surfaces of the broken blocks show. In the restoration of the work, as I shall presently point out, this evil will not recur. But so far there is no evidence to show that these breakages have contributed in any way to the failure of the work.

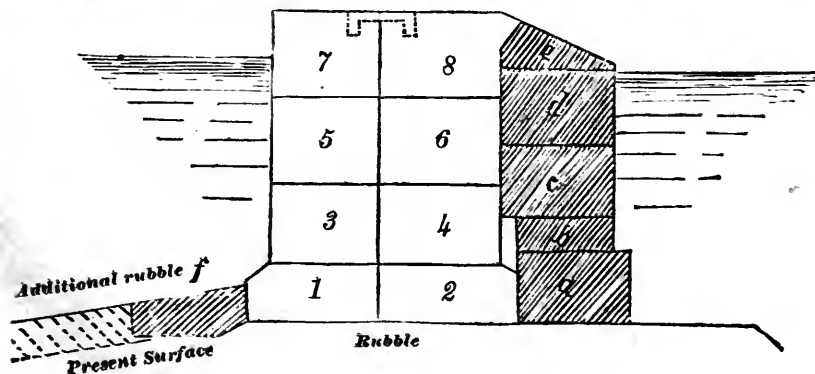
“Subsidence.—Another point which has given rise to a good deal of remark is the subsidence of the structure, but in this I can see no evidence of weakness. It is quite certain that a rubble bank 20 feet high must consolidate under the weight of 30 feet of concrete, and it is equally certain that the effect of agitation of the water must be to cause the rubble to sink into the sandy bottom, but beyond involving the necessity of adding to the top if it sinks below the required level, there is really no harm done. We have the experience of years to show that subsidence does not involve loosening of the superstructure, but rather the contrary, while the sinking of the foundation to a still lower level is a substantial advantage. The portions of the piers standing entire have settled under the action of the storm about 9 inches at their outer ends, gradually diminishing to nothing near the shore, the amount of sinking being inversely proportioned to the length of time since they were built. The damaged portions, which of course are newer, have sunk about 2 feet, as far as can be ascertained. There may probably be a further subsidence, though its rate will decrease as time goes on, but it is, I repeat, a perfectly harmless process. The above are the settlements due to this particular storm. There had been previous settlements due mainly to the natural consolidation of the rubble base, generally amounting in the aggregate to from 2 to 3 feet, the maximum

being near the south pier head, where it was 4 feet. The further settlement due to the storm is probably caused by subsidence into the sandy bottom.

Reconstruction.—In the scheme for reconstruction, then, we have especially to keep in view the two weak points, the foot of the outer wall and the top of the harbour wall. The required object may be attained either by breaking the force of the waves before they reach the weak points or by giving additional strength to the weak points themselves. The former principle has received full consideration. It appeared at first sight that the remains of the original piers would form a good outer barrier under shelter of which a new pier would be safe from damage. But further examination was not favourable to this idea. The shelter it would give in its present state is too irregular. In some parts it might be fairly-efficient, but in others it would allow the sea to pass over it on to the new work with increased violence. To prevent this such places would have to be made up with new material, and this would lead to a serious amount of work, and I think a not very satisfactory result. Besides which there is a considerable proportion of the old work remaining, and the rubble base especially having been well consolidated would offer a better foundation than a new one, especially in not being liable to the immediate settlement which caused the fracture of the blocks. Two out of the four courses of blocks are also for the most part in a good state, and an uncertain proportion of the displaced blocks may be recovered and used again.

Preference was therefore given to the principle of rebuilding the piers on their original foundations, and making such additions as experience shows to be necessary. The one great objection to this is the immense difficulty of clearing the ground of fallen blocks. The magnitude of this difficulty can hardly be realised without inspection of the ruins. It will undoubtedly be a slow and costly operation, but all who are concerned in it are satisfied of its practicability, and the difficulty being simply a mechanical one, we may safely conclude that it will diminish with practice and experience.

"I propose, therefore, that the work be rebuilt on the former lines and to the former section, but with the additions shown shaded on the accompanying sketch, to give increased strength to the two weak points.



The rubble base and blocks 1, 2, 3, and 4 are generally in a serviceable state. 5, 6, 7, and 8 are new blocks similar to the old ones, except that they will be 9 feet high instead of 8 feet, so as to make up for the 2 feet of subsidence. *a*, *c*, and *d* being of the same dimensions as the old blocks, the latter can be used so far as available; *b* is a thin block inserted for the purpose of bringing the top of *d* above water level, so that *e* may be set upon it in a bed of cement, thus making *d* and *e* together into one block of 36 tons weight. The top of *e* is sloped off to give an escape for the falling wave. If it were level like the top of 8, the effect would be simply to transfer the vulnerable point from the top of 8 to the top of *e*, as is shown by the fact that at the pier heads where the structure was increased to three and four blocks in width the one next the harbour still gave way.

“Block *f* is intended to protect the toe of the outer wall from scour and ultimate undermining. It should be placed at as low a level as practicable, so as to avoid encroaching on the profile formed by the sea itself. It is a noticeable feature in the cross sections of the damaged parts of the piers that a scanty slope of rubble and severe damage to the superstructure do not go together. On the contrary, where the sea wall was actually undermined at the south pier, and the nearest approach to a clean breach was made, the rubble base happened to be particularly full. The evidence is at present not more than negative, but it is to the effect that a full foreshore is not an element of strength. The object of the footing, therefore, is simply to substitute a surface of concrete for one of loose rubble, preserving as nearly as possible the level and slope which the sea has formed. From the outer end of the block the slope will be continued in rubble. It may probably be desirable where the blocks are fallen to seaward not to disturb them, but rather add some more so as to make protective mounds of random blocks at those places.

“Besides these actual additions to the section I propose to introduce two extra securities into the top course of the old section. It has always been an object, though hitherto unattainable, to connect the top blocks together, both longitudinally and transversely, so as to make all the portion of the section which is out of water into a monolithic mass; but it is impossible to do this in new work efficiently in consequence of the settlement to which the structure is liable. An unequal settlement would sever any attachments we could apply. Now, however, in rebuilding on an old foundation this difficulty will be much diminished. What settlement does occur will be more uniform, and slight inequalities in it may even be prevented by the adherence of the attachments. It is proposed, therefore, so to make the cross joints of the top blocks that they may be filled with cement, not during the progress of building, but on a suitable opportunity afterwards. It is also proposed to connect the two top blocks by an iron cramp made of a bent, worn-out rail with the ends turned down and cemented into the blocks. Thus each longitudinal row of blocks will become, so far as the cemented joints can

be depended on, a monolith, and the two monoliths will be tied together at intervals of $4\frac{1}{2}$ feet. It cannot be anticipated that the monoliths will be absolutely continuous. Some of the cement joints will separate, but the majority will hold together, and the top of the breakwater will consist of much larger masses than hitherto, which will lend support to one another in a way that the detached blocks could not do.

“The section thus modified would have the following additional elements of stability over the old section :—First, it would have 50 per cent. greater width as a whole. Second, the vulnerable block No. 8 would be supported (a) by a buttress one-third heavier than itself, (b) by a tie to block No. 7, (c) by its longitudinal continuity afforded by the cemented joints. Third, the toe of the sea wall would be protected from undermining by an apron of concrete blocks. I must repeat that it is impossible to show the sufficiency of this by figures, as the force of sea is an indeterminable quantity. But I think it quite outside the limits of reasonable probability that we shall have to encounter a force of sea so much greater than that of the late storm, as the strength of the new section would be greater than that of the old.

“*Uninjured portions.*—I do not propose that the additions to the section should be applied to the portions of the piers which have stood uninjured. They have shown no sign of weakness beyond some scouring away of the foreshores at the foot of the sea walls. These should be fed with some heavy granite boulders. It would be desirable, however, now that the block work has settled down to a solid bearing, to tie the top blocks together with iron cramps in the same way as described for the new work. This would give additional resistance to block No. 8 in the event of the next heavy sea coming from a point more northerly or more southerly than the last, and the cost would be small, as there are a great number of rails which are of no value for any other purpose.

“There is one further additional security which I would propose to apply to the curved portions of both piers. These have a special element of weakness in the fact that if there should be any leaning over to seaward, the upper course of blocks would open out like a fan. The late storm showed that there is a greater scouring force on the foreshore of the curves than elsewhere. I hope undermining from this cause will be effectually prevented by the precautions above recommended, but I would propose, as an additional precaution for the support of the superstructure, to form a groove longitudinally along the top of the sea wall about 12 inches deep all round the curves, in which a strong chain cable will be laid, strained up tight and then buried in concrete. The whole curve would thus be bound together.

“I would beg to call attention to the fact that each one of the additions I have recommended is intended to meet some weak point disclosed by the

action of the sea upon the work. I have made no attempt to meet theoretical objections that are not supported by the special experience of this particular occasion. My object has been to preserve what experience has shown to be good in the work, as well as to supplement what was shown to be insufficient, and I submit that it is by this process rather than by radical changes of plan, which would involve much experimental work, that ultimate success will be best assured."

He estimated the total additional cost at between $15\frac{1}{2}$ and $18\frac{1}{4}$ lakhs. He then went on to show the advantage and accommodation afforded by the harbour even in its ruined state, and concluded with the following interesting paragraphs:—

"The experience gained since the harbour piers approached completion is to the effect that the entrance facing the eastward admits an amount of swell (particularly with easterly seas, which are more frequent than was supposed) which will render it desirable so to arrange the berthing of ships that they may lie with their heads towards the incoming swell, instead of towards the prevailing winds as had been at first intended. For the great majority of days in the year this can be done without difficulty, but there are occasions (about 25 to 30 days as estimated by the officers of the Marine Department) when a ship cannot lie with her broadside directly or even obliquely exposed to the wind. On such occasions it becomes necessary to cast off the stern moorings and allow her head to swing to the wind. As the ship will then roll to the swell, landing and shipping cargoes will be more difficult, and sometimes even prevented. With a strong wind from one direction, and a heavy swell from another, the ship would roll very uneasily, and though it might be only in extreme cases that she would be in actual danger, such danger could only be avoided by sending her to sea. This in itself is no unforeseen contingency, but it is now suggested that there would be a difficulty in getting a ship clear from such an uneasy berth as that just described while subject to the combined influence of wind and swell. This difficulty could only be avoided by an earlier anticipation of the danger, and by taking the ship out of the harbour at an earlier period of threatening bad weather.

"The officers of the Marine Department are of opinion that this evil can only be effectually cured by closing the present easterly entrance and making an opening facing southwards in the south pier. If I do not enter into the merits of this proposal, it is not because I question the reality of the evil, but because I think it premature to discuss a question upon which no practical action could in any case be taken for the three or four years that will be required for the restoration of the damaged portions of the piers. During those three or four years the harbour will be in daily use, and the bearing of this one particular evil upon the whole question of the development of the advantages afforded by the harbour will be more easily seen.

It is not a question of a harbour or no harbour, but of a harbour affording a greater or less degree of shelter, and the value of the increased shelter will be more precisely ascertained by the experience of actual work. The proposal may then be put forward (if its desirability be confirmed by experience) as one giving an advantage directly comparable with the cost.

“So far as carrying out the alteration is concerned, nothing would be gained by an immediate decision, nor do I think, even if the idea had been entertained from the beginning, any materially cheaper plan could have been devised—certainly none more expeditious—than that of advancing both piers to near their meeting point, using the interval between them as a temporary entrance, and then making the final opening in such a position as might appear most desirable by drawing back one of the Titans, removing the necessary length of blocks, and dredging away the rubble. The materials, of course, could be used for the final closing of the original entrance, which would be carried on by the other Titan from the side opposite to that in which the new opening would have been made. This process will still be available if the alteration be ultimately determined on.”

Last comes the report of a Committee consisting of Sir John Hawkshaw, F.R.S., Sir John Coode, and Professor Stokes, appointed by the Secretary of State for India to consider the whole matter. This report is reprinted *in extenso*.

Report of first Home Committee.

Madras Harbour.

“On the 8th July last we had the honor to receive a communication from Lord Enfield referring to serious damage to the works of the Madras Harbour by a severe cyclone which had occurred in the preceding autumn, and informing us that certain proposals having been made for restoring the works, the Secretary of State for India was desirous that the subject should be investigated by competent professional authorities in this country, and that Lord Hartington had decided to appoint a Committee for the purpose, and proposed that we should constitute that Committee.

“Lord Enfield’s letter is given in the appendix, and having consented to act under its instructions and provisions, we have now to report our proceedings, and the conclusions at which we have arrived.

“The following documents have been forwarded to us, and have had our consideration, viz. :—

Report by Guilford L. Molesworth, Consulting Engineer to the Government of India for State Railways, to the Secretary of the Government of India, “Public Works Department,” dated Calcutta, 1st March 1882.

Report by A. W. Stiffe, Port Officer of Calcutta, to the Secretary of the Government of India, “Public Works Department,” dated Calcutta, 13th March 1882.

Note by Colonel R. H. Sankey, R.E., Chief Engineer of Government of Madras, "Public Works Department, Buildings and Roads, Civil Works," dated 23rd March 1882.

Report by William Parkes, Engineer-in-Chief of Madras Harbour Works, to the Secretary of the Government, "Public Works Department," dated Madras, 9th March 1882.

Note by Colonel R. H. Sankey, R.E., referring to and accompanied by sections of Pier, dated 26th July 1882, and by an extract from the Proceedings of the Madras Government, "Public Works Department."

Government of Madras, "Public Works Department." Papers, numbered 33, 34, 72, and 73. Remarks on correspondence on the comparison of the storms of 1872 and 1881 by William Parkes.

Letters from D. E. Dalrymple, late Master Attendant, Madras, and Chief of the Marine Department, Madras Presidency, dated July 11th and August 24th, 1882.

"In the course of our inquiry we have been in frequent communication with Mr. Parkes, the Engineer-in-Chief of the Harbour Works, who has from time to time supplied us with documents and information explanatory of the state of the works and of his views of methods and cost of restoration. We have also had interviews with Mr. Thorowgood, the Resident Engineer of the works.

"We thought it desirable to request Mr. Dalrymple, to whose letters we have referred, to attend one of our meetings and to afford us such further information as he thought proper on the statements in those letters, and we have had the benefit of his explanations and opinions.

"We have also taken advantage of Mr. Guilford Molesworth's visit to England to obtain his views on several matters.

"A question raised in the correspondence is, whether the cyclonic storm of 1872 or that of 12th November 1881 was the stronger, and on this point the evidence of boatmen and others is adduced, and contradictory statements are made. Mr. Chisholm is of opinion that the waves of the storm of November 1881 were more formidable than those of the storm which passed over Madras in 1872. Lieutenant Taylor expresses an opinion that the attack upon the works by the storm of November 1881 was a mild one. In the absence of accurate means of measurement there is nothing on which greater diversity of opinion is more likely to arise than on the intensity of storms. It would be useful to know, could any one tell whether the storm of November 1881 was the most severe the Harbour Works can ever be subjected to, but this is information that cannot be obtained. The facts we have as regards the storm of November 1881 are its effects on the Harbour Works, and though we can have no doubt the storm was a very severe one, it will be safer in considering the question referred to us to assume that neither the storm of 1872 nor that of 1881 was necessarily a maximum one.

as the period of nine years within which both occurred is too short an interval to justify such a conclusion.

“In all estimates of the intensity of storms, it should be observed that long waves, more of the nature of heavy ground swells, may severely try Harbour Works, and that such waves are compatible with the absence of strong winds at the place itself and with comparative smoothness in the offing.

“The present condition of the piers, and the damage they sustained by the cyclone, have been fully described in the reports before us. Generally, we may say that, from the shore ends to the commencement of the elbows, the walls are standing, but, from the commencement of the elbows outward, they are so far destroyed as to render it necessary to reconstruct them.

“In considering proposals for restoring and strengthening the Harbour Works, questions naturally arose whether any portion of the damage done could be attributed to the mode of construction, or whether it arose entirely from the dimensions and mass of the piers being insufficient.

“The method adopted of building the piers was to form a rubble mound, on which the walls were built, and though we do not concur in Mr. Parkes' view as to the depths below which wave action in engineering works may be disregarded, for those depths must have relation to the magnitude and character of the waves and the weight and size of the material acted upon, yet, having regard to the magnitude of the seas then contemplated, the walls were founded sufficiently deep below low water, and the general outline of the design was not inappropriate, but there appears to have been difficulty in procuring suitable material for the rubble mound. Mr. Molesworth states that the size of the stones of which the rubble base is composed varies from 5 lb. to 2 cwt., which is small for the purpose, especially where laterite is used, which varies much in quality and is sometimes so soft as to be easily still further reduced in size by the slightest movement.

“The superstructure of the piers was not built of one bonded mass, but consisted of two parallel walls placed side by side in juxtaposition, having a vertical joint between them; and from the portion of the walls on the Harbour side of the piers having in places fallen away from the portion on the outer or sea side, it seems probable that the pressure of water in the joints led in great measure to this result. The oscillation of the two halves of the wall, also caused by the want of bond and the consequent opening and closing of the vertical joint referred to in Mr. Molesworth's report, must be remedied, as it may in time prove mischievous. No doubt the method of building adopted by Mr. Parkes conduced to rapidity of construction, but were the work to be begun again, we could not recommend this method, but should prefer the work being bonded throughout.

“ Though of this opinion, we do not wish it to be inferred that the walls if bonded would have proved strong enough to have withstood the storm to which they were exposed. To make the piers secure against severe gales, it will be necessary to add materially to their strength of resistance, and having regard to the magnitude of the waves which roll into Madras roads and overtop the walls, the piers should be raised to a higher level than that hitherto contemplated. They were originally built by Mr. Parkes to an average height of about six feet four inches above high-water mark before settlement, but we are of opinion they should be raised so that their finished level shall not be less than twelve feet above high-water mark. This will add to the security of vessels within the Harbour in rough weather, and will greatly strengthen the work, as we propose the piers should be raised to this extra height by adding a monolithic capping of concrete in mass which, aided by iron cramps to be inserted in the upper courses of blockwork, will help to secure and hold together the concrete blocks in the wall beneath, and tend to remedy the want of bond we have before referred to.

“ The works we recommend, and have had under consideration, will be understood from the accompanying drawings, Nos. 1 and 2, to which we beg to refer, and which consist of—

A plan of the Harbour, Drawing No. 1.

Five cross-sections of the piers, numbered respectively 1, 2, 3, 4, and 5, Drawing No. 2.

The portions of the piers to which the cross-sections apply will be seen by reference to the drawings.

CROSS-SECTION No. 1 will be applicable to the shore ends of the piers, from their commencement to the point A in the case of the north pier, and to the point D in the case of the south pier, being a length of 400 feet and 650 feet respectively.

CROSS-SECTION No. 2 will be applicable to both piers, viz., from A to B on the north pier, being a length of 1,800 feet, and from D to E on the south pier, being a length of 1,750 feet.

CROSS-SECTION No. 3 will be applicable to both piers, viz., from B to C on the north pier, being a length of 1,600 feet, and from E to F on the south pier, being a length of 1,520 feet.

CROSS-SECTION No. 4 is an alternative to Cross-section No. 3, and would be applicable under the conditions hereafter explained.

CROSS-SECTION No. 5 shows a method of reconstruction by adopting random concrete blocks.

“ For the landward portion of the piers, the works we recommend to be undertaken (shown on Cross-section No. 1), consist of cramping each pair of blocks in the upper course, and the addition of a mass of concrete carried up to 12 feet above high-water spring tides, the level to which we consider it necessary to raise the piers throughout their entire length. This mass of

MADRAS HARBOUR.

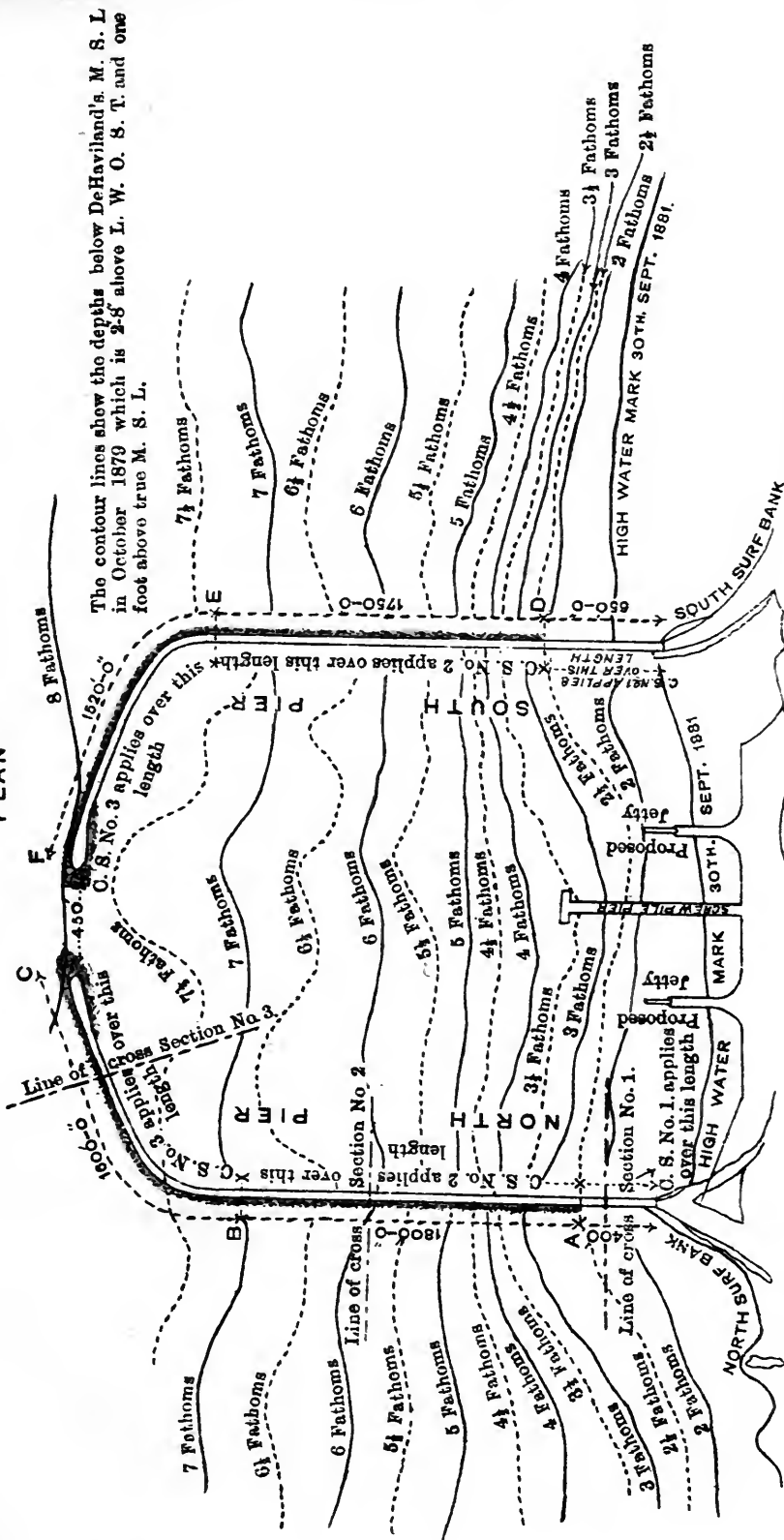
PROPOSED WORKS OF RE-CONSTRUCTION.

