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KURRACHEE HARBOUR.



REPORT OF WILLIAM PARKES, ESQ., M. INST. C. E.,

ON THE PRESENT STATE

OF THE HARBOUR.

WITH RECOMMENDATIONS AS TO FUTURE PROCEEDINGS.

Bombay ;

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KURRACHEE HARBOUR.

REPORT OF WILLIAM PARKES, M. INST. C. E., ON THE PRESENT STATE OF THE HARBOUR, WITH RECOMMENDATIONS AS TO FUTURE PROCEEDINGS.

The instructions under which I have the honor to submit the following report, are thus expressed in a letter to me from the India Office, dated 7th May 1868:—

Instructions. “To visit Kurrachee, and, after examining the state of the Harbour, and “watching the effects of the monsoon, to report the results of your observations to “the Governments of India and Bombay, and to himself (Sir Stafford Northcote), “submitting, at the same time, a full statement of your views as to the course “proper to be pursued thenceforward with respect to the improvement works.”

2. In pursuance of these instructions, I arrived at Kurrachee on the 10th July, and remained there till the 1st August, during the whole of which time I was occupied in observing the state of the Harbour and Entrance under the action of the monsoon, and in conferring with the local Officers as to the present state of the Harbour, the changes that have taken place in consequence of the works already executed, and the nature of the recommendations to be now made.

The monsoon had burst with more than ordinary violence, but during my stay there was an unusual amount of calm weather. With the high tides, however, which followed the new moon of the 20th, there was a fair average monsoon swell and break on the Bar, and it was not difficult to imagine what would be the aspect presented by a heavier sea. My own observations are confirmatory of the descriptions which had been previously given me.

3. The information obtained during this visit, however, must be looked on as only supplementary to the materials for forming a conclusion which have gradually accumulated around me since I was at Kurrachee in 1864, and when I submitted certain recommendations to the Government of Bombay, part of which have been since carried out. During the past four years I have been furnished by the Superintendent with full information as to the state of the Harbour; copies of the periodical surveys have been regularly sent to me (after the first year) as soon as completed; and other observations of tides, currents, waves, winds, sections of parts of the shores, &c., many of them made in consequence of suggestions by myself in private communications to Mr. Price, have also been sent to me. All these documents received early and most careful attention from myself personally, and I was thus able to bring to the aid of my direct observation of the present monsoon, a tolerably intimate knowledge of the results produced by previous ones. Whatever, therefore, may be the errors in my present conclusions, it can, I think, hardly be alleged that they are due to imperfect local information; and it is right to add here, that the documents to which I have alluded form, I believe, one of the most perfect records of the effects of natural forces upon the bed of a harbour which have ever been made, and they reflect very great credit on Mr. Price who directed, and on Mr. Humby who executed, the surveys.

4. It would be beyond the scope of my instructions to attempt any systematic reply to the objections to the Harbour improvement works which have been put forward within the last few years; but there are one or two points on which I think false impressions are prevalent, which I will endeavour to remove.

5. Exception has been taken to Mr. Walker's estimate of the capability of the entrance to be permanently maintained at a depth of at "least 20 feet at low water of spring tides." I have taken every means in my power to test the correctness of this estimate, the bases of which are of a fairly definite character, and I am perfectly satisfied that it is a moderate one. I say this with a full sense of the importance of the question, and of the responsibility I take upon myself in speaking thus confidently; and I abstain from saying more, because I feel sure that after this decided expression of opinion on my part, the Government will allow nothing less than a *well supported and definite conclusion* on the other side to outweigh it.

6. I cannot but think that in the discussions which have taken place on the merits of these works, an undue prominence has been given to the question of the improvement of the entrance, and that in many instances they would have been more justly appreciated if they had been viewed as a whole, instead of attention having been restricted to one part of them. The *object* which I have always placed before me is simply this—to obtain the best possible navigation from the deep water at sea, to the new Native Jetty at the head of the Harbour; and the *means* by which I hope to attain this object, is the removal of all obstructions to the natural and equable flow and ebb in one capacious channel of the largest possible body of tidal water. The improvement of the entrance may be the most urgent object at one time—that of the anchorage at another—that of the upper harbour at a third; but they are all equally comprehended within the scope of the design.