OLD WORK IS SHOWN IN BLACK, NEW IN RED.

to accompany the Report of SIR JOHN HAWKSHAW, SIR JOHN COODE, & PROFESSOR STOKES.

Dated 23rd January 1883.

PLAN



The contour lines show the depths below DeHaviland's M. S. L. in October 1879 which is 2-8 above L. W. O. S. T. and one foot above true M. S. L.

Scale for Plan



THE UNIVERSITY OF CHICAGO
DIVISION OF THE PHYSICAL SCIENCES
DEPARTMENT OF CHEMISTRY
5708 SOUTH CAMPUS DRIVE
CHICAGO, ILLINOIS 60637

RECEIVED
MAY 15 1964

TO THE DIRECTOR
FROM THE DEPARTMENT OF CHEMISTRY
RE: [Illegible]

[Illegible text]

[Illegible text]

MADRAS HARBOUR.

DRAWING NO. 2

PROPOSED WORKS OF RE-CONSTRUCTION.

SHEET NO. 1

OLD WORK IS SHOWN IN BLACK, NEW WORK IN RED.

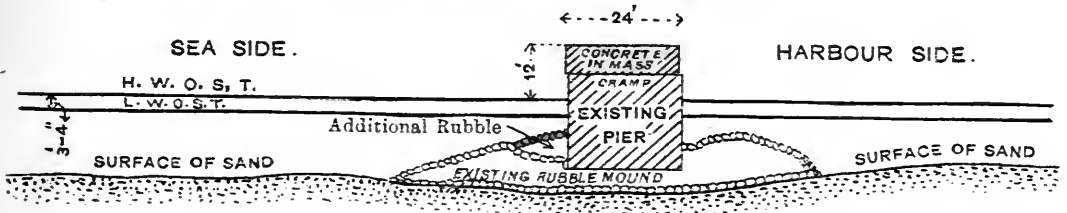
to accompany the Report of

SIR JOHN HAWKSHAW, SIR JOHN COODE, & PROFESSOR STOKES.

Dated 23rd January 1883.

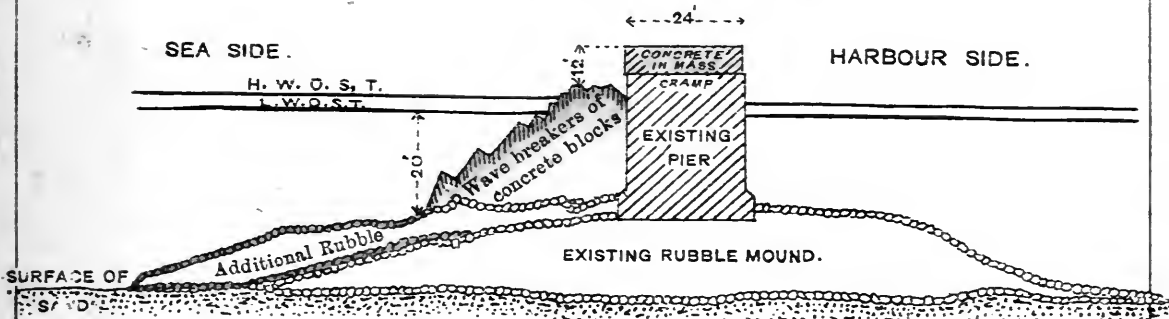
CROSS SECTION NO. 1.

This Section applies from shore to A. North Pier.
Do---Do.....Do---Do----- to D. South Pier.



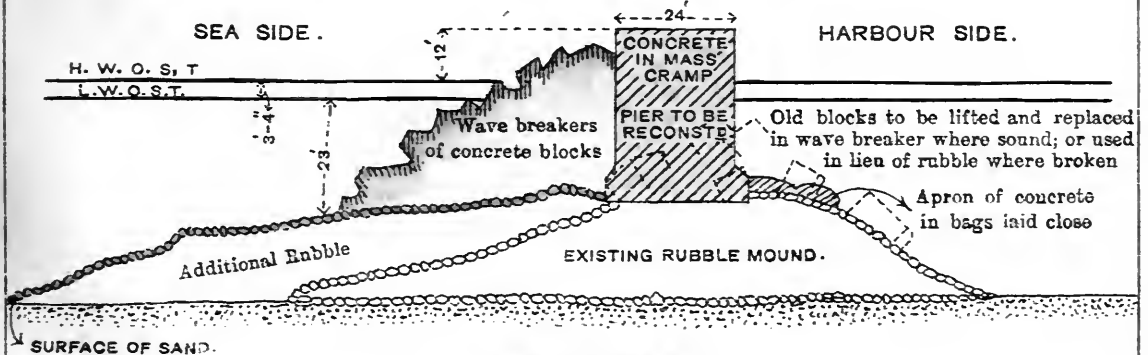
CROSS SECTION NO. 2.

This Section applies from A to B. North Pier.
Do---Do--- Do---Do---D to E. South Pier.

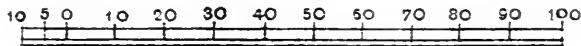


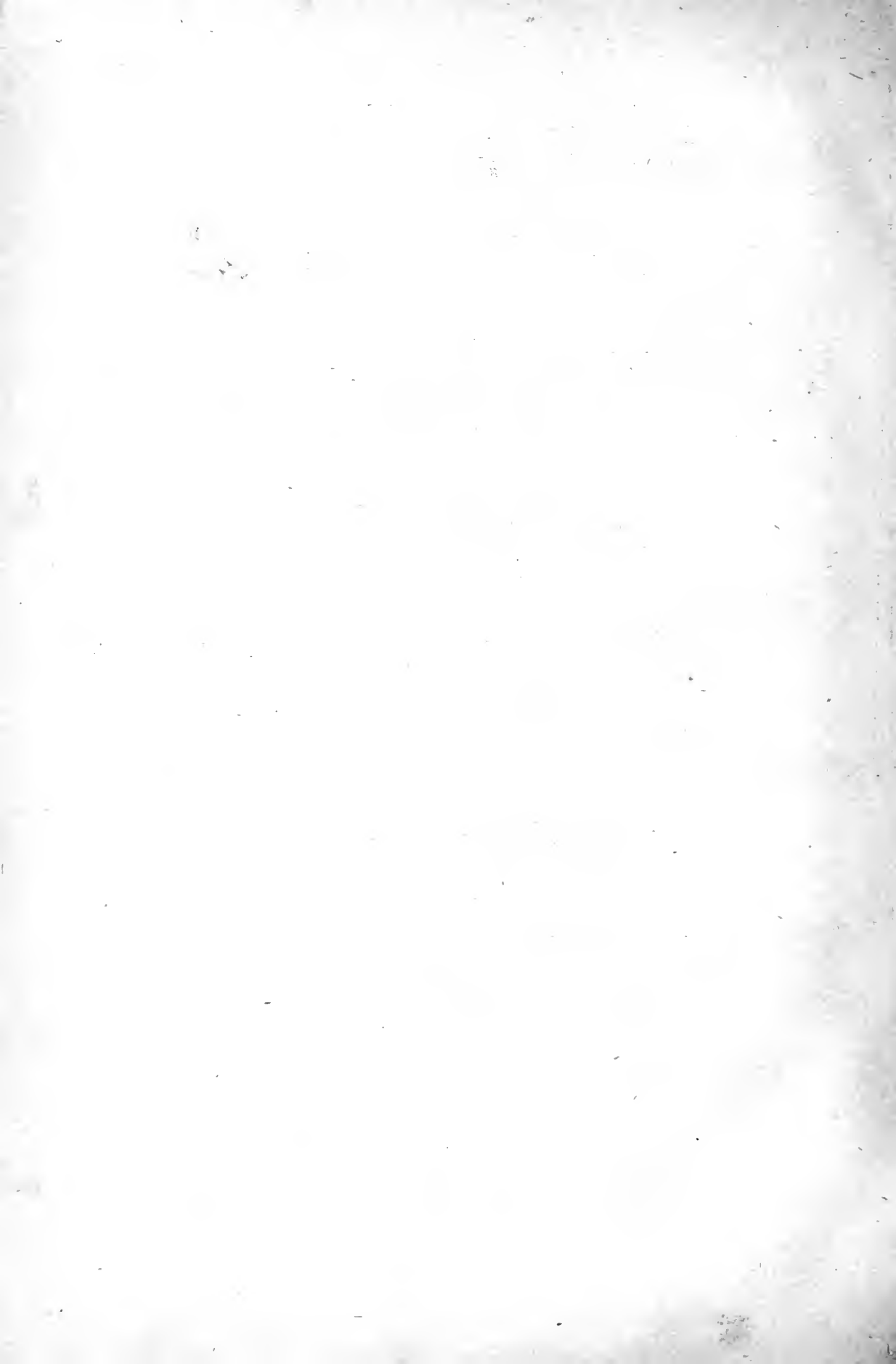
CROSS SECTION NO. 3.

This Section applies from B to C. North Pier.
Do---Do--- Do---Do---E to F. South Pier.



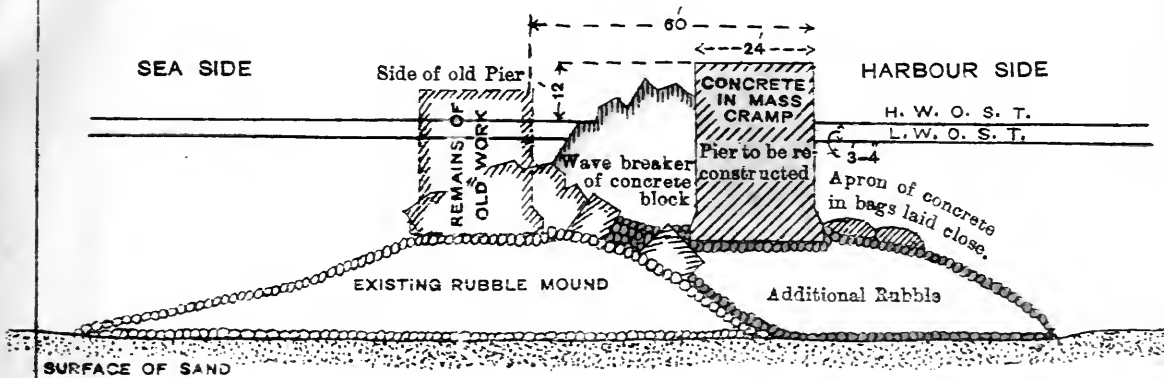
Scale 1 Inch = 40 Ft.



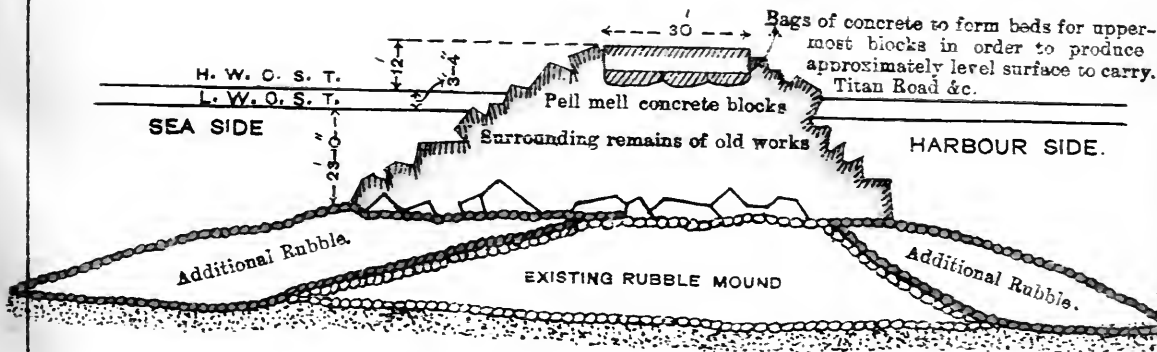


CROSS SECTION NO. 4.

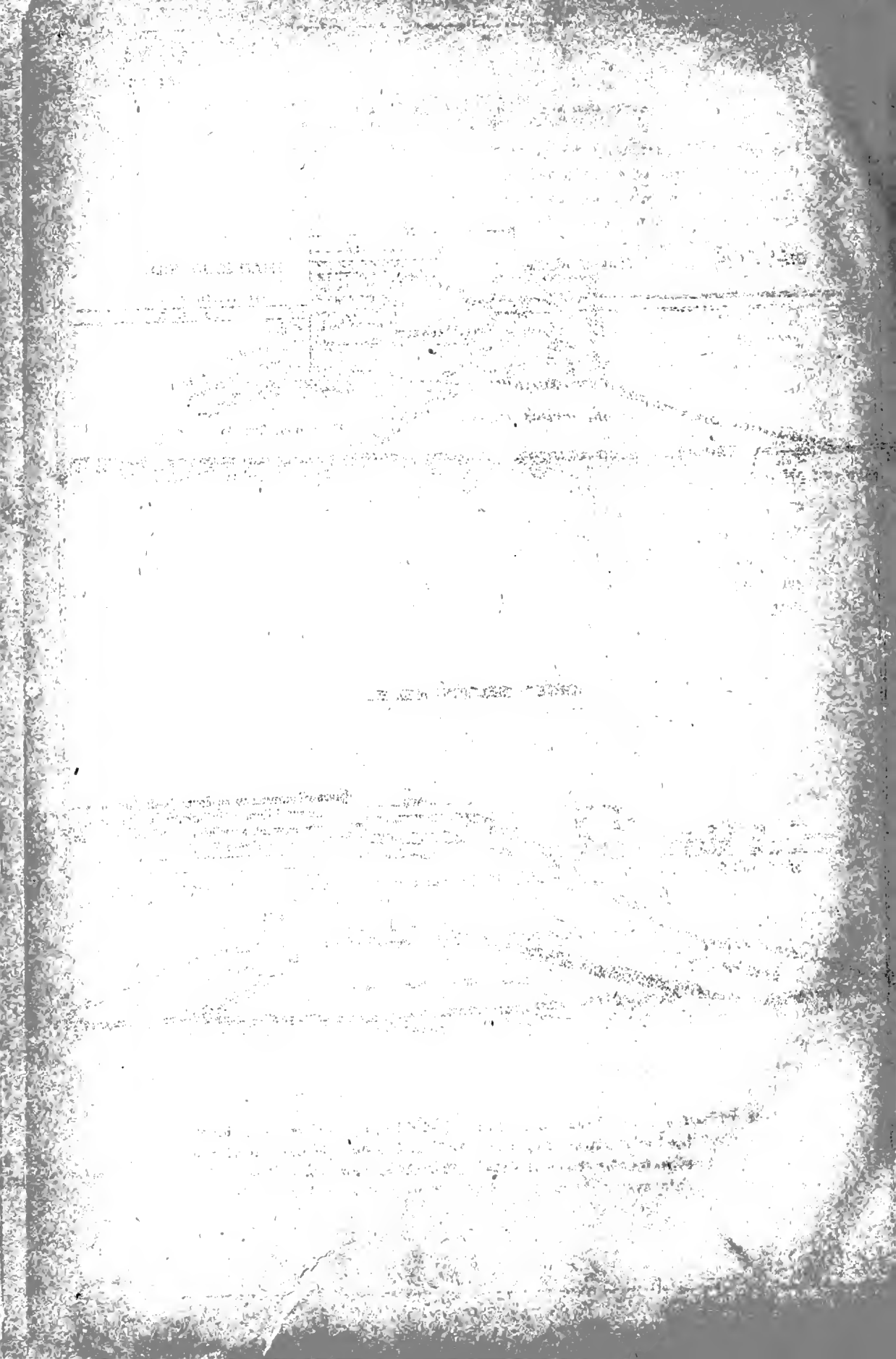
This Section is as an alternative to Fig. 3.



CROSS SECTION NO. 5.



NOTE —The joints of each inclined slice (4-6 thick) of the piers are to break bond to an extent of at least 4 Feet, and are also to break bond to a corresponding extent with the joints of the adjoining slice.



concrete and the cramping will prevent the oscillation of the two halves of the wall, and are necessary to remedy the want of bond we have referred to. We have not shown wave-breakers along the landward portion of the piers, but the rubble mounds should be carefully examined, and, where requisite, made good by gneiss rubble of large size, or by concrete blocks.

“For the next length of the piers, extending to the elbows, in addition to the cramping and the top mass of concrete, a wave-breaker, shown on Cross-section No. 2, of random concrete blocks, should be added on the seaward face, which will render it necessary to widen the rubble mounds. The concrete blocks for the wave-breakers should nowhere be less in weight than twenty tons.

“As respects the piers from the points B on the north pier and E on the south pier to the seaward ends, it would be desirable, if it could be done, to continue the walls on the original foundations, bonding the blocks in the manner shown, strengthening and protecting the walls as they are built by wave-breakers, and depositing bags of concrete at the toe of the walls on the Harbour side to form a continuous apron. (See Cross-section No. 3.) But picking up the blocks buried or nearly so in debris, for the purpose of resetting them, or preparing a sufficiently level bed on the site of the destroyed wall, will involve great labor and expense, and possibly even it may be found impracticable to continue the wall on the original foundations.

“A more certain plan of procedure for the reconstruction of these outer lengths of the piers would be to move them into the Harbour to the extent of about 60 feet, so that the new walls may clear the fallen blocks of the old structure, adopting the design shown on Cross-section No. 4, and this would involve a somewhat less expenditure than building on the original foundations. But it would shorten the Harbour—already very short—to the extent of about 60 feet; and also it would be undesirable if it could be avoided to build on a new foundation of unconsolidated rubble instead of taking advantage of the old consolidated mounds.

“The plan, therefore, we recommend for the reconstruction of the outer lengths from B on the north pier and E on the south pier, to the seaward ends, is in the first instance to endeavour to continue the walls on the old foundations, as shown on Cross-section No. 3. Before the elbows of the piers are finished it will be seen whether this plan can be successfully carried out; if so, the system should, we think, be followed. If not, the piers should be brought in to the extent of about 60 feet, following the design shown on Cross-section No. 4.

“We have carefully considered the question of reconstructing these outer lengths from B on the north pier and E on the south pier to the seaward ends by mounds of random concrete blocks, more especially as the plan has been recommended by others. It possesses advantages, and as regards construction is a safe system to follow. But it would be necessary to build a

short length of wall at the extremity of each pier upon which to place the entrance lights, and, owing to the size of the vacancies, amounting to between one-fourth and one-third of the mass, the seas may pass through sufficiently to produce some disturbance inside. If the Madras Harbour were of larger size, and there were ample space for the waves to disperse, the system would be more applicable; but, the sheltered area being limited, it is important that the whole space should be made as quiescent as possible. We have, however, thought it right to go carefully into the cost of reconstruction by adopting random mounds for these outer lengths, and find that there would, comparatively speaking, be but little saving in expenditure in adopting this mode of procedure, in preference to building walls on the original foundation with the wave-breaker (shown on Cross-section No. 3), as recommended for adoption.

“The order of proceeding with the works should be first to secure by iron cramps the top courses of the walls which are now standing, that is to say, from the shore to the commencement of the elbows; to reinstate the walls which have been disturbed or thrown down, carefully cramping the top courses together as the work proceeds, and simultaneously in both cases to proceed with depositing the blocks for the wave-breakers so as to afford early protection to the rubble mound and the walls. Raising the walls by concrete in mass will be the last process, as that portion of the work can only conveniently be done by beginning it at the outer extremities of the walls and working back towards the shore.

“For the purpose of arriving at an estimate of the cost of reconstruction, we have assumed the definite lengths previously referred to for the different methods of procedure recommended to be followed and shown on the cross-sections. The details of the estimates are given in the appendix. We estimate the cost of restoration, strengthening, and raising the piers at £480,000 (see Estimate No. 1), assuming that the lengths from B on the north pier and E on the south pier to the seaward ends were reconstructed on the original foundation. If, however, these outer lengths of the walls were brought in 60 feet, the cost, we estimate, would be reduced to £430,000 (see Estimate No. 2). We have also given an estimate of the cost, assuming that these outer lengths were reconstructed by random mounds of concrete blocks (see Estimate No. 3).