7. I will now ask the Government to put on one side all conclusions that may have been formed from a verbal criticism of Mr. Walker's reports as to his supposed intentions, or as to the relative importance which he attached to scour and sea shelter as *means*, and to the improvement of the entrance, or of the Harbour, as *results*; but to take the works, whether executed or proposed, as they stand, and judge of them by the light of past results and present requirements. Not that I have any desire, either for Mr. Walker's sake, or my own, to shrink from an *ex post facto* criticism of the early reports; but, as the matter now stands, *facts* may to a great extent be substituted for *hypotheses*, and will form a far more satisfactory basis for practical recommendations.

8. On the ground, then, that results actually attained are the best guide for future action, I shall have to submit in some detail the results which have been produced by the only works which have yet been brought to bear on the general economy of the Harbour, viz. :—

I.—The Keamaree Groyne, commenced in December 1861, and completed in April 1863.

Works now effective.

II.—The extension of the same for 1,500 feet (known as the East Pier), commenced in May 1864, and completed in October 1865,

III.—The removal of Deep Water Point, commenced in 1864, and carried on chiefly by natural scour, but partly by artificial means, during that and the two following years.

IV.—A training Groyne, constructed in 1866, running for 1,000 feet northward from the site of Deep Water Point.

The total cost of these works has been £75,000, including their share of the cost of plant.

9. Taking first the results produced upon the portion of the Harbour most directly affected by the part of the Groyne completed in 1863, viz., that between sections 1 and 16 A, we find that up to October 1867, there had been an increase in water space at low water, since January 1858, of from 266,451,428 cubic feet, to 299,341,289, being 32,889,861, or $12\frac{1}{2}$ per cent. Assuming that in 1861, when the Groyne was commenced, the water space was the same as in 1858, every year shews an increase (except October 1864 to October 1865, which shews a slight decrease), but the increase is not continuous throughout the year; during the monsoon in each year, there appears to have been a quantity of sand washed into the Harbour which neutralized to a greater or less extent the results of scour.

The following are the results of the five monsoons over which the observations now extend :—

Monsoon of 1863—	Decrease of 6,500,114*
„ 1864—	Increase of 21,821
„ 1865—	Decrease of 1,942,091
„ 1866 „	292,404
„ 1867 „	852,774

10. From this it appears that the effect of the monsoon of 1863 was exceptionally great. That of 1865 was also exceptional, but in a much less degree. Now, were there any causes acting in these two years to account for these exceptional results, and for the difference in their degree? Most clearly there were. Previous to the monsoon of 1863, the Groyne had been pushed rapidly forward, forcing the flood tide to take its course with an accelerated velocity before entering the Harbour, over an area of shallow water in which the sandy bottom was disturbed by heavy surf.

In 1865 there was a similar cause in action, though to a less extent, in the advance of the East Pier. The action of the current had, before the next monsoon, in both cases enlarged the flood tide channel over the shallows sufficiently to prevent more than the *ordinary* influx of sand in the following year. The *exceptional* results of 1863 and 1865 being thus fully accounted for, there remain the *ordinary* results which recur every year. Can they be accounted for, and are they of importance? It is clear that during every monsoon a large quantity of sand is set in motion, both by the action of the waves and of the wind, both within the Harbour and outside, and the most sheltered resting-place for this sand is, for the time being, the deep water of the Harbour. Here it rests till the slower, but not less certain, action of the tidal currents expels it.

11. With respect to the importance of this annually recurring monsoon action, it is now matter of experience that it does not prevent the ultimate enlargement of the channel; at the same time it sets in motion a quantity of sand, which, if collected within a limited space in the line of navigation, would cause an obstruction. To avoid this it is only necessary to take care that there shall be nothing to encourage deposit in any one particular spot.