“These sums are large, but, in our opinion, a smaller expenditure will not render the work secure.

“Even with this additional expenditure the cost of the piers, having regard to their length and to the depth of water, will not be excessive.

“In comparing our estimate of cost with that prepared by Mr. Parkes, it must be remembered that his did not provide for raising the piers to the height which we think is essential. We have also, in some cases, assumed higher prices than he has done, ours being given in the annexed estimates.

If the work can be well and properly executed at lower prices, so much the better.

“With the additions to the works which we advise, their strength and durability will still be dependent on the materials and workmanship being of the best quality; for such works, if they are to last, must be thoroughly well done.

“Whether from defects in the quality of the concrete or from the blocks being used too soon, or from placing them upon the rubble base before it was sufficiently consolidated, several of the blocks appear to have been broken. No concrete block of such large size ought to be used until at least three months after it has been made, and giving them six months to harden would be still better. The local laterite also does not appear to be of good quality, and hence nothing but gneiss should be used in the additions to the rubble mound.

“Suggestions have been made to stop up the present or eastern entrance in front of the Harbour, and to make an opening facing southwards in the south pier. This would involve very large additional expenditure, and we cannot recommend it, more especially as we do not think it would be an improvement.

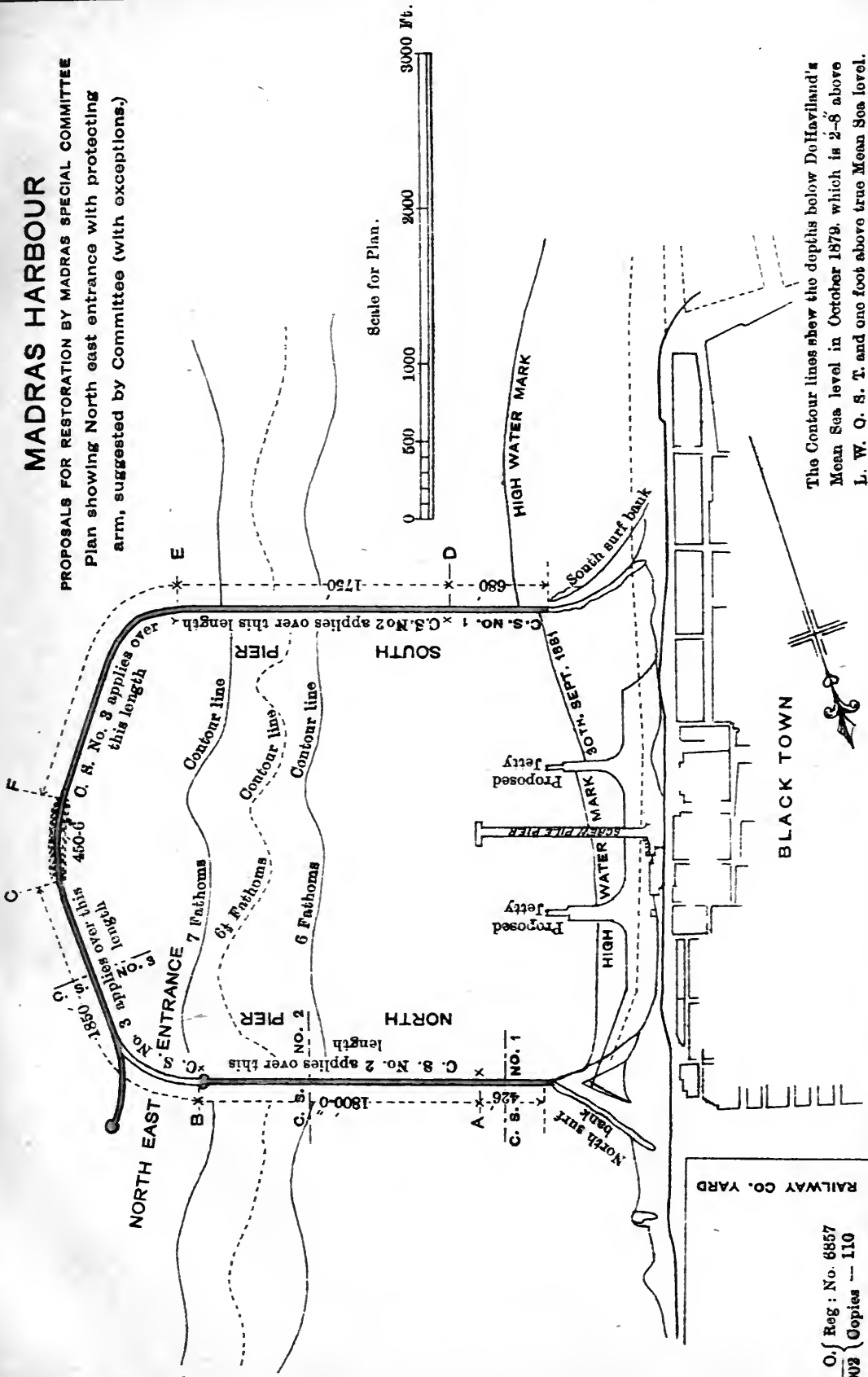
“We think the Harbour, if completed in accordance with our recommendations, will be useful for shipping, and that raising the piers so as to prevent their submergence by seas rolling over them will, with the present width of entrance, render it quieter than before. But its stillness would be further increased by reducing the width of its entrance from 550 feet to 450 feet, and, as we think this ought to be done, we have included the cost of it in the estimates. The reduction of width might be carried out hereafter, but in that case the cost would be increased.

“Mr. Parkes does not appear hitherto to have made provision for lighting the entrance of the Harbour. This will be necessary, but we have not sufficient information to propose a plan for or to estimate the expense of doing it.”

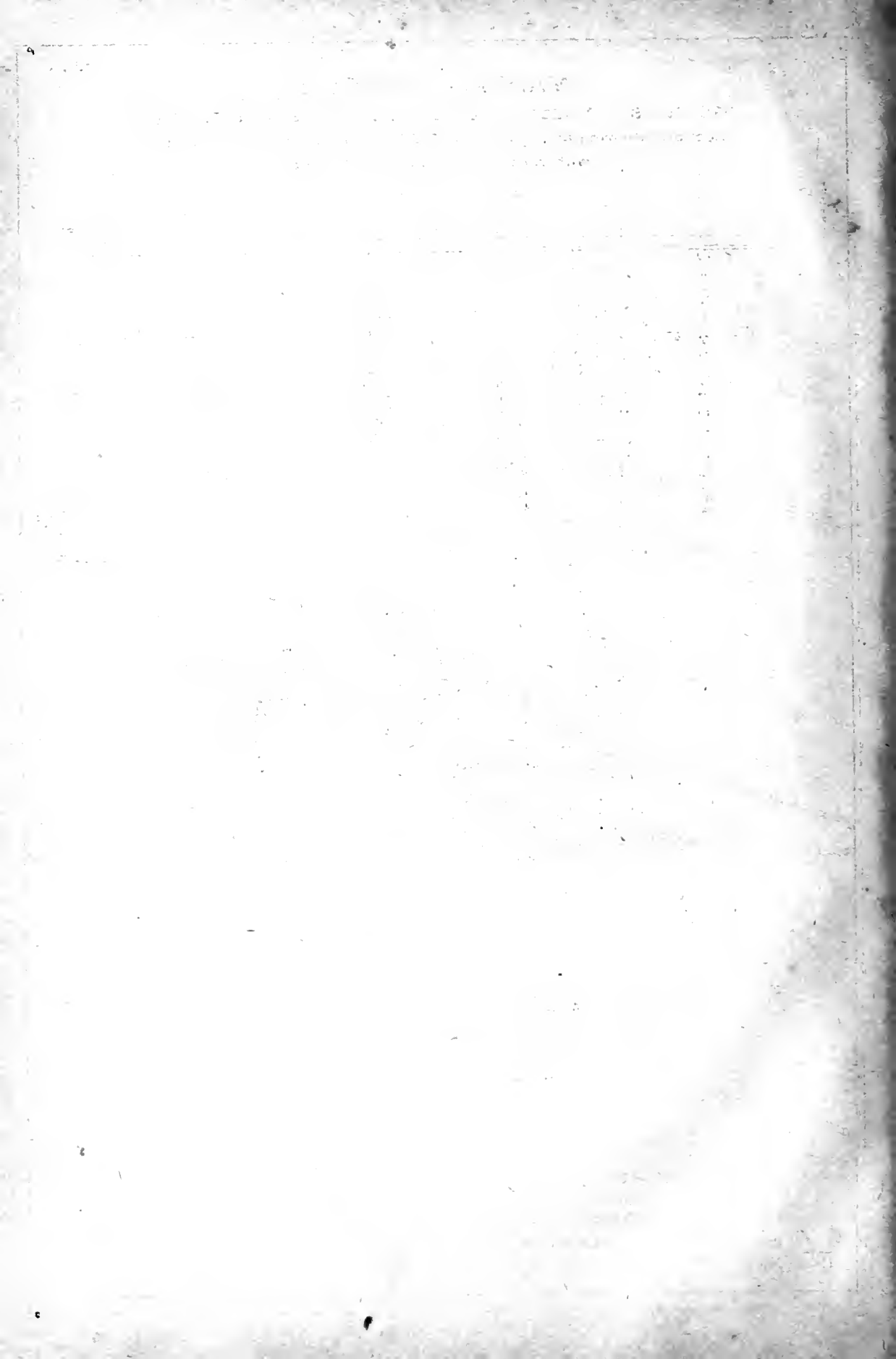
Quantity.	Particulars.	Rate.	Amount.
ESTIMATE No. I.			
Cubic Yds.		£ s. d.	£ s. d.
266,888	Additional rubble in mounds	0 5 6	73,394 4 0
88,862	Concrete blockwork in walls of piers	1 3 0	102,191 6 0
161,678	Concrete blocks in wave-breakers	1 3 0	185,929 14 0
5,408	Aprons of concrete in bags	1 3 0	6,219 4 0
40,410	Concrete in mass on the top of the piers	1 0 0	40,410 0 0
53,733	Removal of old blocks, at 10 s. 26,866-10 0 Deduct value of old blocks put into mounds instead of rubble 53,733 cubic yds. at 5 s. 6 d. 14,776-11-6		12,089 18 6
Tons.			
171	Wrought-iron cramps	20 0 0	3,420 0 0
No. 2	New setting machines ... ..	...	12,000 0 0
	Establishment 7½ and contingencies 2¼ = 10 per cent. ... ..	...	435,654 6 6
	Say £480,000 ... ..	...	43,565 8 8
			479,219 15 2
ESTIMATE No. II.			
Cubic Yds.		£ s. d.	£ s. d.
286,177	Additional rubble in mounds	0 5 6	78,698 13 6
88,862	Concrete blockwork in walls of piers	1 3 0	102,191 6 0
128,051	Concrete blocks in wave-breakers	1 3 0	147,258 13 0
5,408	Aprons of concrete in bags	1 3 0	6,219 4 0
40,410	Concrete in mass on the top of piers	1 0 0	40,410 0 0
Tons.			
171	Wrought-iron cramps	20 0 0	3,420 0 0
No. 2	New setting machines ... ..	...	12,000 0 0
	Establishment 7½ and contingencies 2¼ = 10 per cent. ... ..	...	390,197 16 6
	Say £430,000 ... ..	...	39,019 15 8
			429,217 12 2
ESTIMATE No. III.			
Cubic Yds.		£ s. d.	£ s. d.
353,270	Additional rubble in mounds	0 5 6	97,149 5 0
26,062	Concrete in mass on the top of the piers	1 0 0	26,062 0 0
242,178	Concrete blocks in mounds and wave- breakers and blockwork heads at extre- mity of piers	1 3 0	278,504 14 0
7,067	Concrete in bags in the upper part of mounds	1 3 0	8,127 1 0
Tons.			
71½	Wrought-iron cramps	20 0 0	1,430 0 0
No. 2	New setting machines ... ..	...	12,000 0 0
	Establishment 7½ and contingencies 2¼ = 10 per cent. ... ..	...	423,273 0 0
	Say £466,000 ... ..	...	42,327 6 0
			465,600 6 0

MADRAS HARBOUR

PROPOSALS FOR RESTORATION BY MADRAS SPECIAL COMMITTEE
 Plan showing North east entrance with protecting
 arm, suggested by Committee (with exceptions.)



The Contour lines show the depths below De Havilland's
 Mean Sea level in October 1879, which is 2-8' above
 L. W. O. S. T. and one foot above true Mean Sea level.

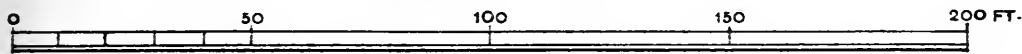


MADRAS HARBOUR

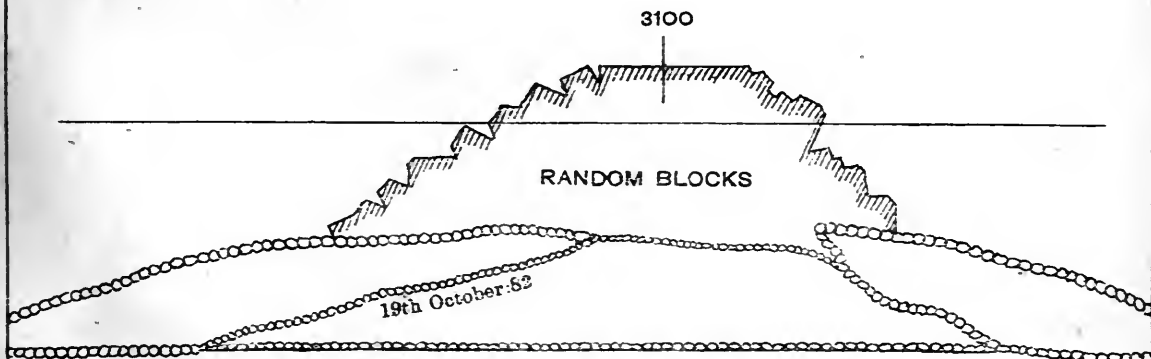
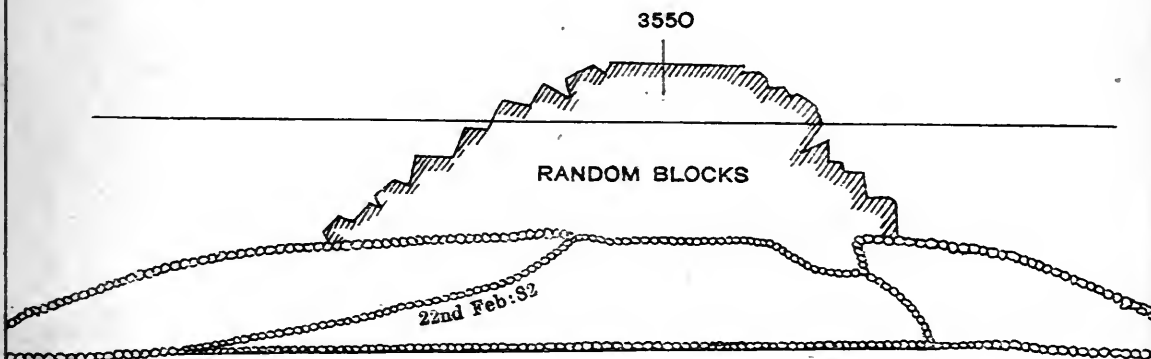
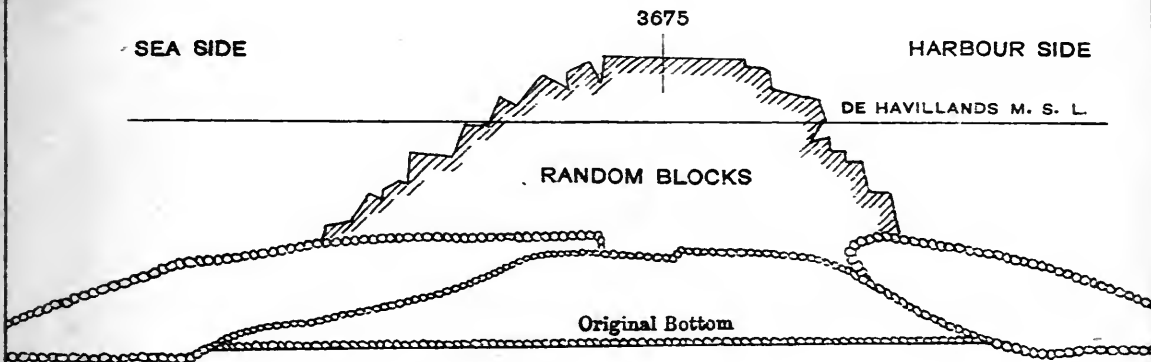
PROPOSALS FOR RESTORATION BY MADRAS SPECIAL COMMITTEE

Sections shewing actual state of PIERS in outer straight portions,
with random blocks over old work.

Scale 40 Ft. = 1 Inch.



NORTH PIER



NOTE —The sections are at points as shown measured from the point B. i. e from the commencement of the concrete block pier, and are shewn looking out to Sea so that the left hand is the Sea side and the right hand side is the Harbour side.

1870

SOUTH PIER

3425

HARBOUR SIDE

SEA SIDE

DE HAVILLANDS M. S. L.

RANDOM BLOCKS

Original Bottom

3325

RANDOM BLOCKS

Original Bottom

2900

RANDOM BLOCKS

Original Bottom

NOTE —The sections are at points as shewn measured from the point E. i. e from the commencement of the concrete block pier, and are shewn looking out to Sea so that the left hand side is the Harbour side and the right hand side is the sea Side.

S. O. { Reg : No. 6359
1902 { Copies — 110

A local Committee was formed in Madras to consider this report and submitted the results of its sittings on 30th April 1883. These were, that it would be most undesirable to attempt to erect the new superstructure on the existing damaged work, that the random block system for reconstruction would be best, and that it would be dangerous to narrow the entrance. Finally the Committee was of opinion that—

“No matter what the direction of the wind, the unceasing swell on this portion of the coast rolls in with the crests of the waves parallel, or very nearly so, to the coast line. In no case it is believed that the angle exceeds 30° to the general line of the coast. The result is that seas enter the present mouth freely, and owing to the small length of the harbour, are not dispersed before reaching the shore at its base. The action is, of course, greatly intensified during storms, and particularly with the wind from the east. As such times the sea inside the harbour, though not so high as outside, is certainly of a dangerous character, being exceedingly broken. Taking these and other facts into consideration, the Committee have to record their opinion that unless means be found for closing entirely the present entrance, no radical cure will have been applied to the chief defect of the work as at present designed

In this view they beg now to submit a plan for the completion of the harbour (see annexed drawings and estimates D. E. F.), the leading features of which are—

- (i) The opening of a new entrance 500 feet in width, in from 7 to 7½ fathoms of water at the North-East angle of the harbour.
- (ii) The closing of the present entrance.”

STATEMENT D.

	RS.	RS.
Estimate for repairing by Sections I, II and III—see Summary of Estimates A .. ..	..	42,32,200
Deduct 100 feet for making 550 feet entrance .. ..	..	91,600
		<hr/> 41,40,600
<i>Add—</i>		
For building across entrance .. ..	..	6,87,300
Do. 400 feet of protecting arm .. ..	..	7,64,400
Excavating and opening North entrance .. ..	..	2,12,292
		<hr/> 58,04,592
<i>Deduct—</i>		
Saving	5,49,750	
Also saving	7,44,913	
		<hr/> 12,94,663
Carried over		<hr/> 45,09,929

OFFICIAL PAPERS CONCERNING THE

STATEMENT D—*cont.*

	RS.	RS.
Brought forward ..		45,09,929
CLOSING NORTH ENTRANCE.		
<i>Plant—</i>		
One titan crane	45,000	
One crane for wave-breaker	30,000	
Other plant as in Summary of Estimates		
A	1,27,000	
		<u>2,02,000</u>
		47,11,929
<i>Add—</i>		
15 per cent. for establishment and contingencies		7,06,788
		<u>54,18,717</u>
Grand Total ..		

STATEMENT E.

	RS.	RS.
Value of restoring work by I, II and IV (as shown in Summary of Estimates B) ..		37,34,460
<i>Deduct</i> for 100 feet to restore 550 feet entrance ..		76,400
		<u>36,58,060</u>
<i>Add—</i>		
For building across entrance		6,87,300
600 feet of protecting arm		7,64,400
Excavating and opening Northern entrance		2,12,292
		<u>53,22,052</u>
<i>Deduct—</i>		
Saving	4,08,400	
Also	7,44,913	
		<u>11,53,313</u>
		41,68,739
<i>Plant</i> as before		2,02,000
		<u>43,70,739</u>
<i>Add—</i>		
15 per cent. for establishment and contingencies		6,55,609
		<u>50,26,348</u>
Grand Total ..		

STATEMENT F.

	RS.	RS.
Restoring work, Sections I, II and V with		
450 feet entrance .. .. .	..	40,22,280
<i>Deduct</i> for 550 feet entrance 100 feet .. ..	..	85,200
		<hr/>
		39,37,080
<i>Add—</i>		
Building across entrance .. .. .	..	7,42,400
Do. extra protective arm .. .. .	..	6,29,200
Excavation in North pier .. .. .	..	2,12,292
		<hr/>
		55,20,972
<i>Deduct—</i>		
Saving	5,11,200	
Also	7,44,913	
		<hr/>
		12,56,113
		<hr/>
		42,64,859
<i>Plant—</i>		
One special titan	80,000	..
Other plant as in summary of Estimates A.	1,27,000	..
		<hr/>
		2,07,000
		<hr/>
		44,71,859
<i>Add—</i>		
15 per cent. for establishment and contingencies .. .. .	..	6,70,777
		<hr/>
Grand Total ..		51,42,636
		<hr/>

The Committee's estimate for completion on this plan was Rs. 51,42,636.

This report being submitted to Sir G. Molesworth, that officer agreed in the main with the Committee's conclusions. He however considered that—

“The entrance to a harbour at right angles to the general direction of the swell is generally considered to be a very disadvantageous arrangement; for when a vessel is entering such a harbour, half protected by the entrance, and half exposed to the action of a heavy wave, it is liable to be swung round, and strike the entrance before it can recover itself: this is a

contingency to which modern vessels from their extreme length are especially liable.

“The projecting breakwater proposed by the Madras Committee will allow some distance for a vessel to recover itself under these circumstances, but I think scarcely sufficient. Colonel Trevor, the Secretary, suggests an increase to the length of this projection, and I am of opinion it should be increased not only for covering the entrance, but also in order to allow a vessel to recover itself if struck by a wave when half protected.

“I presume that the nautical authorities on the Madras Committee have satisfied themselves as to the practicability of a ship entering the harbour by such an entrance in stormy weather; but I think it would be desirable to refer this question to the highest nautical authorities in India.

“Supposing the entrance to be practicable, the change of entrance would doubtless add very greatly to the quiescence of the harbour; but I must confess that I am somewhat sceptical of the *absolute* safety of vessels in Madras Harbour during a cyclone, even under the conditions of having raised the face and elbows and closed the seaward entrance.

“Assuming, however, the feasibility of such an entrance, I am of opinion that the form of breakwater proposed for covering this entrance requires some modification. In its proposed form it is open to serious objections, involving, as it does, a re-entering curve which would never stand the blow of a cyclonic wave.

“I have, in my previous report, adverted to the confluent action of the waves along the faces and round the elbows of this breakwater, and I annex a diagram (No. 3) showing in black arrows the action of waves on a breakwater such as that proposed by the Madras Committee.

“It will be seen by this diagram that the meeting of the confluent waves along the face with those rolling in direct from the sea would set up a very severe action, and the blows on the concave surface at A would be so severe that nothing in the shape of a breakwater could withstand it.

“Moreover, the action of the waves would not only be severe on the breakwater, but, as the confluent action would be diametrically opposed to the direct action of the waves rolling in at B, a very turbulent action of the waves would be set up, which would seriously affect the passage of a vessel into the entrance.”

And he proposed certain modifications.

These views were laid before the Home

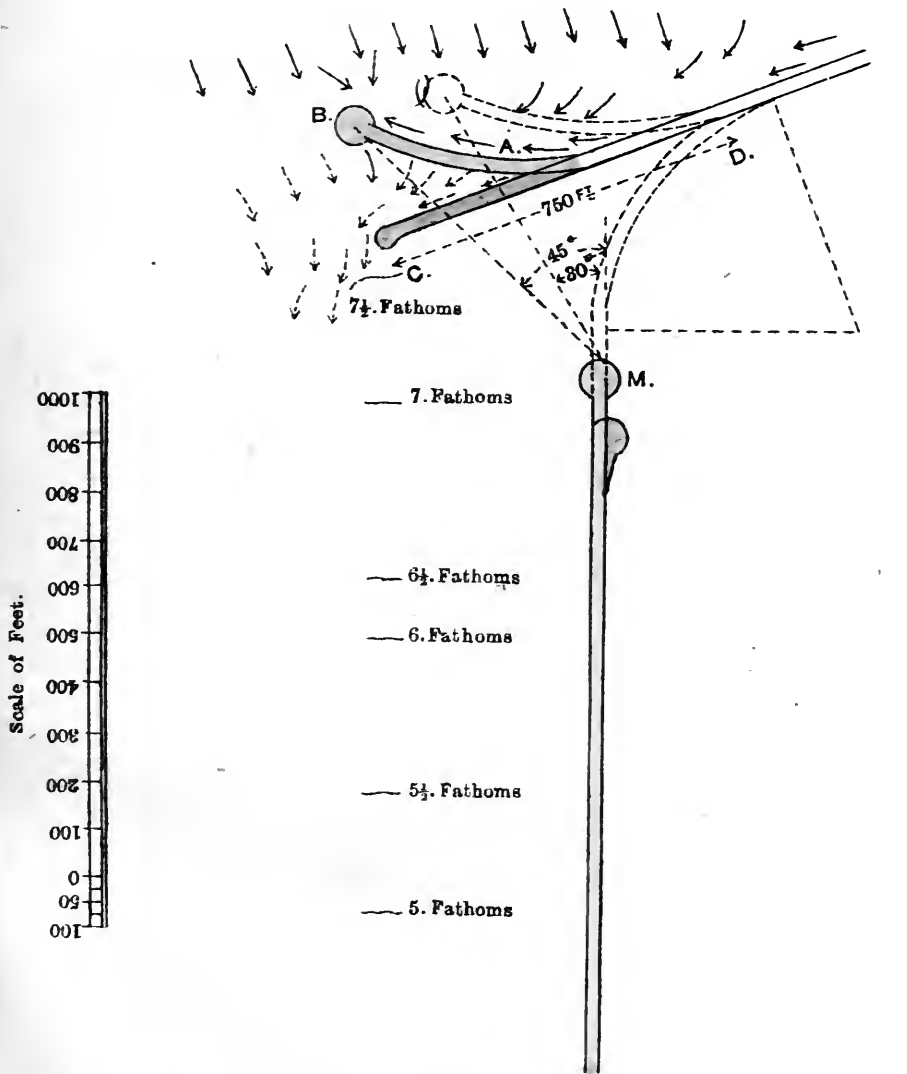
Further report of first Home Committee. Their second report is also printed in full.

“In obedience to instructions contained in a communication from the India Office, dated 6th of February last, copy of which is annexed, we have read and considered the papers forwarded to us, and have now the honour to report our opinions on the modifications suggested by the Madras Committee of the plan we last year recommended.

MADRAS HARBOUR

Diagram No. 3 to accompany note by Mr. MOLESWORTH dated July 17th 1883.

Diagram illustrating action of waves on the breakwater proposed by Madras Committee.



NOTE - The dotted lines shew the breakwater as proposed by the Madras Committee. The portions coloured black shew the increased length suggested by Col. Trevor. The portions coloured red shew the modification proposed by Mr. Molesworth.



“The change suggested by the Madras Committee requiring the gravest consideration is their proposal to make a new entrance to the harbour at its north-eastern elbow and to stop up the existing entrance. Their object in making this proposal is to secure stiller water inside the harbour, a thing desirable in itself if attainable with due regard to other considerations, and they state that the work remodelled in this and in other respects as they recommend will cost much the same as the works advised by us in our report of the 23rd January 1883.

“The Madras Committee arrive at this conclusion of equality of cost by leaving out from their project the wave-breaker on the south side and the concrete cap on both sides of the harbour, and appear to have assumed, though we are at a loss to know why, that we did not attach any very indispensably constructive value to this portion of our recommendation. They seem to have looked at our proposal to raise the piers by a concrete capping mainly as a question of waves spilling over them into the harbour, though the observation in our report was that raising the piers to the height we advised would add to the security of vessels within the harbour in rough weather, and would greatly strengthen the work.

“We cannot approve of further expensive works, the money for which is chiefly to be found by reducing the strength and efficiency of those recommended in our report of January 1883, which we now see no reason to abate.

“It follows, therefore, in our opinion, that the proposal to form a new entrance and to stop up the old one must be treated as an additional expenditure to that previously contemplated by us.

“We have consequently estimated the cost of making the new entrance and of stopping up the old one; and taking the overlapping arm, as the Madras Committee show it, to be 600 feet long, which, in our opinion, would be the minimum length required, we make this additional cost to amount to £127,000. In considering the propriety of incurring such further expenditure, the following observations should be borne in mind.

“The danger to vessels within the harbour in a cyclone would arise from the winds as well as from the waves, probably more from the former than the latter, and we think that prudent commanders, on those occasions, would prefer getting out to sea to remaining inside the harbour.

“If the piers at the sides of the harbour were left as low as is contemplated by the Madras Committee, they would in cyclones be nearly, and might be altogether, submerged, and vessels lying in the harbour would be floating in a receptacle brimful, or nearly so, of water, and exposed on the north and south to the full force of the cyclone. In such case, with submerged piers, vessels breaking from their moorings would in all probability be lost.

“Though the piers raised to the height we have recommended, while strengthening the work, would afford some additional protection from the

wind, we do not assume that even then it would be safe to remain in harbour during a cyclone. Mr. Dalrymple, late Master Attendant, Madras, who has had lengthened experience of that coast, and who favored us with his views on the occasion of our former inquiry, was of opinion that nothing short of 18 feet above high water would be high enough for the piers, and we consider the height of 12 feet, which we have recommended, to be quite low enough. Hereafter, in special cases, should vessels be required to lie at loading places inside the harbour and near the piers, screens or walls, say 6 feet high, increasing the total height above high water to 18 feet, could be erected, and might prove necessary to give further protection from wind.

“In large harbours it may almost be taken as an axiom that in proportion as you seek greater stillness inside you have to obtain it by rendering access to and egress from the harbour less easy.

“On the occasion of our inquiry last year we were informed that a new entrance to the harbour had been suggested at the south-east elbow, and we then considered the question of changing the entrance, and reported against it.

“Though the Madras Committee say that the strongest winds are from the north-east, and though winds blow twice as long from that quarter as from the south-east, they now propose a new entrance fully open to those prevailing winds.

“It is, perhaps, more a nautical than an engineering question, but we fear that access and egress through this new entrance would, in cyclones, be very difficult, the difficulty increasing just in proportion as the entrance was made to face the north, and diminishing as it faced easterly. Even with the north-easterly kant shown on the Madras Committee's plan, vessels could not make or leave the harbour without being exposed to waves striking them on their beam, and tending to heel them over, or to carry them into shoal water on shore, or to cause them to strike against the end of the northern pier.

“With regard to the new entrance, there is another consideration of some moment. The present entrance could not be stopped up until the new entrance was made, and there would, therefore, for a considerable time, be two entrances, and during that period there would necessarily be greater disturbance in the harbour.

“With regard to the methods of reinstating the work, the Madras Committee appear to prefer the random block system. This is shown in our report of 23rd January 1883 by cross section No. 5. Though we did not give it a preference, we stated in that report that it possessed advantages, and was a safe system to follow.

“In framing that report we had to deal with a work which had been much more damaged in some places than in others, the extent of damage at some points not being very clearly ascertainable, nor capable of being

determined until the work of restoration should be in progress; and hence we devised different methods of restoration.

“ Besides the objections we pointed out to the random block system, not perhaps very weighty in themselves, we were also influenced, to some extent, by difficulties of manipulation in that system.

“ On this subject we beg to remark generally that, referring to the three methods of reconstruction shown in our previous report, viz. :—

1. According to cross sections 1, 2, and 3,
2. Do. do. do. 1, 2, and 4,
3. Do. do. do. 1, 2, and 5,

we consider that any of them may be adopted with safety, provided they are in nowise weakened by diminution of their dimensions or otherwise.

“ In considering the matters now referred to us, we have had interviews with Mr. Parkes, who has explained to us his views. He sees some difficulty, as we did, in carrying out the system shown on cross section No. 5, and seems farther to be of opinion that he should prefer to adopt cross sections 1, 2, and 4. With regard to this question, we think you may be guided by Mr. Parkes with the clear understanding, so far as we are concerned, that nothing is done to weaken any of the works recommended by us, whichever of the methods be adopted, and that the piers be not built to a lower level than we have already advised.

“ The only question remaining to be dealt with is the important one of change of entrance.

“ We have already pointed out that the change of entrance would add £127,000 to the cost of what we consider to be necessary works. We think also that in cyclones there would be difficulty in getting into and out of the harbour through the proposed north-eastern entrance, and if, during a cyclone, captains were not disposed to remain in the harbour, and could not get their vessels out, it would be a serious matter. We have also mentioned that, if a n-w entrance be formed, the harbour will, for some time, be left with two openings instead of one, and will consequently be more disturbed.

“ We are still of opinion that the present entrance might, with advantage, be reduced to 450 feet, having walls vertical, or nearly so, on both sides of the entrance as we always contemplated, and see no reason to alter the opinion given in the last paragraph but one of our former report of the utility of the harbour if completed in accordance with our recommendations.

“ It must not be forgotten that, whether the harbour were completed with the present or with a new entrance, there are now no sufficient facilities within it for loading or unloading vessels; and if further expenditure is to be incurred, it is a question whether it would not be better to incur it in providing such facilities at or near the base or shore end of the harbour, rather than in making a new entrance.

“After giving the fullest consideration to this question, we cannot recommend the construction of the proposed new entrance.

“In conclusion, we beg to call attention to the fact that in all the estimates we have made, whether in this or our previous report, we dealt with our own prices in English money only, and our prices were in no wise modified or increased (as Mr. Parkes seems to have inferred) by adopting his rates and converting them into sterling money at the rate of two shillings to the rupee. The conversion of our estimates into rupees must, therefore, be made at the current value of the rupee, whatever that may be.”

The opinion of the Madras Government as expressed by their then Chief Engineer Colonel Shaw-Stewart, R.E., is also printed in full in order to show the unswerving local preference for a northerly entrance.

Local persistence in favour of northerly entrance.

“The three points specially dealt with in the papers now under acknowledgment are—

- (1) The position of the entrance to the harbour, together with its shape and width.
- (2) The section to be given to the sea-face.
- (3) The officer under whom, as chief executive authority, the restoration of the harbour is to be proceeded with.

“With respect to the first point, I am to state that His Excellency the Governor in Council still remains strongly of opinion that the entrance should be placed at the north-east angle of the harbour, in from 7 to 7½ fathoms of water, as recommended by the Madras Committee; and that it should have a width of 500 feet.

“As bearing on this point, it appears to this Government that sufficient weight has not been attached to the unanimous opinions of nautical experts on the spot, copies of which were forwarded to you with my letter, dated 11th October 1883, No. 2862 W. It is admitted by Sir John Hawkshaw's Committee that the question of access and egress through the proposed new entrance is ‘*more a nautical than an engineering question.*’ That it is emphatically a nautical question scarcely admits of doubt; and on this point the nautical authorities who have been consulted are singularly unanimous. In a letter, dated 6th May, No. 4354, copy of which accompanies this, and to which special attention is solicited, the Master Attendant of Madras states: ‘All commanders of vessels who have been consulted, and that includes nearly all that have visited Madras since the accident, approve entirely the alteration from every point of nautical convenience.’ Captain Taylor adds: ‘I submitted some of the chief opinions, but could have collected hundreds, all giving testimony of the same nature.’

“I am directed to again solicit attention to those opinions; and, in doing so, to point to the fact that they represent the views of experienced men, commanding the largest steamers visiting the port; men who have

known this coast and these seas for years, and who have watched the progress of the harbour works from the beginning. If there be any more competent nautical authority, thoroughly conversant with the somewhat complicated local conditions and with the nature of cyclonic storms, I am to state that His Excellency in Council earnestly requests that the question at issue may be referred to such authority before it is irrevocably decided.

“ In further connection with this point, I am directed to observe that Sir John Hawkshaw's Committee appear to have misapprehended the circumstances from want of the necessary local knowledge. In paragraph 11 of their last report, they state that during 1883 they considered the question of forming a new entrance at the south-east elbow, and reported against it; and in paragraph 12 they continue: ‘ Though the Madras Committee say that the strongest winds are from the north-east, and though winds blow twice as long from that quarter as from the south-east, they now propose a new entrance fully open to those prevailing winds.’ The argument being apparently that, if a southern entrance cannot be entertained, *a fortiori* a northern entrance must be objected to still more strongly.

“ With advertence to this, I am to point out that the Madras Committee did not say the strongest winds were from the north-east, but ‘ the heaviest seas yet observed have invariably been from the north and the north-east.’ As matter of fact, the wind does not at Madras blow from the north and north-east for more than four months of the year, from October to February, the direction of the wind during the remaining eight months being more or less southerly. The direction of the wind, however, seems to have little effect on the swell, which rolls in with the crests of the waves parallel, or nearly so, to the coast line; with the result that seas enter the present mouth freely, and do not disperse before reaching the shore at the base of the harbour. Those seas would be deflected from a north-east entrance by the proposed protecting horn.

“ A further objection to the north-east entrance raised by Sir John Hawkshaw's Committee is that ‘ there would, for a considerable time, be two entrances;’ but I am directed to state that this Government do not attach much weight thereto, inasmuch as the old entrance could probably be closed, and the new one opened, during the interval between two stormy seasons.

“ After most carefully considering all that has been urged against the proposed new entrance, His Excellency the Governor in Council adheres strongly to the opinion he has already recorded in favour of it. He considers that the retention of the eastern entrance will involve the loss of the greater part of the advantage which Madras might otherwise confidently expect to obtain from the harbour, and that it will also, in all probability, involve heavy and ever recurring outlay to repair storm damages. And I am directed to add that this opinion is in no way contingent upon the decision that may be arrived at with respect to the necessity for providing the south arm of the harbour with a wave-breaker. If such provision can

be dispensed with, as recommended by the Madras Committee, the new entrance can probably be opened within the sum (£480,000) named by Sir John Hawkshaw's Committee; but if otherwise, this Government are of opinion that the additional outlay, estimated by the same body at £127,000, *must* be incurred in view to the efficiency of the harbour and the security of vessels lying therein.

“The question of whether ships could safely ride out a cyclone in the harbour may, in the opinion of this Government, be left to be decided by the commanders of such vessels. In most cases sufficient warning is given of the approach of a cyclone to enable vessels to get to sea, if they desire to do so; but it is impossible to entertain doubt that a vessel in the harbour would have a much better chance during a cyclone if the eastern entrance were closed, than if it were open. It should, moreover, be remembered that the main object of the harbour is not to provide a refuge for vessels during the brief period of cyclonic storms, but to secure smooth water for landing and shipping operations in ordinary weather, and to protect the jetties and other appliances necessary thereto from the destructive effects of a cyclone to which they are liable so long as they are exposed to the direct influence of the sea from the east. Every convenience of this sort was wrecked in 1881; and unless the proposal to close the eastern entrance is accepted, it will be useless to attempt their reconstruction.

“Respecting the proposal to reduce the width of the present eastern entrance to 450 feet, which is renewed by Sir John Hawkshaw's Committee in paragraph 22 of their late report, I am directed to observe that this too is more a nautical than an engineering question, and that the weight of local nautical opinion has been recorded strongly against the proposal. Upon this point I am to refer to paragraphs* 25 to 27 of the Madras

* See extracts below :—

Copy of paragraphs 25 to 27 of the Madras Committee's Report referred to above.

The Committee now proposed to consider the subject submitted for their opinion in paragraph 3 of G.O., No. 1259 W., as to the propriety of reducing the width of the present entrance from 550 feet to 450 feet, and to submit an alternative scheme, should such reduction appear to be undesirable.

In reference to the feasibility of narrowing the width of the entrance in the manner proposed, the Committee have been favoured with the following recorded opinion of two of their members, the Master Attendant and Deputy Master Attendant.

These officers observe :—“As regards the proposal of the Home Committee to narrow the entrance 100 feet, we consider that it will render it difficult and dangerous to a degree out of all proportion to any advantage that can be gained by it. A large amount of sea and swell must always enter from the eastward, and no comfort to the ships or the boating operations or to beach improvements can be expected till this evil is removed. The completed harbour walls existed long enough to teach this lesson. This is the opinion of all nautical men who have been consulted, and especially the Harbour Master, who has daily opportunities of judging and appreciating the difficulties that attend the entry of large steamers (many of them over 400 feet long) even with the present width.”

Committee's first report. With that opinion on record, His Excellency the Governor in Council must continue to object to the proposal.

“With respect to the second point dealt with in the papers under acknowledgment, namely, the section to be given to the sea-face of the harbour, I am directed to state that His Excellency the Governor in Council greatly prefers the third of the methods of reconstruction quoted by Sir John Hawkshaw's Committee in paragraph 18 of their last report, namely, the random block-work system. Its adoption was strongly recommended by the Madras Committee; and as Sir John Hawkshaw's Committee consider that it may be adopted with safety, it is hoped by this Government that all objection will now be removed.”

The Secretary of State however, supported by Mr. Parkes, felt that he had no choice but to accept the decision of such eminent authorities as Sir J. Hawkshaw and Sir J. Coode. In the meantime the restoration work was practically in abeyance and was not rigorously resumed till the early part of 1885. During this year progress was steady though not rapid, the chief feature of interest being the difficulty experienced in recovering the blocks belonging to the old pier that lay under water. After several trials the attempt to recover blocks was abandoned as too difficult, expensive, and dangerous. By the early part of the next year new and powerful plant had been prepared and progress improved.

In 1886 the Madras Harbour Trust Act was passed, transferring the direct control, property, and liabilities from the Government to a Board of Trustees. At the end of that year the Board raised again the question of a north-east entrance. The then Harbour Engineer, Mr. F. N. Thorowgood, being consulted gave it as his opinion that a north-east entrance would make the harbour perfectly smooth for 340 days in the year, while a north entrance with a protecting arm would make it perfectly smooth all the year round. He considered however that long deep steamers would have a difficulty in making the entrance in heavy weather, and finally drew attention to the danger of complete closure of the harbour if the protecting arm were demolished by a sea of unprecedented force. On the whole he considered that, as things stood at the moment, to change the design would be too bold an experiment.