I have given the effects on this part of the Harbour separately, because the exceptional result of the monsoon of 1863, was made the basis of what is now proved by experience to have been an exaggerated view of its importance.

12. The effects upon the lower part of the channel have been similar, but greater in proportion to its length. Between sections 16 A and 24, which latter section runs a little outside the end of the East Pier and the end of Manora Point

* It is stated by Colonel Tremenheere in his report of May 1864, (Harbour Works Correspondence, page 165), that the loss of water space in the year was 15 millions; but this is an obvious miscalculation from the figures which precede it. No principle is affected by the error.

(without taking account of the deep hole which has scoured out close to the end of the East Pier), the increase of water space, from 1858 to October 1867, has been 11,685,540 cubic feet, or 20 per cent., making, with the $12\frac{1}{2}$ per cent. in the channel above, an increase of nearly 14 per cent. on the whole length. This expulsion of sand has rendered the sectional area of the channel nearly uniform throughout, with the exception of the portion immediately above where Deep Water Point stood (sections 12 to 15); but even this part is gradually enlarging and becoming more regular.—Besides the sand removed from below low water level, there have been removed 15,458,533 cubic feet from above low water mark, principally from Deep Water Point and the Keamaree sand spit, making in all a quantity of 60,033,774 cubic feet, or $2\frac{1}{2}$ millions of cubic yards of sand expelled from the Harbour.

13. I now pass to some other results obtained by the works in question.

Tidal Currents more regular. The courses of the Tidal currents have been rendered much more regular. Formerly the flood tide, rushing round Manora Point from the westward, entered the Harbour after making a long circuit to the eastward over the Keamaree sand spit, and then setting again to the westward, caused the greatest run of tide to be up the western side of the Harbour. The ebb tide, on the contrary, set fairly down the east side of the Harbour, losing its volume, however, as the waters escaped over the sand spit, but leaving the last of the ebb, when this side escape was closed by the sand spit becoming uncovered, to rush with great violence through the deep gorge off Deep Water Point, while it was again deflected to the eastward by the point itself, away from the best line of navigation.

14. Now, however, the flood and ebb currents set up and down the Harbour with great regularity, and in the same channel. There are no cross currents, and the few eddies that were caused by changes in progress are gradually disappearing. The West Harbour Channel is silting up, and yielding its anchorage space to the more favorably situated East Channel. This, together with the interception of a most inconvenient cross current, which formerly entered the Harbour just below Keamaree, on the flood, has had the effect of carrying the improvement up and above Keamaree, which is the most valuable part of the anchorage.

15. The value of these results to the trade of the Port will be best described in the words of a statement with which Captain Giles has favoured me:—

“I do not think ships could have possibly been placed at fixed moorings at Keamaree before the Groyne was built, as this anchorage was then full of violent eddies and cross tides, caused by the run of water along the south shore of Keamaree on flood, spring tides, meeting at right angles the main stream in the Harbour just at the point (Keamaree); moreover the anchorage space there (with a depth of 20 feet) was very narrow, hardly permitting room to berth and swing large vessels.”

“We could not then have berthed in 1858, with every appliance, above 20 loaded ships of from 500 to 900 tons, 8 of these at Keamaree, 12 at Manora. This, of course, does not include ships in ballast that might be anchored on the flats.

“I am of opinion that from 40 to 45 vessels could now with screw moorings be placed at Keamaree, with 12 at swinging moorings in the lower part of the Harbour, say in all 55 loaded ships of from 500 to 1,200 tons. I should not like to go beyond this.”

Thus, on Captain Giles authority, which no one, I imagine, can call in question, the capacity of the Harbour is virtually *trebled*; and I feel justified in saying that the limit of capacity has not yet been reached.