The Madras Government referred the question to the Government of India, expressing the view that new matter had arisen with the advance of the reconstruction works. The Government of India supported the views of the Madras Government and addressed the Secretary of State in the following despatch, dated 7th June 1887 :—

“ In Lord Kimberley’s Despatch, No. 56 P.W. of 25th September 1884, reference was made to the views of Sir John Hawkshaw’s Committee and to those of Mr. Parkes, on the subject of the proposed change in the position of the entrance to the harbour, and it was said that ‘ Mr. Thorowgood, who is in full possession of Mr. Parkes’ views, and of the reasons which have led him and the Committee to adhere to the eastern entrance, has already started on his return to Madras, and will be able to furnish the authorities there with any additional particulars they may require, and it is to be hoped that conflicting views may be reconciled by further discussion.’

“ At the time when this despatch was received we thought it better to take no immediate action concerning the question of the entrance, partly for the reason that it was evidently our duty to allow scope for the further discussion which Lord Kimberley thought would have beneficial results, and partly because there was no apparent advantage to be gained by attempting

Letter, dated 9th March 1882, from Mr. Parkes, to the Secretary to Government of Madras, Public Works Department, paragraphs 44 and 45.

Letter, dated 10th February 1883, from Mr. Parkes, to the Under Secretary of State for India, paragraph 14.*

to arrive at an early decision on the matter. The opinions expressed by Mr. Parkes in the documents noted in the margin showed that, if it should prove desirable to alter the entrance, the alteration could be both more cheaply and more expeditiously made when the works had been

completed in accordance with the authorized design.

“ The difference of opinion to which Lord Kimberley referred may be

* *Vide extracts below :—*

Letter dated 10th February 1883 from Mr. Parkes to the Under Secretary of State for India.

14. With regard to the entrance, it is satisfactory to find that the Committee confirm the propriety of its present position as a question of general design. As to the special nautical considerations on which a change has been advocated, no evidence, except that contained in the papers, was brought before them, and as that is all on one side, their conclusions adverse to a change is based entirely on general grounds. I am bound to say that, if an immediate decision were necessary, I should agree with the Committee; but considering that no measures can be taken to carry out either the narrowing or the entire change of position till all the other works are completed, I would submit that it is undesirable, in view of the strong opinions, expressed by the Marine authorities, to come to any decision at present. The eastern entrance, 550 feet wide, exists, bad or good, and must be used for the next four or five years. During that time it will have a more extended trial than it has yet had, and there will be more material for a final judgment. I would express a hope therefore that no definite order be given, either for reducing the width, or for altering or retaining its position, until nearer the time for carrying out the actual work. It need not be concluded, however, that the efficiency of the harbour is dependent upon the width or position of the entrance. Even admitting that a change in either respect would be an improvement, it will not make the difference between a harbour and no harbour; it would only give more accommodation, which, of course, if required, would bring more revenue.

said to have been the difference between the opinion of Sir John Hawkshaw's Committee, in which Mr. Parkes concurred, and the opinion of all persons or bodies in India who were interested in the harbour, or who had been officially or professionally consulted concerning it.

“ Among those who maintained an opinion favourable to an alteration in the site of the entrance were:—

The Madras Committee of local professional gentlemen, which reported on the 30th June and 22nd September 1883.

The Madras Chamber of Commerce.

The professional advisers of the Government of India.*

* Mr. G. L. Molesworth.

Colonel H. A. Brownlow, R.E.

„ W. S. Trevor, R.E.

All Commanders of first-class steamers using the port of Madras who had been consulted.

The local Nautical authorities.

The Madras Government.

“ We are not in a position to know whether the opinion of the gentlemen who were members of Sir John Hawkshaw's Committee may have been in any way modified, but it is a fact that the experience of the last three years and the further discussions which have taken place have in no way altered the opinion of all competent authorities in this country. That opinion is steadfastly opposed to the retention of the eastern entrance, and generally, although not quite unanimously, in favour of a north-east entrance to the harbour.

“ The Government of India has hitherto refrained from the assertion of any very decided opinion on this question of the entrance. We think that the time has now come when our opinion may be advantageously expressed. The balance of evidence is strongly adverse to the eastern entrance, and it may well be deemed hardly politic or safe to compel the Madras Harbour Board to construct a harbour in a manner which is opposed by nearly all, if not by all, persons in India who are competent to judge of the matter, or who have interests at stake in the work. But we would add that the opposition of the Madras Government and of all Madras local authorities to the eastern entrance has our entire concurrence, and that we are convinced that no harbour at Madras, which is made with an eastern entrance, can be at all effective. We append a brief summary* by our

* *Memorandum by Mr. G. L. Molesworth, C.I.E., dated 9th May 1887.*

With regard to the engineering points at issue I may sum up my opinions as follows:—

1st.—It is impossible, with an eastern entrance, to exclude from the harbour waves of considerable magnitude, even should the entrance be narrowed to 450 feet.

2nd.—The adoption of a north-east or south-east entrance is the only mode of excluding such waves from the harbour.

Consulting Engineer, Mr. Molesworth, of the opinions he has previously recorded on the subject.

“We understand from the reports of Mr. Parkes and of Sir John Hawkshaw’s Committee, that there is no engineering difficulty in constructing a north-east entrance. The Committee, indeed, appear to admit that the question of the proper site for the entrance is more a nautical than an engineering one. The absolute unanimity of all commanders of steamers using the port, against the eastern entrance, must, we think, have great weight in this respect.

“We would ask your Lordship to take this question of the position of the entrance again into consideration; for we are convinced that the matter cannot be set at rest until either our views and those of the other authorities in this country are accepted, or the views held by Sir J. Hawkshaw’s Committee and Mr. Parkes have received the support of the highest nautical authorities. It would seem to be essential, in the latter case, that the opinion of those authorities should be given after they have fully satisfied themselves, by local investigation, concerning all the circumstances, and have shown good cause for setting aside the opinion of all the commanders of local experience who have been acquainted for many years past with the various conditions of the problem.”

The Secretary of State upon this agreed to a new Committee consisting of Admirals Salmon and Nares, and Sir John Coode, at the same time intimating that the works should be prosecuted with a view to a possible change of entrance.

3rd.—The north-east entrance appears to be preferable to the south-east entrance, because the north is less exposed than the south to encroachments from sand.

4th.—The re-entering curve proposed by the Madras Committee in the overlapping arm to the north-east elbow is open to serious objections, but I notice that Mr. Thorowgood, in his letter, dated January 31st, 1887, has submitted a sketch in which this is modified to meet the objection to a re-entering curve raised in my note of July 17th, 1883.

5th.—A prolongation of the present face of the harbour so as to avoid the necessity for this re-entering curve would throw the entrance 200 or 300 feet nearer to shoal water.

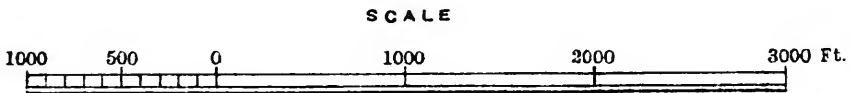
6th.—The alternative plan for forming a north-east entrance by the prolongation of the south-east face so as to overlap the present eastern entrance as suggested in my note of July 17th, 1883, would afford shelter to the harbour and would at the same time allow more sea room for vessels entering the harbour, but it would involve greater expense.

The feasibility of entering or leaving the harbour by the north-east is a question for nautical men to decide, and whether an entrance at the north-east elbow would allow sufficient sea room is also a nautical point on which I do not feel qualified to offer an opinion.

MADRAS HARBOUR

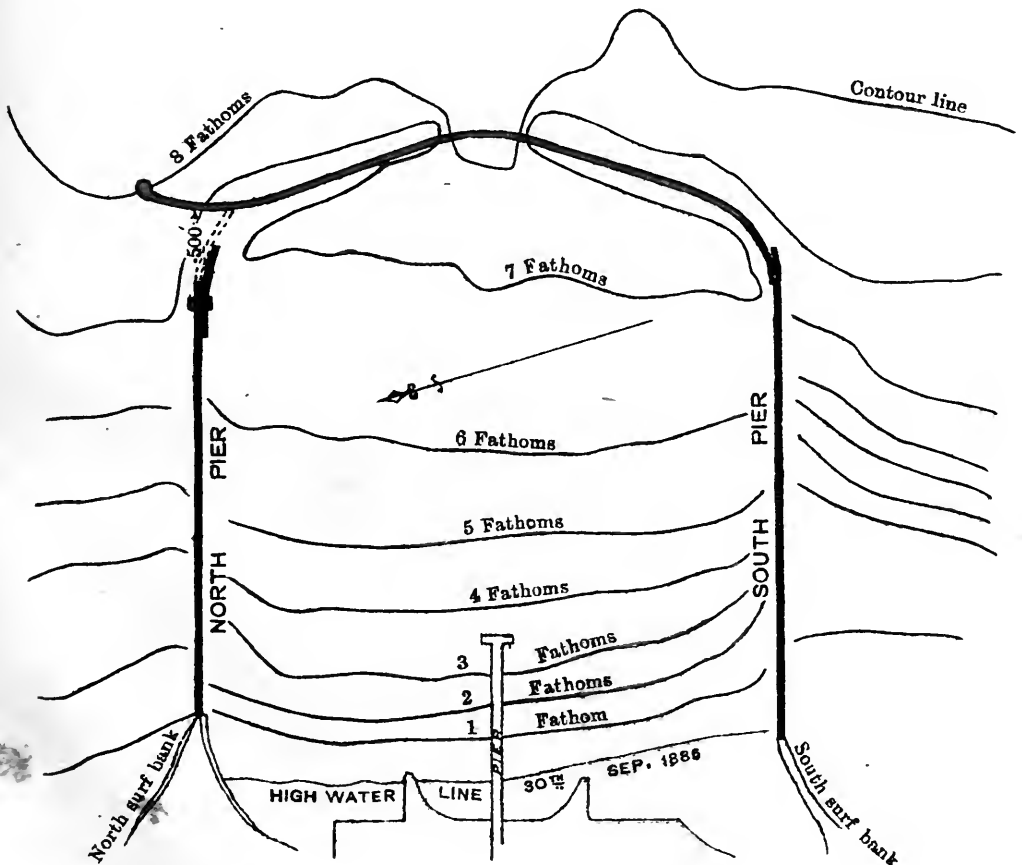
TO ACCOMPANY REPORT OF COMMITTEE, APPOINTED BY VISCOUNT CROSS—APRIL 1887,
TO CONSIDER THE QUESTION OF THE ENTRANCE.

PROPOSALS FOR ENTRANCE REFERRED TO IN LETTER FROM THE CHAIRMAN OF
MADRAS HARBOUR TRUST BOARD, DATED MAY 4TH 1887.



No. 1

PROPOSAL OF SPECIAL COMMITTEE IN MADRAS 1883.



This Committee examined a great number of witnesses at length and finally on 19th October 1887 submitted the following important report recommending on the whole a north-east entrance :—

“ We have taken evidence upon this highly complicated subject, and beg to report as follows :—

“ It is agreed on all hands that, owing to the frequently disturbed state of the water, the facilities for landing and embarking passengers, cargo, etc., offered by the harbour, are very much restricted, nor would it be feasible, for the same reason, to use without serious interruption, wharves and jetties along the shore line, or to keep in safety within it, such improved lighters, tugs, and other harbour craft as would greatly increase its value as a trading port. Much cargo is said to be lost overboard in the process of transhipment, and, for want of tugs, no sailing vessels use the harbour at all.

“ The confused sea within the harbour is attributed, by all who have given evidence, to the nearly constant swell from the eastward which runs in through the present entrance, and, being deflected from the side walls, causes what is variously described as a ‘ nubby sea ’ or ‘ joggle of a sea, ’ and in bad weather as being like ‘ a boiling pot. ’ In consequence of which it is the opinion of many of the most experienced captains that, excepting for the distance from the shore, loading and unloading could be as advantageously done outside as inside. During the cyclone of November 1881 the greater portion of the craft within the harbour were wrecked before the walls gave way.

“ The swell, which is the source of so much trouble at Madras, appears to be generated in the Bay of Bengal, and, as it approaches the harbour, advances ordinarily in a line parallel with the coast, but is occasionally deflected as much as 30° each way.

“ It is contended by the Madras Harbour Trust Board that the remedy for all the defects in the present harbour lies in closing the eastern entrance and opening one elsewhere. Captain Taylor, the Port Officer, who was charged to represent to us the views of that Board, goes so far as to say that the one thing needful is smooth water, that smooth water can only be got by closing the present or eastern entrance, and that no engineering difficulty nor expenditure, however great, should be allowed to stand in the way of such a change being made, and that without it ‘ the harbour will never be worth having. ’

“ We have carefully considered the different proposals for remedying the defects in the present harbour.

“ In order to render this report as clear and comprehensive as possible we have caused the three accompanying drawings to be prepared.

“ Drawing No. 1 exhibits the projects (numbered I, II, III, and IV) described in a report on the different proposals for a north-east entrance,

dated 2nd May 1887, and addressed to the Chairman of the Madras Harbour Trust Board by the Superintendent of the Harbour Works. These proposals were referred to by different witnesses in the evidence taken in the course of our inquiry.

“Drawing No. 2 contains a plan of the harbour in its present condition, and also three sections which we have had prepared in order to illustrate, as clearly as possible, the changes which have taken place in the depths immediately to the northward and southward of the harbour within the last few years.

“Drawing No. 3 shows, by red colour, the position, aspect, and covering arm of the new north-east entrance, which we have to recommend for adoption.

“The proposal to open the harbour at the south-east corner, whether alone or in conjunction with another opening at the north-east corner, we feel bound to dismiss. Our calculations, founded upon soundings taken and submitted to us by Mr. Parkes, more especially a comparison of those taken in 1886 with those taken in 1882, show that, so rapid and regular is the encroachment of the sand on the south side, that, if continued at the same rate, which we have strong reason to apprehend will be the case, within twenty years the depth of water at the south-east corner will be reduced to four fathoms.

“The present, or east entrance, we believe to be the easiest and safest for ingress or egress, but not only does it admit the sea in the manner described, but we are of opinion that the time is not very far distant when the depth at this entrance will be so far reduced as to become too shallow for the larger class of vessels frequenting the port.

“The designs on which the harbour is being reconstructed include reducing the width of the present entrance from 550 to 450 feet; the opinions of nautical men differ as to whether the reduction is advisable from the navigating point of view, but all concur in thinking that the alteration would not have a sufficiently quieting effect on the state of the water inside.

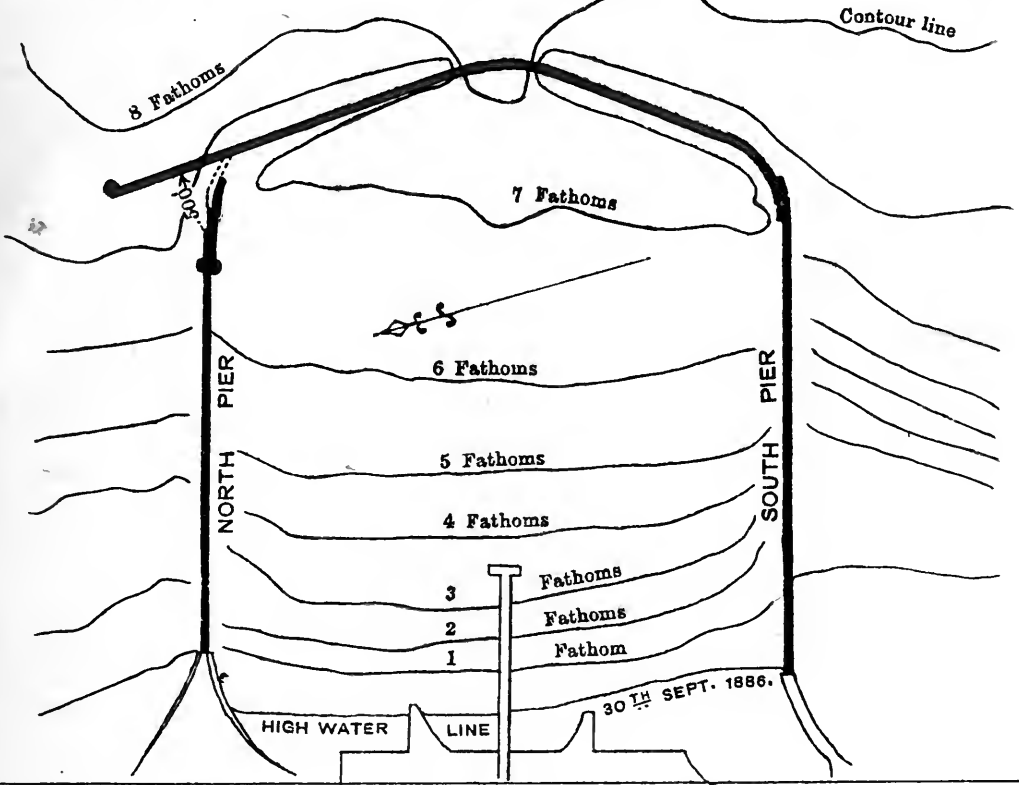
“A proposal has been brought before us to protect the present entrance by constructing a detached breakwater to the eastward of it. This appears to us a difficult and costly operation; a breakwater outside would not, we believe, prevent the entrance of sand into the harbour.

“The alternative is an opening in the north-east corner with a covering arm. This is the plan favoured by the Madras Board, and to this we have given our most careful consideration.

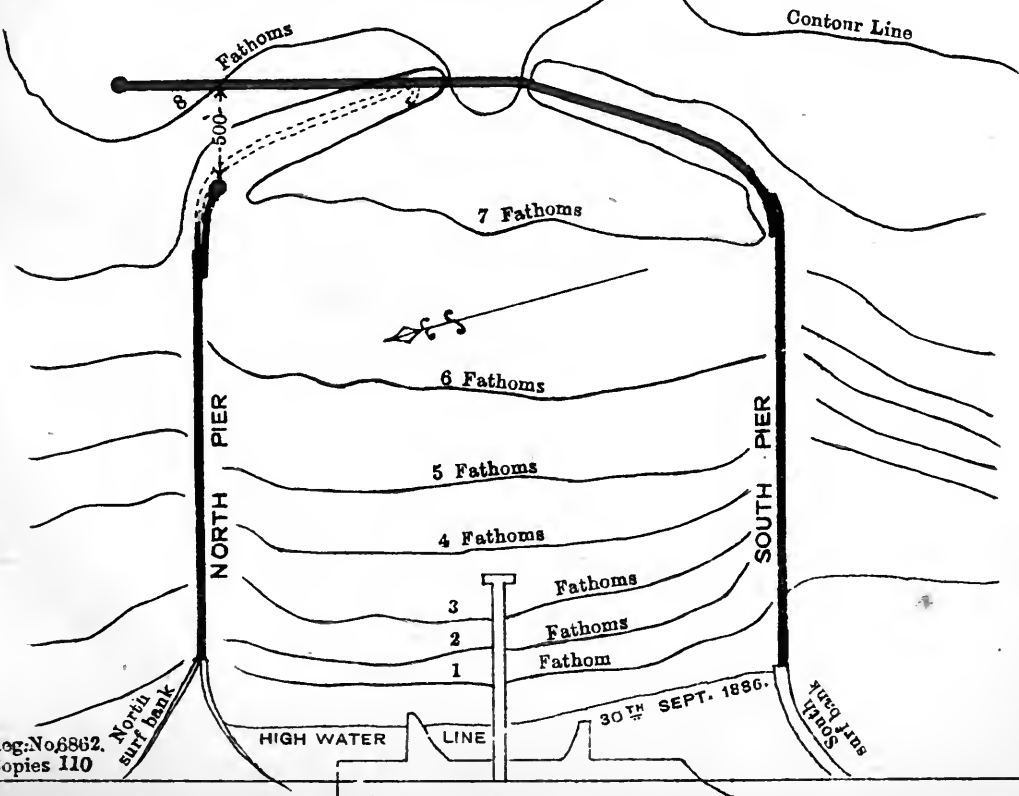
“The opinions of the captains of steamers frequenting the port differ materially. Some see considerable difficulty and danger in taking an entrance so placed, others see none. We give it as our opinion that, although it may not be so easy of ingress, and ships may be detained

No. 2
 MODIFICATION OF NO. 1 PROPOSED BY SUP^T. OF HARBOUR WORKS—1887.

SHEET NO. II



No. 3
 ALTERNATIVE PROPOSAL BY SUP^T. OF HARBOUR WORKS—1887.



SECTION ON LINE. A. B. (800 FT. NORTH OF NORTH PIER)

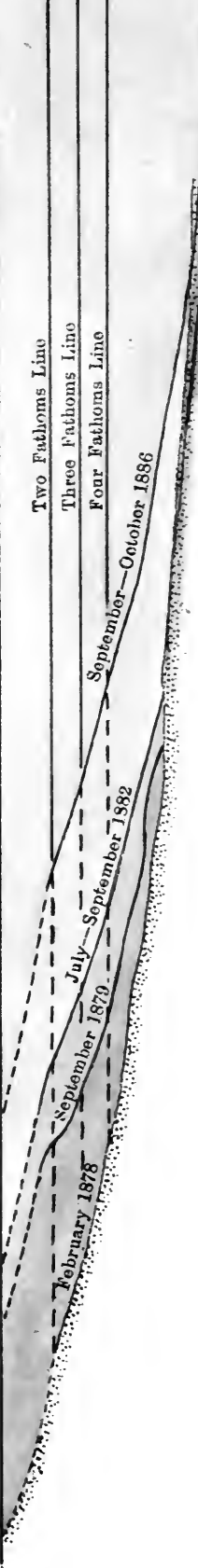
MEAN SEA LEVEL (DE HAVILLAND)



Two Fathoms Line
Three Fathoms Line
Four Fathoms Line

SECTION ON LINE. C. D. (300 FT. SOUTH OF SOUTH PIER)

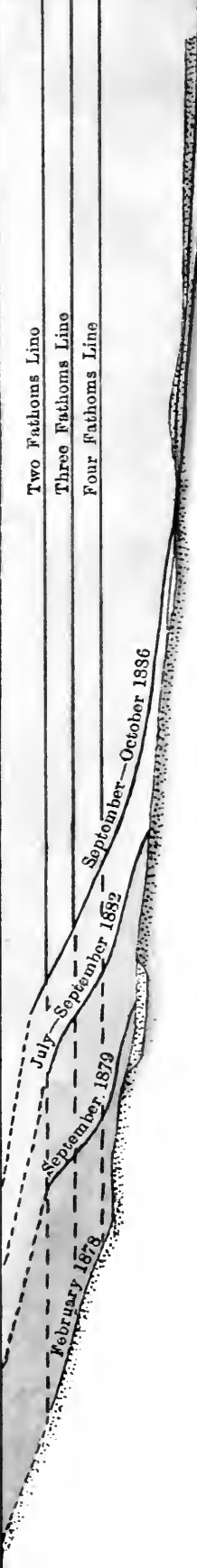
MEAN SEA LEVEL (DE HAVILLAND)



Two Fathoms Line
Three Fathoms Line
Four Fathoms Line

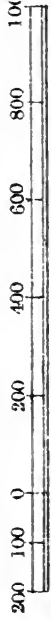
SECTION ON LINE. E. F. (1350 FT. SOUTH OF SOUTH PIER)

MEAN SEA LEVEL (DE HAVILLAND)



Two Fathoms Line
Three Fathoms Line
Four Fathoms Line

Horizl. Scale for sections 1 Inch = 400 Ft.



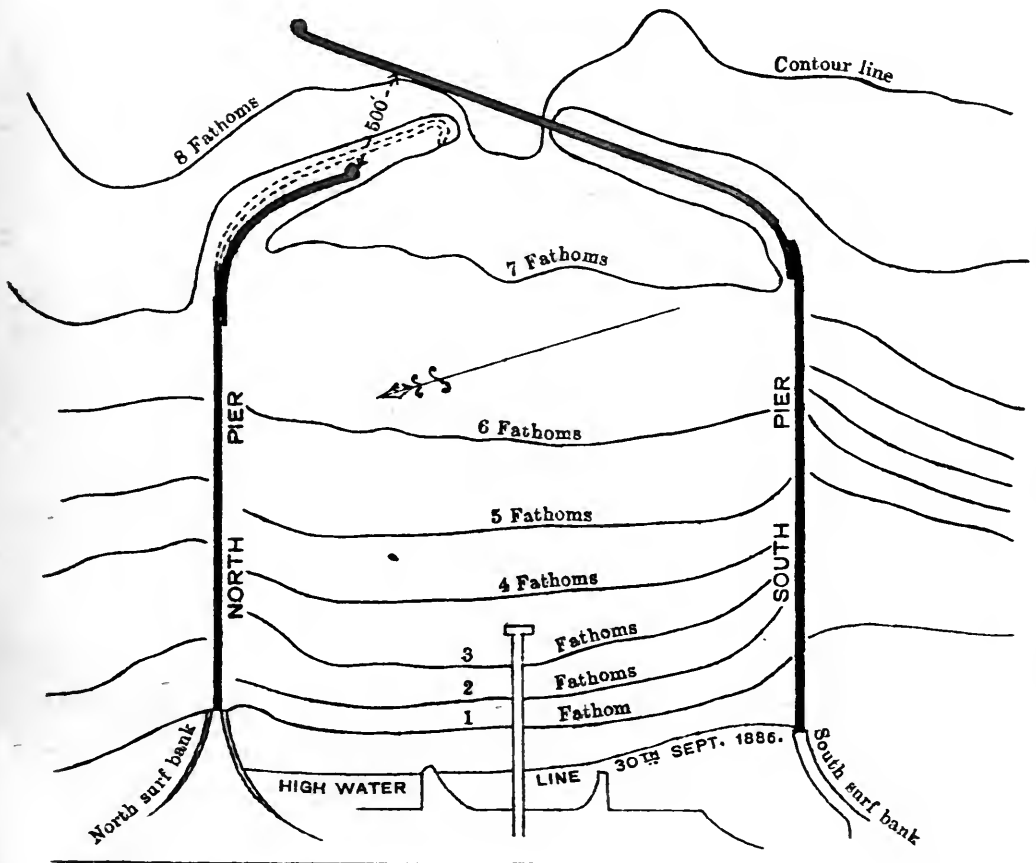
Vertical Scale for Sections 1 Inch = 40 Ft.



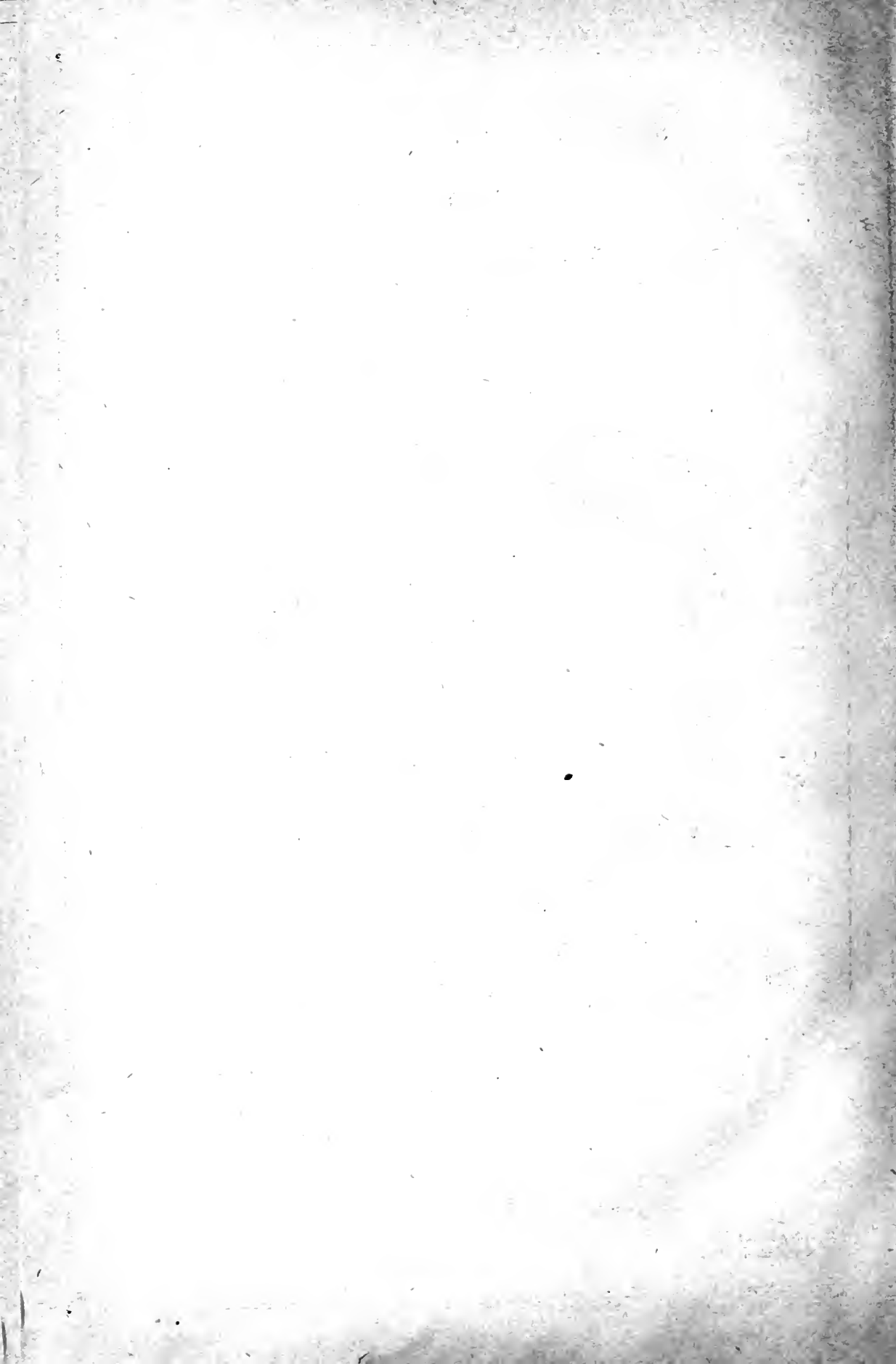


No. 4

ALTERNATIVE PROPOSAL BY SUPDT. OF HARBOUR WORKS—1887.



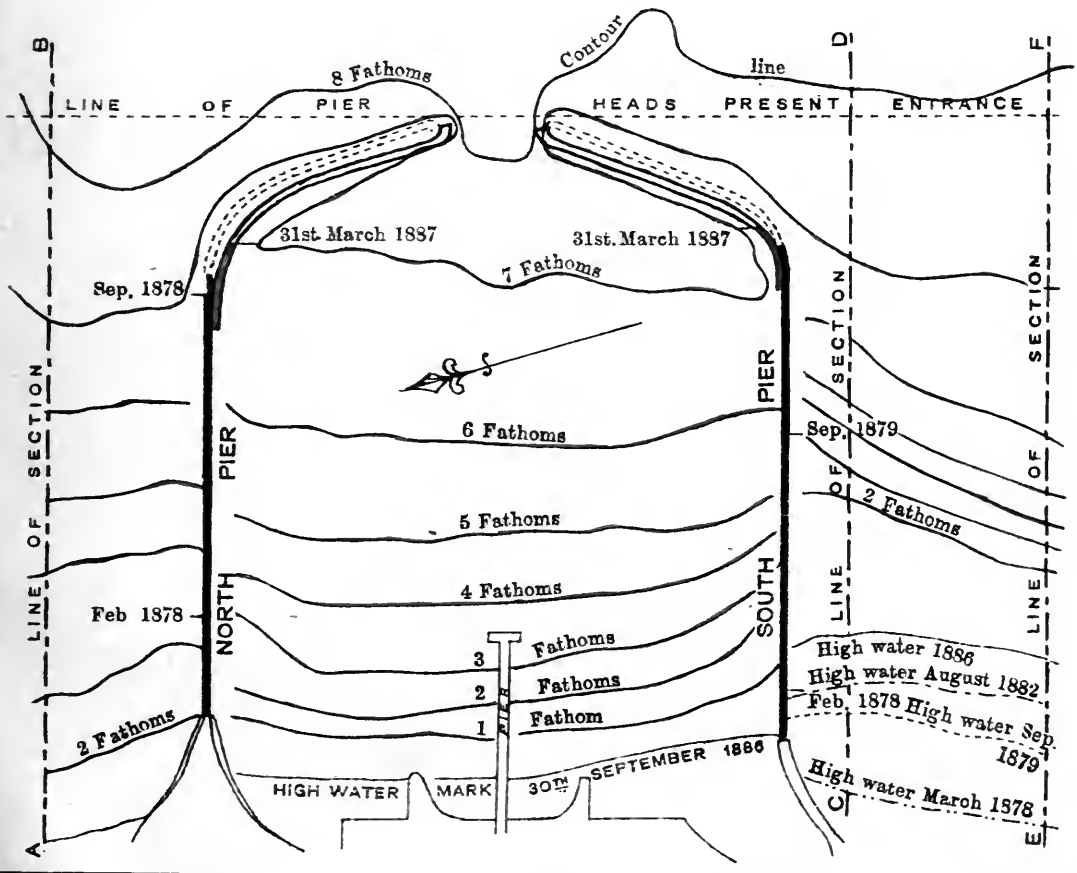
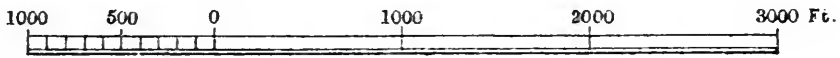
NOTE.—Contours in blue show depths in fathoms below DeHavilland's Mean Sea Level, September 1886.



MADRAS HARBOUR

TO ACCOMPANY REPORT OF COMMITTEE, APPOINTED BY VISCOUNT CROSS—APRIL 1887,
TO CONSIDER THE QUESTION OF THE ENTRANCE.

SCALE



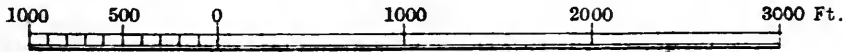
NOTE.—Contours in blue show depths in fathoms below DeHavilland's
Mean Sea Level, September 1886.



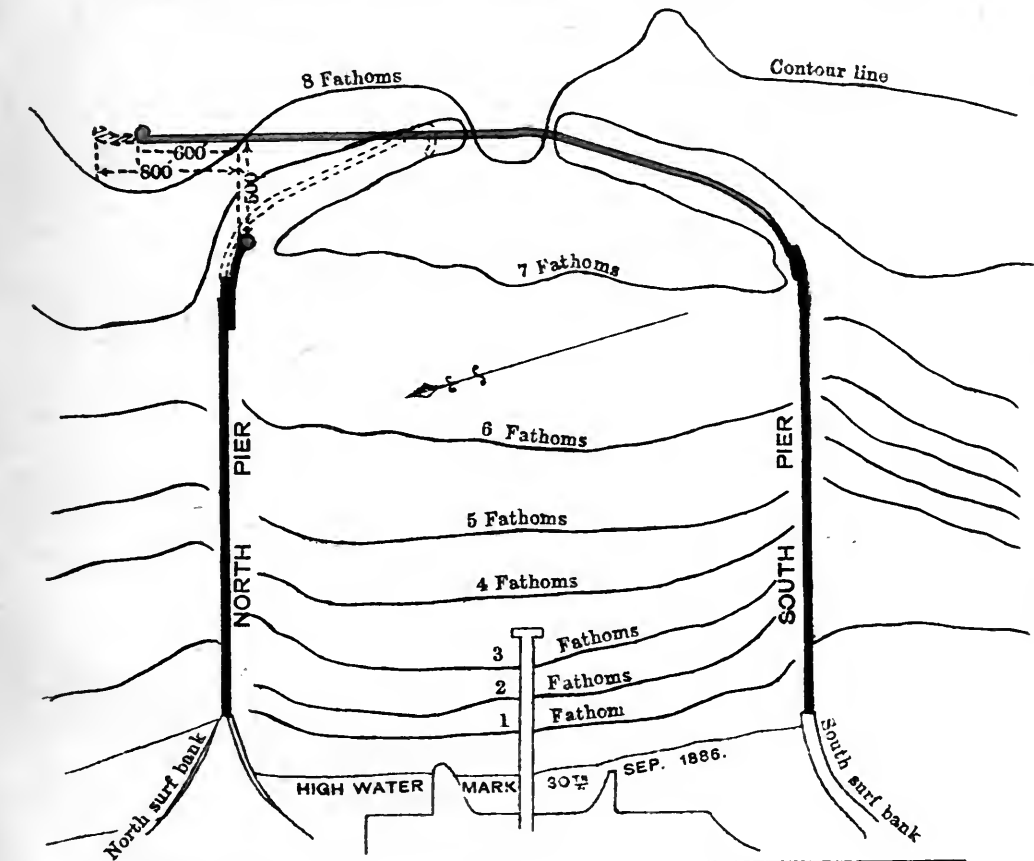
MADRAS HARBOUR

TO ACCOMPANY REPORT OF COMMITTEE, APPOINTED BY VISCOUNT CROSS — APRIL 1887,
TO CONSIDER THE QUESTION OF THE ENTRANCE.

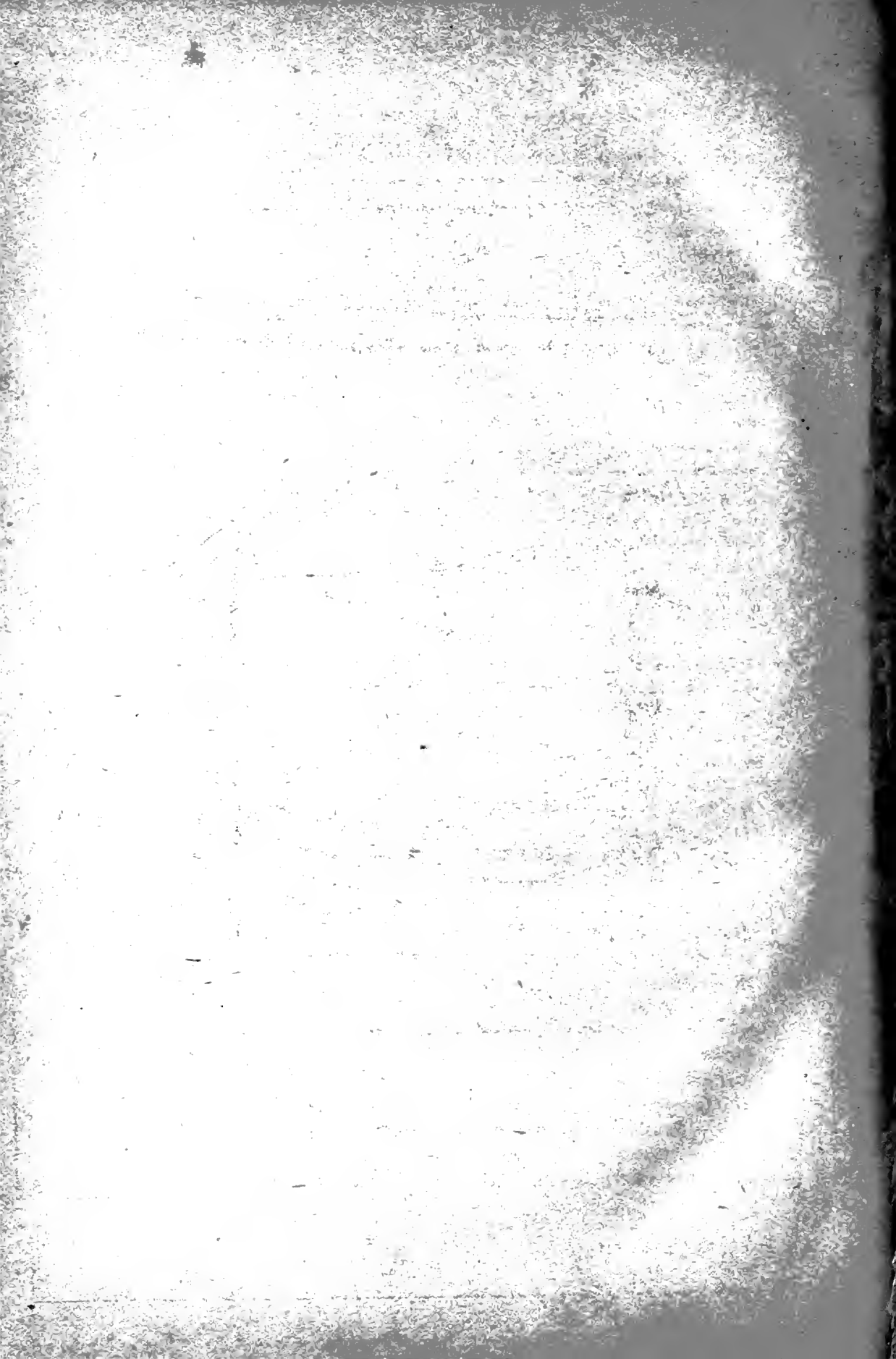
SCALE



WORKS RECOMMENDED BY COMMITTEE SHOWN IN RED COLOUR



NOTE.—Contours in blue show depths in fathoms below De Havillaud's
Mean Sea Level, September 1886.



outside more frequently than at present, the increased difficulty is not sufficient to condemn it.

“Experience alone can prove whether the harbour reconstructed, with the east entrance closed, and an opening made in the north-east corner, with a covering arm, will prove a safe anchorage during a cyclone. One captain only says that he would rather risk staying in than go out under such circumstances, while others look upon such a harbour as “a trap” from which there would be no escape. The Port Officer expects to be able to move ships about as in a dock, and the pilot thinks that, with warps and the ‘assistance of a tug,’ ships could be taken out on the approach of a cyclone. Our view is, that we should be indisposed to risk remaining in the harbour until it has been proved that vessels can lie there in safety during cyclones, but while admitting the doubt, especially if the harbour is crowded, we see no reason why, with proper appliances, ships should not be got safely out on receiving warning.

“Having carefully weighed all the evidence we have been able to collect, which comprises the views of all classes interested, or who have had opportunities of forming an opinion, we pronounce in favour of an entrance at the north-east corner, with a covering arm, and that the entrance on the east face be closed up.

“Of the four plans submitted to us by the Madras Harbour Trust Board we give the preference on nautical grounds to Plan III, but with an addition to the length of the covering arm. What the precise length should be can be best determined by experience. We are of opinion, however, that the overlap should not be less than 600 feet, and need not be more than 800 feet.

“According to an approximate estimate which we have obtained from Mr. Parkes, the cost of completing the harbour with a north-east entrance, if the overlap be 600 feet, will be Rs. 22,81,345, and, if the overlap be 800 feet, Rs. 25,56,611, in excess of the cost of completing the harbour on the design adopted in 1884, with an east entrance 450 feet wide, estimated by Mr. Parkes in August 1884 to be Rs. 45,90,051, out of which about 21½ lakhs had been expended up to 31st March last.

“It appears, therefore, according to the estimates put before us by Mr. Parkes, that the expenditure to be incurred as from 31st March last, in executing the work according to our recommendation (shown in red colour on Drawing No. III annexed to this report) will amount to about 47½ lakhs of rupees with an overlap of 600 feet, and to about 50 lakhs of rupees if it should be found necessary to make the overlap 800 feet.

“In this estimate it is assumed that the *débris* of the old work will be removed to a depth of 36 feet below low water of lowest tides throughout the new entrance, which depth we regard as a minimum, and we are distinctly of opinion that not less than this should be sanctioned.”