16. Another result of the Groyne is one which, in an engineering view, is of great importance, but which cannot, like the two last named, be presented to view by actual comparison of the former and present states of the Harbour. I allude to the protection which the Groyne affords against the large quantity of moving sand which formerly was kept during the monsoon in a state of disturbance by the surf on the Keamaree sand spit, and was driven towards the Harbour by the waves along the shore of Keamaree island, and carried into it by the flood tide. The effect of the prevention of this formerly annually recurring evil has been hitherto concealed by the apparently similar, and, for the time, much greater, though temporary, action caused by the scour of the channel itself; but in reality the Groyne has established a condition of freedom from a constantly disturbing action, without which, I believe, any attempt to act upon the Bar and entrance would have been futile.

17. I will now recapitulate the effects produced by the Groyne, independent of its action upon the Bar and entrance, and I will ask the Government to consider their value apart from the idea—if such may exist—that the primary object of this work was to improve the entrance. I say, then, that—

I.—It has expelled $2\frac{1}{2}$ millions of cubic yards of sand from the Harbour at a cost of 8d. per yard, and effected an increase of 14 per cent. in the water space.

II.—It has improved and equalized the run of the tidal currents so as to render the anchorage in all parts more secure, and in the most valuable part has increased the possible accommodation five-fold; on the whole it has increased it three-fold.

III.—It has established a condition of protection from moving sand necessary for effective action on the entrance.

Can any work of this nature be cited as more effective for its cost?

18. I now come to its direct action upon the Entrance, and in doing so I must ask that its beneficial effect shall not be measured by the amount of improvement which it may have directly effected on the navigation. A good navigable entrance is produced by the combination of several conditions, of which the Groyne only provides a part. If it can be shewn that it has actually provided those which it was calculated to provide, it can be no cause of surprise that it has failed to provide others for which it was not calculated, but which are necessary to make the first practically effective.

19. If the various charts which have been made since 1863 be compared, a process will be found to have been going on, which, so far as it affects navigation, may be shortly described as follows:—

In January and May 1863, the entrance was choked with sand, which, for a time, quite obliterated the 14 feet channel round the tail of the Bar.

After the monsoon of 1863, the channel was re-opened to the 14 feet depth, but was very narrow and tortuous.

During the following two years the channel gradually widened and deepened, so that in January 1865, it had, at 14 feet depth, a width of about one-half what it had in 1858, but a continuous maximum depth of 17 feet, against 16 feet in 1858. Thus the greatest extreme depth was coincident with almost the worst state of the navigation.

After the monsoon of 1865, a great change was observable. The 14 feet channel, instead of being *half* the width it was in 1858, was now *double* the width, but the extreme depth was reduced to 16 feet.

The capabilities of the main navigable channel may be said to have been at that time (October 1865) restored to what they were in 1858, and since then the changes in it have been of an unimportant character.

20. In the mean time the Bar, which was greatly increased in width in 1863 and the beginning of 1864, lengthened out to the eastward, and narrowed nearly in the inverse proportion to its length.

This also continued up to the end of the monsoon of 1865, at which time it was 1,300 feet longer at the 14 feet line than in 1858; since then it has not extended materially to the eastward, but it has continued to decrease in width, and the outer end to move seawards, so that it has changed in form from almost a semicircle, to nearly a straight line.

21. It would seem probable that in their most prominent features the Bar and Main Entrance Channel are now again in a permanent condition. We may therefore compare their present state with their state in 1858. The main East Channel is now as capable of passing large ships as it was in 1858, though, owing to the increased length of the channel, and the more leeward position of the entrance, it is inferior in point of convenience, and perhaps even of safety, in very bad weather; but it should be remembered that it was better in 1858, and probably from temporary causes only, than it had ever been previously known. The present state of things, however, may be said to be due to a balance between the good and bad results produced by the works. The *good* result is that the navigable channel is *doubled* in width; the *bad* that the Bar has lengthened so as to neutralize the advantage. The lengthening of the Bar is due to the fact that out of the 60 millions of cubic feet of sand which have been discharged from the Harbour, *one* million have been deposited at the tail of the Bar.

We have, then, as a *favorable* result, a channel of doubled capacity, which is obviously one essential condition of a greatly improved navigation. We have as an *unfavorable* result, the small incidental one, that one part in 60 of the scoured out sand has found its way into a temporarily inconvenient position. That the one great result has failed to assume a useful form, and that the other small result exists, are alike to be attributed to the fact that nature has been allowed to act without any control.