This report was forwarded by the Secretary of State to India accompanied by a note by Mr. Parkes criticising the report. Mr. Parkes was of opinion that the sand difficulty had been exaggerated and would not be of practical importance for 50 years, that the nautical evidence as to the superiority of a north-east entrance was very far from being unanimous, and that the work might well be virtually completed according to the original design before the north-east entrance was commenced. The Harbour Trust Board and the Government of Madras both concurred in Mr. Parkes' opinion as to the sand travel, but considered that the north-east entrance as proposed by the Committee should be accepted and commenced at once.

On 31st July 1888 Mr. F. N. Thorowgood resigned his post as Superintendent of the Harbour works and was provisionally succeeded by Mr. A. L. Pogson.

On 1st October 1888 Mr. Pogson submitted to the Harbour Board a proposition which is produced without alteration.

"In reply to your letter No. 1952, dated 9th August, forwarding the Board's Proceedings of 7th August 1888, and calling for further information regarding the cost of carrying out a north-east entrance under design No. III.

"I have the honour to state that I consider Mr. Thorowgood's letter No. 1404, dated 16th February 1888, with his estimate of Rs. 75,98,414, to be as explanatory as I can make it, considering the uncertainty of ever being able to remove the ruins by floating dredgers; and the detail plan I now submit, will, I hope, convince all concerned that the only reliable way to raise or remove the old wall is from a fixed base, viz., a masonry pier. Of course had there been 10 or 15 feet of water over the ruins, a dredger would have no difficulty in working.

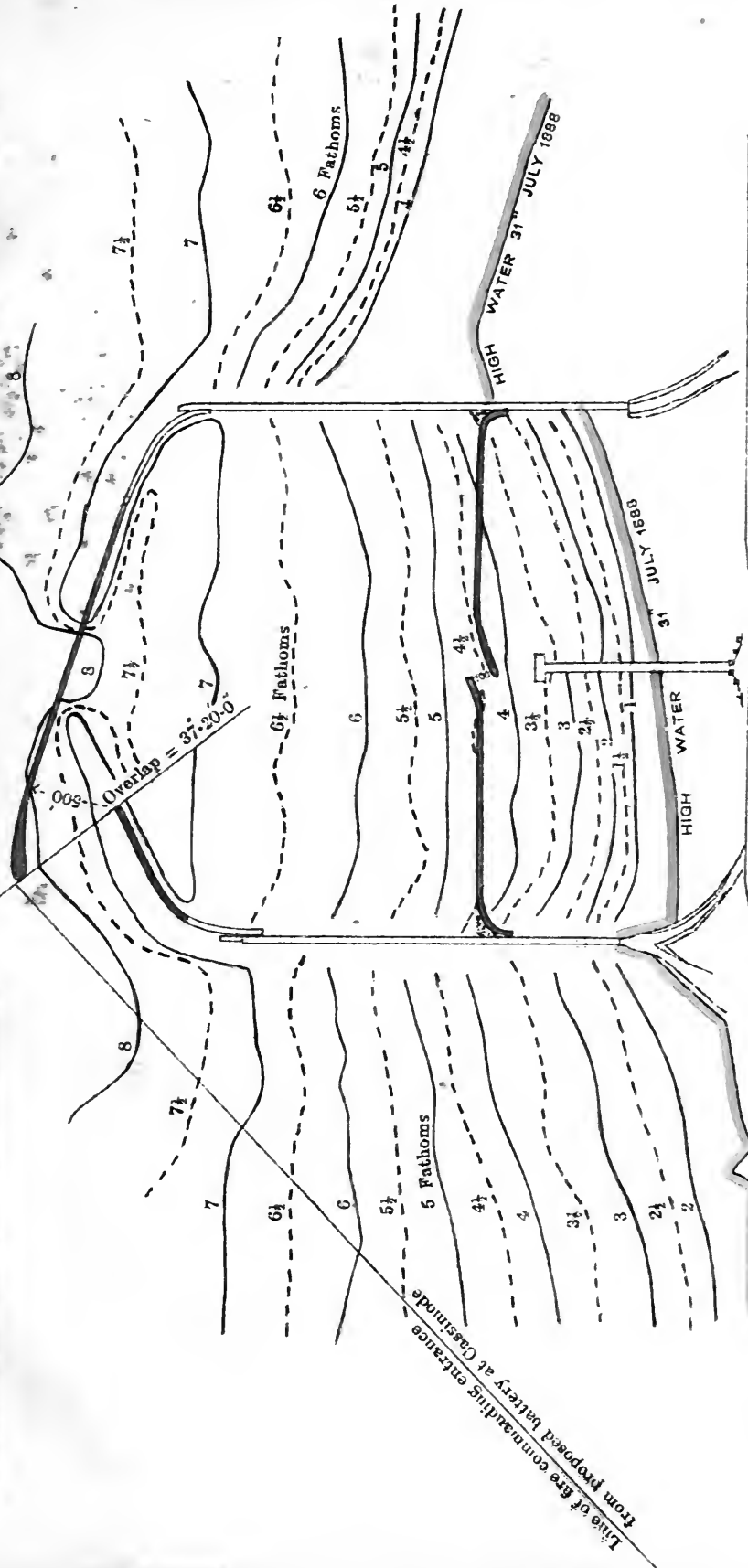
"With my proposition to remove the old wall, I propose to use a crane (working from a temporary structure), and therewith dredge down to a depth of 20 feet, then remove the rubble with a floating dredger.

"To commence dredging, and to open a north-east entrance at once, as in design No. III, would be an irrevocable decision and would condemn, without a fair trial, a design which has been approved of by eminent engineers and authorities. I certainly think a design (for an entrance) preferable where the eastern entrance can first be *proved* a failure, or otherwise; before condemning it and thereby delaying completion for 4½ years, besides burdening the port with an additional outlay of upwards of 26 lakhs, that may or may not give all the requirements, and shelter to future jetties, wharves, and heavy lighters, which it is wished to obtain.

"Under these circumstances, I have endeavoured to produce a design for a north-east entrance which will overcome all these difficulties and put

MADRAS HARBOUR

NO. IV A



NOTE.—Old work shewn in black, proposed & now works shewn in red.
The contour lines shew the depths below DeHavilland's Mean Sea level in Septbr, 1886

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MADRAS HARBOUR NO. IV A

PLAN AND SECTIONS FOR NORTH-EAST ENTRANCE ACCOMPANYING ESTIMATE AND LETTER BY SUPD'T.

No. 909, dated 1st. October 1888.

NOTE.

- ESTIMATE No. 1** Neutral tint shows progress completed to 31st August 1888, (sanctioned estimate) expenditure Rs 26,52,113.
- " " Red shows design No. IV A (Permanent work)
- " " Blue " Temporary work (Necessary to complete) N. E. entrance.
- " " 3. ----- Rod " Proposed North-East entrance, No III by F. N. Thorowgood Esq., letter No. 1404, dated 16th Feb. 1888.

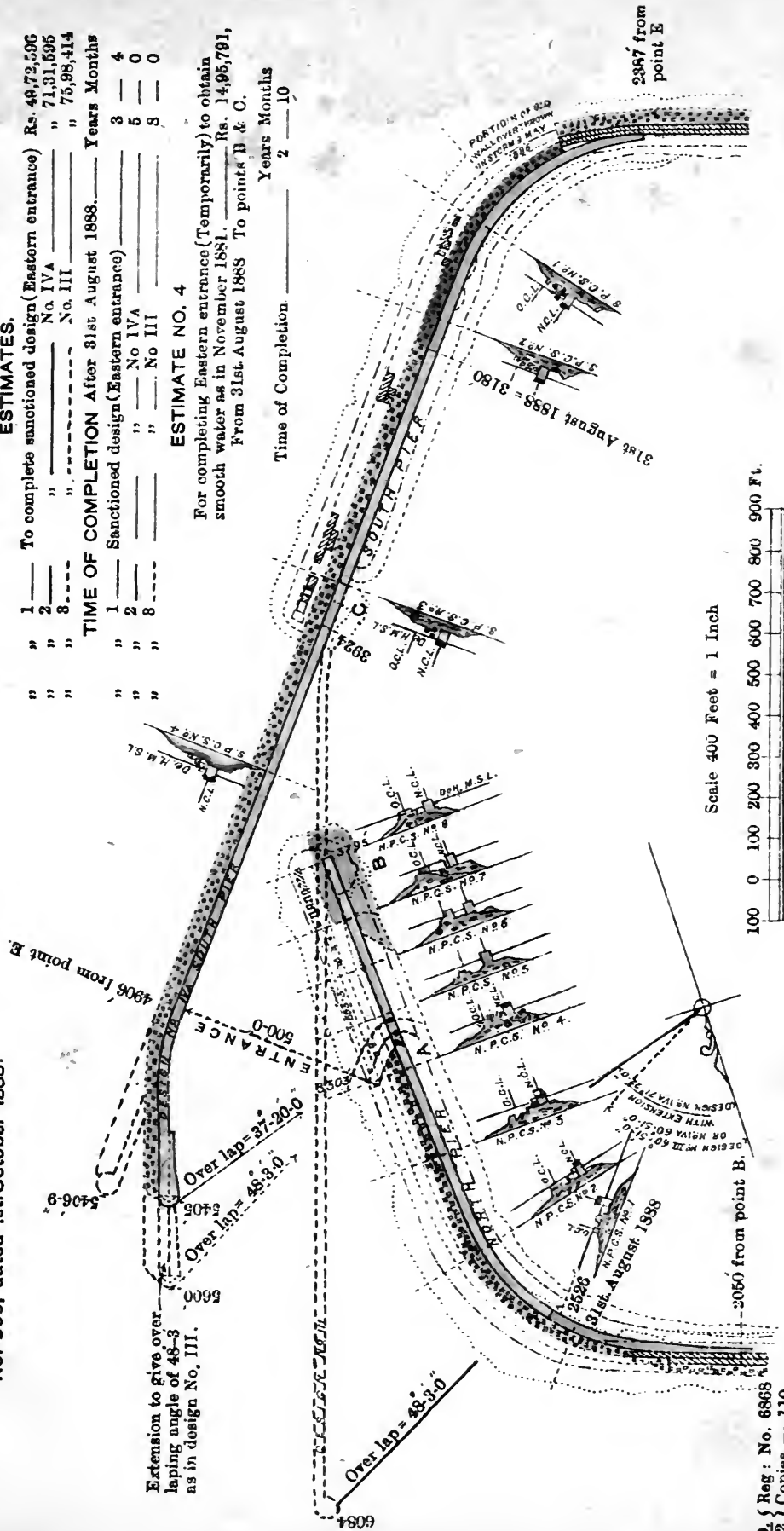
ESTIMATES.

"	1	To complete sanctioned design (Eastern entrance)	Rs. 48,72,500
"	2	" " " " " " " "	No. IV A " 71,31,595
"	3	" " " " " " " "	No. III " 75,98,414
TIME OF COMPLETION After 31st August 1888.			
"	1	Sanctioned design (Eastern entrance)	Years Months 3 4
"	2	" " " " " " " "	No. IV A " 5 0
"	3	" " " " " " " "	No. III " 3 0

ESTIMATE NO. 4

For completing Eastern entrance (Temporarily) to obtain smooth water as in November 1881. Rs. 14,96,791, From 31st August 1888 To points B & C.

Time of Completion _____ Years Months _____ 2 _____ 10





Mr. Parkes' design to the test; and should the water eventually be found smooth enough for the *shipping*, the harbour could be completed on the sanctioned design and probably within the cost of the estimate. Then I should urge the Trustees to look to improvements inside the harbour, to secure the cranes, lighters, sailing ships and native craft in cyclones. This I propose to carry out by building the inner walls shown on the lithographed plan and estimate No. 5 at a cost of Rs. 12,80,213.

"If Mr. Parkes' design does not give smooth enough water for all practical purposes, then my design No. IV-A could be proceeded with, and completed in five years from now, at an extra cost of Rs. 21,58,999.

"The mode of procedure under design No. IV-A, estimate No. 2, for Rs. 71,31,595, will be as follows:—

"*Design No. IV-A, north pier.*—The north pier will be proceeded with strictly in accordance with the sanctioned design as far as point A.

"From A to B a pier of the sanctioned bonded superstructure will be built, but not protected with wavebreakers, until the eastern entrance has been tested and accepted or *condemned*. If the former case, the pier from A to B can be made permanent by adding the 'wavebreaker' etc., in a very short time. If the latter decision is come to, then I propose to dredge up the old wall with the combined 'wavebreaker and dredging crane,' down to the rubble base; then remove the temporary wall (in blue on plan), the blocks to be transferred and re-set at the south pier; advancing it as the north pier recedes; and thus maintaining an entrance varying from 500 to 550 feet, but gradually *developing* into a north-east entrance. The rubble base would be dredged up in sections of 50 feet with a self-propelling Priestman's dredger.

"*South pier.*—The south pier will proceed as far as point C as fast as possible, and will also be strictly in accordance with the sanctioned design, and be thoroughly protected with wavebreaker blocks and the old wall.

"At the south pier we have the wavebreaker crane already transferred from the north pier.

"*Time of completion.*—In two years and ten months from the time of commencement, the points B and C would have been reached, and the harbour would then have an eastern entrance of 527 feet (but without the pier heads, hereafter explained), at a cost of Rs. 14,95,791 from 31st August 1888. See estimate No. 4.

"It will then be for the Trustees to decide whether the sanctioned design is to be completed, or whether my design for a north-east entrance is to be carried out; in other words, whether they prefer to spend Rs. 12,80,213 to 'improve the facilities for landing and shipping cargo' as fast as they can be discharged from the ships side, and enabling them to have 100-ton iron lighters ready loaded and alongside within an hour after the return of a steamer which has had to proceed to sea during a cyclone; or

whether they will spend an additional Rs. 21,58,999 over the north-east entrance No. IV-A and do without the landing and beach improvements, till the port can afford the extra outlay.

“Should the position of the north-east entrance, then ultimately decided upon, be No. IV-A, *no money* will have been wasted on the test, and condemnation of Mr. Parkes’ design; and the north-east entrance can be proceeded with at once as in estimate No. 2, and will have cost from 1875, Rs. 71,31,595 when completed.

“*Extension.*—If on reaching the end of the southern arm the overlap is not considered sufficient, the extension shown in red (dotted lines) can be added, which will give the same overlapping angle as in design No. III at a total cost given in estimate No. 2 which will be Rs. 74,36,566; but the overlapping angle in design No. IV-A already exceeds that considered sufficient by Sir G. Molesworth, and I think the Trustees could not do better, than to accept an opinion coming from so high an authority as decisive.

“I may add that the depth of water at the pier head No. IV-A will only be one foot greater than pier head No. III; but this extra depth will not weaken the arm, as I have allowed (in the quantities) for the base being 11 feet wider than in No. III and the pier head, which I propose, will be 50 feet across as against Mr. Parkes’ pier head 38 feet in width.

“*Pier heads.*—The pier heads shown in estimate No. 1 include the superstructure, wavebreaker and base, etc. complete, from the commencement of widening out from the 24 feet wall. These pier heads, under present design, necessitate a decision being arrived at when the piers have advanced to within 300 feet from the end of each pier head, so that with 600 feet short length of piers, added to the sanctioned entrance of 450 feet, there would remain (as a minimum) an opening of 1,050 feet, and if a north-east entrance is then decided upon, this would mean condemning Mr. Parkes’ design before it has had a fair trial.

“But, with a view to *proving* whether the eastern entrance will be the anticipated failure or not, I have designed a pier head (a model of which I shall be able to submit to the Trustees in a few days, with a detailed drawing), under which design a pier head can be formed, at any distance along the arm, at a cost of Rs. 95,644 (see estimate No. 2, South Pier). By this means, the main piers can be advanced to within 38’ 6” short of the proposed ends of the pier heads, so that, to test an entrance of 450 feet, I can give (temporarily) an entrance 23 feet narrower than the entrance *was* in November 1881, viz., Mr. Parkes’ entrance = 450’ + 38’ 6” N.P. + 38’ 6” S.P. = 527 feet; entrance of November 1881 = 550’—527’ = 23 feet less than the old design. I can then, under my design, add the pier heads, and complete an entrance of 450 feet; or, at the Trustees’ option, remove the north pier between A and B, still unprotected by the wavebreaker, and extend the south pier, if a north-east entrance is to be carried out; while with Mr. Parkes’ old design for the pier heads the work must be permanent.

“ Another point strongly in favour of my design for a pier head, is that the cost will be considerably reduced, as the Trian cranes will work straight ahead; while to build the pier heads as constructed in 1881, the present cranes will have to be turned after every course set, and no one knows better than I what will be the difficulty, responsibility, and extra labour.”

With Mr. Pogson's letter are here printed the letter with which it was forwarded to the Government of Madras, the order of that Government upon it, and the reply of the Secretary of State sanctioning prosecution of the work on the lines proposed :—

“ I have the honour to acknowledge the receipt of G.O., No. 2335 W., Public Works, dated 1st August 1888, and to submit herewith, for the information of Government, copy of letter No. 909, dated 1st October 1888, from the Board's Engineer furnishing all details that the late Superintendent has left on record with regard to No. III design, and further forwarding his report, plans and estimates for carrying out a modification of plan IV; also copy of a resolution passed thereon by the Trustees at their meeting of 5th idem, in accordance with which a telegram was despatched to you that evening, copy of which is enclosed.

“ 2. In my letter No. 69, dated 6th April 1888, paragraph 7, I informed Government that the Trustees preferred ‘ plan No. III, but . . . any modification of plan III or IV, or any plan, which will give them . . . this (smooth water) within a reasonable time, at a cost which the port can afford to pay, is all they have contended for as being absolutely necessary.’ The enormous mass to be removed to carry out plan No. III has never until now been clearly explained to the Trustees, nor has the great protection the old, partly submerged, wall will afford to the new work ever before been clearly demonstrated, as has now been done, in the cross sections shown on the plan forwarded herewith, and the Board are now of opinion, in view of this very clear information afforded by their Engineer, that the danger of repeated wreckage of dredging plant, and the uncertainty as to the time of completion, are fatal objections to Mr. Thorowgood's proposals, although approved by the Home Committee, who, however, were not in possession of the information now placed before the Board, and only approved of plan No. III on *nautical* grounds.

“ 3. The Trustees observe that in his note, dated 27th June 1888, the Honourable Colonel Hasted remarks that ‘ It may possibly prove, as the best way of completing the harbour expeditiously, that the northern arm should be nearly completed on the lines of the present design, so that one crane could be used in constructing the protecting arm of the committee's approved plan while another is pushing on the southern arm, but it can hardly be the most economical plan, and it should be considered, if this method of working is to be adopted, whether the section of the work, which

would only have to stand for a year or two, should not be modified with a view to the easy removal of the blocks as soon as the protecting arm is completed.' The Trust now note that Mr. Pogson's proposals for carrying this suggestion into effect would appear to be not only the most expeditious, but also the most economical. I should mention here that a sketch of the modification of the design of the proposed completed entrance, No. IV-A, has been shown to Sir Guilford Molesworth by one of the Trustees, Mr. Hanna, M.I.C.E., now at Simla, and has met with his 'entire approval,' and Sir Guilford has authorized me by wire to use this expression of his opinion.

" 4. The Trustees unanimously approve of Mr. Pogson's proposals for a north-east entrance and prefer his plan to all others that have come before them. As regards his remarks at paragraph 27, the Trustees have no possible objection to this plan affording as it progresses further practical information as to what would be the effect of an eastern entrance when completed. If, then, it is found that an eastern entrance will not give sufficiently smooth water, the Board are unanimously of opinion that plan No. IV-A should be adopted, if the financial position of the port will admit of it. Smooth water is essential, and if they obtain this, as they have clearly expressed themselves in their No. 69, dated 6th April 1888, the precise plan by which that result can be obtained is a matter of comparative indifference; but the one now submitted seems more likely than any other, to effect this economically, by using the debris of the old submerged works, as well as utilizing the shelter afforded by it, and the Board have therefore adopted it; and if Government approve of the Board's resolution, I am desired to request that the matter may be referred to the Secretary of State for sanction and that his decision may be communicated by wire, so that the Trustees may be in a position to direct Mr. Pogson to resume work upon the sanctioned design at the north arm immediately the conclusion of the coming north-east monsoon renders active operations practicable.

" ORDER—dated 17th November 1888, No. 3644 W., Public Works.

" The Right Honourable the Governor in Council resolves to submit the papers forwarded by the Harbour Trust Board to the Secretary of State for decision. The plan proposed is in accordance with Mr. Parkes' suggestions and merits much consideration.

" 2. Ordered that the Secretary of State be addressed.

(True Extract.)

(Signed) H. R. MEAD, Colonel, R.E.,
Ag. Secretary to Govt., P.W.D.

To the Chairman, Harbour Trust Board.

„ Marine Department.

Letter to the Secretary to the Government of India, Public Works Department, dated Fort St. George, 17th November 1888, No. 3645 W.

“I am directed to forward herewith, for the information of the Government of India, a copy of the Proceedings of this Government, No. 3644 W., dated 17th November 1888, together with copy of the despatch to the Right Honourable the Secretary of State submitting proposals for the completion of the Madras Harbour Works.

(Signed) H. R. MEAD. Colonel, R.E.,
Ag. Secretary to Govt., P.W.D.

Despatch from the Right Honourable the Secretary of State.

“I have received Your Excellency’s P.W. letter, No. 24, dated 17th November 1888, forwarding a letter from the **Reconstruction of Madras Harbour Trust Board**, submitting detailed proposals for completing the Madras Harbour.

“The design for the entrance which now finds favour with the Trust Board is a modification of the plan IV, considered by the London Committee of 1887, and, in common with the plan A proposed by Mr. Parkes, possesses the advantage of allowing the works of reconstruction to be continued, for the present at least, on the lines of the sanctioned design, and thus affording an opportunity of practically testing the effect of an eastern entrance before taking an irrevocable decision to adopt an entrance facing the north-east. On the other hand, if the plan III, recommended by the Committee of 1887, were adopted, it would be necessary to stop all further progress on the northern arm of the harbour and to proceed at once to clear a north-east entrance.

“I do not now propose to enter upon a discussion of the merits of the different forms of entrance which have been proposed, but I have arrived at the decision communicated to you in my telegram of the 24th December 1888,

Telegram to Governor of Madras, dated 24th December 1888.

“Resume Harbour works as proposed and prepare abutment blocks. With regard to general scheme despatch follows.”

should be adopted. This decision will, however, finally set aside the plan III, recommended by the Committee of 1887.”

noted in the margin, that the work of reconstruction should proceed in accordance with the old design, leaving, for further consideration, the exact form of entrance which

On 5th February 1889 Mr. Parkes died and was succeeded in the post of Consulting Engineer by Sir A. Rendel. The question of the precise form of north-east entrance to be adopted being still a subject

of discussion was referred to that gentleman, who replied in a preliminary report of which the following is an extract :—

* * * *

“ 10. In respect to the second section of paragraph 4, if I understand it rightly, it means that a part of the north breakwater is not to be protected by a wavebreaker at all until the position of the entrance is finally determined by experiment. If this be the meaning of the paragraph, then we must consider if the wall is strong enough alone to stand an exceptionally heavy gale. However temporary may be the existence of the wall, it must plainly from the first be made to a section that will stand under the worst possible circumstances. It seems to be supposed that the wall, as now designed, will stand under the worst circumstances without the aid of the wavebreaker. I confess that I have doubts on the subject, and should like to see the wavebreaker constructed, *paxi passu*, with the wall.

“ 11. This brings me to the vexed question of the position of the entrance ; and here it appears to me that, so long as the question of its ultimate position remains undetermined, there will be vacillations and delays, and perhaps mistakes ending in disasters, and that it is highly desirable to set the question at rest as soon as possible. For my part, I cannot believe that the science of marine engineering is in so low a condition that a point of this kind can only be determined by an experiment which contemplates the possibility of our having to resort to the costly process of taking up several hundred feet of breakwater. And I feel it so necessary that the question should be settled at the earliest possible moment once and for ever, that, at the risk of being thought too ready to express an opinion upon it, I do not hesitate to say that, in my judgment, the eastern entrance as at present designed is a proper one, is a better one than any alternative which has yet been proposed, and is the best which, under present circumstances, can be devised.

“ 12. To make a harbour secure at the expense of its accessibility, which to my mind is what the best of the north-east entrances yet proposed would do, is a worse fault than to make it accessible at the expense of its security, because we can as a rule improve the security by internal works, and we cannot improve the accessibility except by costly alterations which will diminish the security.

“ 13. The simple fact, in my judgment, is that the present scheme for a harbour at Madras will make no harbour worth the name at all. What it does make is a satisfactory entrance to a harbour yet to be designed within it.

“ 14. A harbour, it seems to me, is of little value to Madras unless it provides a quay wall alongside which ships may lie as in a dock, and take in or discharge their cargoes in perfect quiet and security, and there seems no difficulty in providing such a quayage at a cost which the result would

fully justify. But, be the cost what it may, it seems to me that Madras is worth a safe and commodious harbour.

“ 15. The type of harbour to which Madras belongs is very much that of Whitehaven, a copy of the chart of which I append to this report. Many years ago I was Consulting Engineer to this harbour, and I know it well. We have here an outer harbour, forming an approach, and nothing but an approach, to two inner harbours, each so enclosed by quays that ships lie undisturbed within them, with a space between them opening directly on to the outer harbour, and forming a beaching ground for ships and waves. It would be easy to devise a similar scheme for Madras, which would give it, say, 60 acres of enclosed dock (gates of course are not required), 9,000 feet lineal of wharfage, and 40 acres of quay space, enough to make it a first-class port for a very large trade. Or, if it be preferred, the adjacent shores outside the harbour might be utilised for the purpose, and of course a combination of both ideas is possible. I claim no priority in suggesting either plan. Mr. Parkes has, I believe, roughed out the latter idea, Mr. Thorowgood, the former, quite independently of me. But I may say, as a corroboration of their views more than anything else, that the first of the two schemes I have now suggested I broached when the harbour was first proposed; and I may add that, if it be adopted, the entrance might be kept at the width originally given to it of 500 feet, which is by no means more than it should be.”

The Harbour Board replied to Sir A. Rendel's report on 29th August 1889 in a letter which is summarised in a communication from the Madras Government to the Government of India printed below:—

“ With his despatch to this Government, No. 7, Public Works, dated 23rd May 1889, the Right Honourable the Secretary of State for India forwarded a preliminary report drawn up by Sir Alexander Rendel, K.C.I.E., regarding the reconstruction of the Madras Harbour and the position of the entrance, and requested that the views of this Government on the important recommendations made therein should be communicated to the Government of India.

“ 2. In compliance with these instructions, I am now directed to forward a copy of a letter* from the Chairman, Madras Harbour Trust Board, setting forth the conclusions at which the Board has arrived after careful consideration of the report. Those conclusions may be briefly stated as follows:—

- (1) That the present section of the harbour walls, with 40-foot wavebreaker protection, and the further protection at the most exposed parts, afforded by the ruins of the old walls, is sufficiently strong.

* Proceedings of Government, No. 2652-W., dated 23rd September 1889.

- (2) That the only portion which may require an increased section, will be the overlapping arm which must be built should a north-east entrance be eventually decided upon.
- (3) That the Board is strongly opposed to the proposal to place the wavebreaker blocks in orderly rows, and considers that the main feature of the present design is the wavebreaker protection of 'random' work, which experience has shown answers admirably, while the orderly rows do not satisfactorily break up the waves.
- (4) That the question of the position of the entrance should be decided hereafter by practical experience.
- (5) That no useful purpose will be served by, at present, discussing Sir A. Rendel's suggestions regarding the provision of an inner harbour for ships, with quays, etc.

" 3. The general conclusion at which the Board has arrived is that the work should be prosecuted nearly to completion on the lines of the present sanctioned design, and that the question of the position of the entrance should be left to be finally determined hereafter when experience has shown whether or not an eastern opening gives sufficiently smooth water.

" 4. I am directed to say that this Government fully concurs in the views expressed by the Harbour Trust Board. Notwithstanding anything which may be said to the contrary, this Government is of opinion that the Madras Harbour as it is being constructed at present, must be regarded as an experiment, and that to attempt to finally fix the position of the entrance now would be a fatal mistake. Experience alone can show, after completion of the piers on the sanctioned design, whether an eastern opening will give practically smooth water; and if it is found that this object has been secured, no one will dispute that it would be useless to make a north-east opening at an additional cost of 21½ lakhs of rupees.

" 5. This Government sees no reason to doubt the correctness of the other conclusions arrived at by the Board, and as regards the inner docks and quays suggested by Sir A. Rendel, it has yet to be shown that the trade of Madras requires them and that the port is financially capable of providing them.

" 6. In conclusion, I am to say that if the work is allowed to proceed on the present lines, this Government and the Harbour Trust Board will probably in less than two years' time have actual facts to guide them as to the further steps to be taken."

In February 1890 Sir A. Rendel visited the harbour and informed the Trustees that he was strongly of opinion that the tentative portion of the north arm should be thoroughly protected by a 40 feet wavebreaker in the same manner as the rest. Should a north-east entrance be later decided on this wavebreaker would undoubtedly be difficult to remove,

but without it the wall might be immediately destroyed and the east entrance would not receive a fair trial. These views were confirmed by him in a report forwarded by the Secretary of State on 31st December 1890, in which however he added that he had not raised the question of the entrance, because he found that the Trustees held a very strong opinion that a north-east entrance was proper, while his own view was that the evils of an east entrance should be overcome by interior works; and the tentative prosecution of the works on the sanctioned design luckily satisfied both views for the time being.

By this time the erosion to the north of the harbour had assumed formidable dimensions and had been treated by rubble walls to be dragged down by the sea at its pleasure. Should this be unsuccessful Sir A. Rendel considered it might be necessary to protect the shore with concrete blocks parallel to it and possibly also at right angles.

On these lines the harbour works were steadily prosecuted until the end of 1892, by which time it became necessary to consider the pier heads; and on 31st December of that year Mr. Pogson, in his quarterly report of progress, made the following proposition:—

“ 10. Owing to the more rapid progress the north pier has made over the south arm since the suggestion was made in Sir A. M. Rendel’s minute of 25th February 1890 to finish the south pier off with a caisson, and the north pier in blockwork temporarily, in case the entrance should eventually be altered, it is now quite evident the north pier will be completed first, and as the crane for setting the caissons is at the north pier, and apparently no doubt now exists as to which is to be the final entrance to the harbour, it would be more economical to complete both piers with caissons without delay and look to docks for any further improvement necessary in the state of the sea, inside the harbour in rough weather.”

To this proposition the Secretary of State agreed. From now onwards the work proceeded smoothly if slowly, the chief point of interest to be noted in the quarterly reports being the difficulty, danger, and delay in removing old work and preparing the rubble bed for new work. The north pier caisson was set in April 1894 and the concrete capping was proceeded with, and in March 1895 the south pier caisson was set; and by the end of that year the harbour with an east entrance was practically completed. The construction accounts were closed in June 1896. Up to that date the expenditure had been as follows:—

Total expenditure	..	..	..	Rs. 1,26,21,212
Expenditure previous to 1883	..	..	..	61,41,985

The Harbour Trust was debited with the difference between these sums, viz. Rs. 64,79,227, on which interest at $4\frac{1}{2}$ per cent. was required by Government.

It is to be remarked that by this time the entrance had already shoaled $2\frac{1}{2}$ feet by accretion of sand from the southward, while high-water mark on the sandy beach against the south arm was steadily advancing at an average rate of nearly 70 feet a year, and accretion was perceptible at a distance of 5 miles south of the harbour. The seriousness of this shoaling received the close attention of the Harbour Trust and the professional officers of the Government, by whom full particulars were communicated to Sir A. Rendel. The latter after full consideration advised the tentative use of a suction dredger, the cost of which would be about 2 lakhs. Such a dredger he thought would be able to remove the deposit of each year in less than 90 days, the limit of time during which the weather would permit of its working at Madras.

In 1897 a special marine survey was made by Lieutenant Beauchamp, R.I.M. This officer in summarising the results stated that between 1876 and 1897 the depth between the pier heads had decreased by 3 feet, the corners of the harbour had all shoaled by 3 feet to 4 feet and the fore-shore had advanced 350 feet, that south of the harbour the point where highwater mark met the breakwater had advanced 750 feet since 1886 and probably 1,800 feet since 1876, but that all to the northward and all outside the 7 fathom contour south-eastward and eastward remained the same.

The Harbour Trust having expressed its unwillingness to go to the expense contemplated by Sir A. Rendel, the Madras Government sold to them the bucket dredger "Wenlock" for Rs. 1,04,000, and this vessel was then converted into a suction dredger at a considerable cost. To close this subject it may be stated in brief that this dredger has never worked well and in spite of expensive alterations has hitherto been useless. If there had been a dry dock in Madras it would probably be possible to render the dredger of some service.

Besides dredging there have been, since the completion of the harbour, numerous proposals for improving its utility. The waves inside, caused by swell coming in through the east entrance, frequently cause trouble, expense, and delay in landing and shipping operations, and necessitate the retention of the masulah boats which it was one of the first objects of the harbour to do away with. A ship dock in the sand accretion to the south has been proposed. The objections to this are :

(1) the entrance would have to be protected by a mole, 500 to 800 feet long which would be very much in the way : (2) the entrance would be awkward, and it is doubtful whether vessels staying but a short time at the port would use the dock : (3) it is possible that even a mole would not prevent waves from entering the dock. A boat basin has also been proposed, but this has hitherto been negatived as insufficient for the needs of the case, which are to get rid of boats, whether large or small, altogether and also because of the cost of eventually converting it into a ship dock. Other forms of docks have also been proposed but have not met with a favourable reception.

Various forms of protection to the existing entrance have been suggested, but have been resisted by nautical men on the score of difficulty in entrance and exit. A north or north-east entrance is still the favourite remedy. The objections to this are : (1) that it will need the removal of part of the existing breakwater, which even where the section is slight must necessarily be a difficult and uncertain operation : (2) the protecting arm, being broadside on to the highest waves, will necessarily be very strong and expensive : (3) such an arm will assist the travel of sand along it in a narrow strip and the outer end will soon begin to silt up and must be prolonged much sooner than would an arm projecting seaward : (4) there may be difficulty in making or quitting harbour in a heavy sea. This remedy however would undoubtedly give smooth water and seems on the whole the most satisfactory. Whatever form of entrance is adopted, wharves or jetties to which ships can be made fast and the usual appliances in an up-to-date port are necessary before the Madras Harbour can be considered to answer its purpose. The most authoritative pronouncement on these matters is however contained in a note by Sir A. Rendel dated 12th May 1899, parts of which are extracted :

* * * *

“2. In the first report which I wrote upon Madras Harbour (in 1889) I stated that it seemed to me that the present harbour could only be looked upon as a satisfactory entrance to a harbour yet to be constructed within it, *i.e.*, to an inner harbour. That it is merely an outer harbour, with possibly not a satisfactory entrance, seems now to be the general opinion in Madras also, and the question discussed in the papers sent to me is, the best mode of constructing within it an inner harbour suited to the purposes of trade. As to the position of the entrance, there still seems to be competent opinion in favour of a north-eastern position. I adhere to my preference for the present eastern position ; but I also think it just possible that it may yet be necessary, if the harbour is to fully serve its intention, to place its entrance

in deeper water, that is to say, to construct a new outer harbour. I shall say something more on this point at the end of my report, but rather as a contribution to the discussion on the vexed question of the entrance, than as a practical part of the subject immediately under discussion.

“3. My instructions are to report whether having regard to the state of the harbour it is expedient to expend further large sums upon it.

“4. Although the stability of the breakwaters has not yet been tested by a severe cyclone, yet I think enough is now known to justify my opinion that they are of sufficient strength to resist one. I think also that the deposit of sand which has so far taken place in the harbour, has not yet been such as to make it improbable that a depth sufficient for the berthage of large shipping can be maintained in it by dredging at a moderate cost. There seems good ground also for the opinion that the trade of Madras requires and would use the facilities afforded by a deep water wharf. For these reasons I think that a scheme for the provision of such facilities in a moderate degree is expedient.

“5. Various schemes for both boat and ship docks have been prepared by Mr. Wilson, by Mr. Lee Pogson, the Engineer of the Harbour, and by others connected with it. Those of Mr. Wilson being specially referred to in the papers sent to me and not varying from others in principle, I shall confine my remarks to them.

“6. I should premise by saying that in all schemes yet put forward, a ship dock means a walled dock of such depth that the heaviest class of ships can lie afloat alongside its quays or in any part of it at all times of tide; and that a boat dock means a similar but smaller dock, of such depth that only the large boats or barges employed in Madras for the transfer of goods between ships and the shore can use it.

“7. In respect to a boat dock, I do not think it should be accepted, unless it be clear that a ship dock would cost more than the general circumstances of the case warrant. At any rate a boat dock should not, I think, be so placed as to interfere with a ship dock being constructed later on, and this is a fault, to my mind, of the best schemes for a boat dock which have been prepared in India, so far as I know them. If a boat dock only is constructed, I should still prefer the scheme which I shall propose for a ship dock; because, amongst other reasons in its favour, it may be built, in the first instance, as a boat dock, not quayed, it is true, but with the advantage of a depth which will allow ships to lie afloat within it, and to carry on their business with the shore by means of boats in perfect quiet. The development into a ship dock, requiring as it would only the construction of the quay wall on its western side and some further dredging, might follow when money could be found for it without waste of executed, or greater cost of work to be executed. But the harbour of Madras cannot, in my opinion, be considered as properly equipped for the rapid despatch

which trade of all kinds now requires, until a certain number of ships can lie afloat alongside a quay constructed within it, that is to say, until what is understood in Madras as a ship dock, is provided.

"8. The basis of Mr. Wilson's scheme for a ship dock is the ultimate enclosure of a quadrangular piece of water, about 23 acres in area, in the south-western or shore angle of the harbour, commencing with the construction of part of a covering pier on its east side running out from the south breakwater, and of a quay wall on its south side. The completion of the east covering pier and the construction of the north and west sides of the enclosure are to follow as trade requires, with further extension southwards when necessary into the ground which has grown up south of the harbour. The entrance to this enclosure when finished would face north. Mr. Wilson also proposes to build a quay wall 600 feet long in front of and parallel to the shore end of the north breakwater.

"9. I think one objection which may be raised to this scheme is that, until the enclosure of the south side of the harbour is completed, the accommodation provided for trade will be very small compared with the expenditure; for the east covering pier, being only 42 feet wide, will be much too narrow for rapid loading and unloading. But the main objection to it, in my mind, is that the covering pier alone, specially when only constructed in part, will add little if anything to the power of the harbour to disperse waves, and may even diminish it, because recoil within an enclosed space merely diverts a wave, it does not destroy it. Ships, therefore, would not be able to lie against, at all events, the 500 feet of this pier to be first constructed, or against the south quay which it covers, in much if any greater quietude than they can lie now in the open harbour, that is to say, vessels would be often unable to lie alongside either pier or quay.

"10. The case would no doubt be different when the enclosure was completed by the construction of the north quay; ships might then lie in safety under all circumstances against all the quays which surround it. But it would not even then to my mind be a satisfactory scheme, because by diminishing the area of the harbour, already admittedly too small for the purpose, and surrounded as it would be by nearly vertical walls, it would, like the proposed east pier, and for the same reason, but in larger degree, diminish rather than increase the wave-dispersing power of the harbour. Its entrance also is so placed as to require ships to make a quarter turn to get into it, not perhaps a bad fault, yet one that in such a situation should be avoided if possible.

"11. The quay on the north side of the harbour is open to the objection that it simply converts a part of the north breakwater into a deep water quay. If the sides of the harbour be as disturbed by sea as we are told they are, the use of this quay would be subject to great interruption.

"12. The scheme in fact overlooks, as it appears to me, what I understand from the papers which have reached me, and should expect from the nature

of the case, are the leading characteristics of the wave-action within the harbour, namely—that the main disturbance in it is on its sides, the waves as they enter the harbour running along one or other or both of the inner faces of its two breakwaters to the west shore on which they ultimately disperse, and, that the centre of the harbour is the quietest part of it throughout the year. Assuming this to be correct, the conclusion I come to is, that a thoroughly satisfactory scheme for trading purposes cannot be based on the utilisation of either of the breakwaters, and that we must look for it on the west or shore side of the harbour.

* * * *

“21. I said in the early part of this note that I should make a few observations at the end of it on the subject of a new outer harbour. Whether such work is necessary or not depends, in my opinion, on the amount of sand deposit which takes place in the present harbour. If dredging fails to maintain its depth at a reasonable cost, which I do not think it will do, then, if the harbour is to fully serve the purposes for which it was intended, the difficulty can in my judgment be only met by making a new entrance in deeper water. This can only, in my opinion, be effected by the construction of a new outer harbour. The mere shifting of the present entrance to another point in the present breakwaters will, in my judgment, have no effect. Although I believe I was the first to suggest the construction of an entrance with a north-eastern aspect, having done so before the harbour was commenced, since I came to know it I have seen no reason to think its present eastern aspect wrong; but there is so much opinion in favour of a north-eastern aspect, that I have laid down on the chart which accompanies this note two plans for a new outer harbour, one with an eastern entrance, consisting of two partially detached breakwaters converging to each other from near the angles of the present breakwaters, the other with a north-east entrance, also consisting of two breakwaters, the southern attached to the present southern breakwater, the other partially detached. My own preference is for the former. But the latter is better, I think, though much more costly, than the one I suggested in my report of September 1896, in which, thinking mainly of cost, I showed the present entrance closed and a new one made in the eastern arm of the north breakwater by taking up a portion of it, a scheme which is not, I think, as good as the more costly scheme I now suggest. I propose partially detached breakwaters, where possible, in order that some part of the seas which enter the passage between them may be able to get out again, and may therefore disturb the entrance to what would then be the inner harbour less than they would if confined within the two entrances, and also to maintain as much current past the inner entrance as possible for the prevention of deposit; and I propose that the detachment shall be partial only, because I think it will be necessary to fill the gaps between the new and present breakwaters with stone deposit up to the level of say 20 feet below low

water in order to check the travel of sand along the bottom. But both schemes, as I have before said, are to my mind for the future if ever, and it is fortunate that they are so, for their cost would be very large."

In the meantime silting in the harbour mouth has increased at the rate of something under a foot annually and it has become evident that dredging even with a thoroughly efficient dredger, can hardly be a complete remedy. This view has been gradually gaining weight and local opinion is at the present moment, as it has been almost uninterruptedly for the last twenty years and more, markedly in favour of a protected entrance. It will be seen from the preceding narrative that the east entrance was only accepted tentatively, as a measure of prudence and economy in the unlikely event of its proving satisfactory. It has proved unsatisfactory; and there is reason now in urging a completion of the sanctioned plan for a north-east entrance approved by the strongest Committee that has ever considered the matter, approved by the Secretary of State, by the Government of India, by the Government of Madras, by the Harbour Trust Board, and by local opinion generally; or for any modification of that plan which satisfies the admitted necessity of a north-east entrance.

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