22. These results have not been obtained without a struggle between contending forces, and it is from the details of this struggle that the best idea can be formed of what the executed works have really done, and what they have failed to do.

23. It should be premised that the natural set of the ebb tide is direct from the Harbour's mouth; afterwards curving round to the south-west towards the deep water at sea. The course taken by a ship of light draught, if allowed to drift out to sea on a calm day, would be just that on which a pilot would take her, crossing the Bar at an oblique angle. This current, if powerful enough, would of course have a tendency to carry away the sand of the Bar to seaward, so that when we find that the Bar lies in a direction oblique to that of the current, and has a tendency to lengthen towards the eastward, we are driven to the conclusion that it is acted on by some force which comes from the westward, and overpowers that of the ebb tide current.

24. The effect of the Groyne was to increase the power of the ebb tide current to carry away the particles of the Bar seaward, and thus, by disturbing the equilibrium which formerly existed among the forces which produced the Bar, to exhibit their action separately.

25. A careful study of the charts shews that from 1863, up to the present time, the ebb tide has made repeated efforts to cut through the Bar, so as to form a direct channel to the sea. These efforts have been all successively thwarted by the action of the sea. I have not thought it necessary to give the details of these futile efforts here, but they are interesting in themselves, and I have therefore given them in an Appendix.

26. The conclusion which I draw from them is, that a necessary condition of the existence of a direct and permanently deep channel, is an effectual protection from that action of the sea which has so repeatedly thwarted the natural efforts made towards it.

Conclusion.

If any particular spot be deepened to such an extent as to prevent the waves breaking, it is not necessary to the preservation of the depth that it should be protected from the direct advance of the waves upon it. If unbroken, they would pass harmlessly over it. What is really necessary is, to shelter those parts which cannot be so deepened, and are situated to windward of the required channel. So long as they are exposed to breaking seas, any sand which may be upon them will be lifted and driven to leeward into the deep channel. To prevent the formation of breakers upon any spot, it must be either sheltered or deepened; it is unnecessary to do both; hence so much of the western side of the required channel under the foot of Manora Point as cannot be sufficiently deepened, must be effectually cut off from the action of the sea. When this is done, there will remain nothing to prevent the deepening (whether by scour or artificial means), and permanent maintenance of the depth of the channel to that of the natural slope of the bed of the sea at that point, which is fully 20 feet at low water of spring tides.

27. What is required to provide this necessary protection from the action of the sea is a Breakwater like that originally designed by Mr. Walker. For this immediate and primary purpose, having reference to the very favorable manner in which the deep water within the Harbour is approaching the Manora shore, I believe the length of 1,500 feet to be ample—possibly less might suffice; but the shelter of the channel itself, when deepened, though an independent and secondary object, is also a very important one; and even if the last few hundred feet be not absolutely necessary for obtaining and preserving depth, they will be worth their cost in making that depth more available by reducing the swell in the channel, and preventing its run up the Harbour. Having regard, therefore, to the fact that the exact minimum length required is not determinable, except by experience, and that an additional length will have an equivalent value in giving additional shelter, I cannot recommend the Government to entertain the idea of anything less than 1,500 feet. Indeed, the shelter to the deepened entrance may be found so valuable as to render a further extension desirable for that purpose alone.

28. The line laid down by Mr. Walker is not the very most advantageous for giving shelter. If the direction, instead of S. by E., were S.S.E., one hundred feet more of the present Bar would be brought under shelter, but this advantage would be met by the evil of the pier head being about 300 feet more to leeward, thus contracting the entrance to that extent. Moreover the S. by E. direction is parallel to the course of the ebb tide, and would not, therefore, in any degree divert or interfere with its free outset, while it would lead the littoral current from the westward to make an easy junction with the tidal current.

Another reason in favor of the S. by E. direction is that, if the possibility of an extension be entertained, the starting point for that extension will have the advantage of being 300 feet to windward. In fact the error, if any, is on the right side, and capable of remedy by extension; on the other hand, if the more leeward position should prove objectionable, the evil would be aggravated by extension.

The question of the direction of the Breakwater has been fully discussed with Captain Giles, Mr. Price, and Lieut. Merewether, who have all so carefully watched the place for many years, and they are all strongly opposed to any change from Mr. Walker's direction. They agree, however, with me that it will be desirable to start it from a point about 100 feet to the eastward of that generally shewn on the plans.

29. From what I have said as to the objects of the Breakwater, it will be understood that I do not look upon it as an active agent for obtaining increased depth, but as establishing conditions necessary for the maintenance of depth when obtained. For the actual process of deepening we must look to other means. The original idea of Mr. Walker's design was, no doubt, that when the increased scour was brought to bear upon a place favorably situated for it, that is, sheltered from the action of the waves, it would force itself through the passive obstacle of a bank of sand. But the time for this is now past. It might, and I think it would, have been effectual at the time when the East Channel was choked with sand; but that channel now forms so free an exit for the under current, that the scouring action on the Bar is much reduced. When, therefore, the necessary conditions for making the deepening permanent shall have been obtained, some active measures will undoubtedly be required to assist the scour in effecting the deepening itself. A further extension of the East Pier, and dredging, will probably suggest themselves; but I think it would be undesirable to carry out either of these to such an extent as would have any material effect on the ultimate result, until a considerable degree of shelter has been obtained from the Breakwater, and its effect observed. The last steps in an undertaking of this description must necessarily be *tentative*. We are dealing with forces of which we know the general direction and character, but which cannot be brought within the scope of numerical estimate.

30. Previous to my visit to Kurrachee, I was disposed to make an exception to this principle in favour of a renewed attempt to obtain a direct channel through the Bar at the spot where some dredging was carried on, by order from the Secretary of State, at my suggestion, in January and February last. The results of that experiment were encouraging, as to ultimate success, if a larger opening could be made during the fair season. After conferring with the Master Attendant, however, I have altered my opinion. Captain Giles agrees that if the dredged channel could be made sufficiently good to supersede the present East Channel, it would be a great improvement. In order, however, to do this, it ought to be two or three feet deeper, on account of its being more directly exposed to the sea, and I feel doubtful whether such extra depth could be obtained in the limited working season. If, however, the East Channel is still to be used for the deepest ships, then the new channel would be rather an evil than otherwise, as admitting a cross sea into the East Channel itself.

31. To this may be added that the necessity for such a channel is now reduced by the fact that, for the last two monsoons, there has been open water (free from breakers), with a gradually increasing depth over the Bar, close to Manora Point. The new course thus established has latterly been taken by all light ships, and the shoalest part (9 to 10 feet at low water) being under the shelter of Manora Point, it is really more useful for navigation than a depth 3 feet greater would be in a more exposed position. The favourable position of this channel for navigation gives it an importance which it would be premature to accord to it as an indication of any new action affecting the general economy of the entrance.

32. I think, however, that if only for the purpose of immediate convenience, this channel should be improved, and, if possible, maintained; and I would therefore recommend that discretion be given to Mr. Price to employ the dredgers upon the shoalest part of it, if the soundings, to be taken after the monsoon, shew that it can be done with advantage.

33. I would also recommend that a similar discretion be given to Mr. Price with respect to dredging on the site of Deep Water Point. The removal of the Point produced very favorable results in bringing the scour, and consequently deep water, close to the shore at Manora. A further deepening would be attended with proportionally beneficial results. Beyond these two operations, which would be on a very small scale (the total cost of employing one dredge, and barging away the dredged material, for 6 months continuously, would amount to £4,000), I would recommend nothing to be done in the neighbourhood of the entrance till the Breakwater is in a forward state.

34. There is, however, another operation which is practically independent of any question affecting the entrance, which I am strongly of opinion should not be longer delayed. I allude to the admission of a portion of the Chinna Creek waters into the Harbour, by the removal of the dam at the Napier Mole Bridge. This was deferred at my suggestion in 1863, when the temporary choking of the entrance was at its height, and I feared that the increase of scour would aggravate the temporary evil. A small opening in the dam might have been made after the clearance of the entrance in 1865, and I reported, in reply to a question from the Secretary of State, in favour of a limited opening in January 1867; but the matter was then deferred until the whole question of the Harbour Works should be again taken up. I now repeat my opinion that the dam may be opened without appreciable effect, good or bad, upon the entrance; and that, even if the effect were likely to be appreciable, there could be no object in further delay, for it would not be in any way changed by the shelter of the Breakwater.

35. On the other hand, the boon to the trade would be immense, and, it is worthy of remark, more so to the Native traders, whose voices are less heard in the matter, than to Europeans. In many cases it would save an entire transshipment of cargo, as the great majority of native sea-going craft could come up to the Native Jetty, if the channel were opened out.

36. I would, therefore, strongly recommend that an early sanction be given to this simple, but important, operation, on the details of which Mr. Price and myself are agreed. The cost would be nominal, though it might be necessary to employ the dredges, or manual labour, to remove mud banks in the upper channel (above Keamaree) which the scour may at first throw up. The Chinna Creek should not be closed at present.

37. My recommendations, then, may be summed up as follows:—

I.—The Manora Breakwater, to be carried out 1,500 feet from low water mark, in a S. by E. direction, 100 feet to the eastward of the Manora flagstaff.

II.—The removal of the dam at the Napier Mole Bridge, so as to admit a portion of the Chinna Creek waters gradually into the Harbour.

III.—The use of the Dredges at the discretion of the Superintendent—
 (a.) In the new entrance close to Manora Point.
 (b.) In the shoal water on the site of Deep Water Point.
 (c.) In regulating and guiding the channel between the Native Jetty and Keamaree (hand labour to be substituted here if more suitable).

38. The cost of carrying out the above recommendations would be as follows:—

	£
The Manora Breakwater.....	109,000
Removing dam	500
Dredging for one season	4,000

The above estimate of £109,000 is for a Breakwater consisting of a rubble stone base, and superstructure of Portland Cement concrete blocks, faced with stone on the sea side up to a little above high water mark.

The estimate for the Breakwater is based on actual tenders received from responsible contractors for the rubble stone base, and on *double* the ordinary English rates for the superstructure. I have no doubt of its sufficiency.

39. I have so repeatedly expressed my opinion that this undertaking ought to be carried on by the co-operation of the Engineering Control. Engineers respectively responsible for the design, and the execution of the works, that no apology is needed for my again urging it. Its acceptance is a condition of my assuming the responsibility of any recommendations.

No change of the local organization would be required, and but little in the duties and responsibilities of the local Officers. If the Government decide on carrying out my recommendations, I should stipulate that Mr. Price, Lieutenant Merewether, and Mr. Humby, the Surveyor, retain their present positions, or, if any change be rendered necessary, that I should be consulted as to the appointment of their successors.

40. The Superintendent would make his progress reports, and render his accounts, as at present, to the authorities of the Bombay Government; but he would not, as heretofore, furnish any reports on the periodical surveys, or on the effects of the works. That duty should be transferred to me. I cannot say this without recognizing the admirable character of Mr. Price's reports on these subjects. I can hold out no hope of improvement in these by the transference of the duty of preparing them to me; but it would obviously be a fruitful source of confusion if two persons in the same department were to report independently on the same subject. Moreover, the duty is one of which Mr. Price would gladly be relieved on the resumption of active operations. He would furnish me with all information obtained by his own personal observation.

41. The Superintendent would be in no way relieved of his responsibility as to the security and economical execution of the works, unless by the special interference of the Government under my advice. He would also frame estimates, and prepare working drawings, as heretofore; but if these are made in pursuance of any recommendation from me, they should be submitted to me before being sanctioned by the Government. I should approve them if I found they fairly carried out my intentions, without making myself further responsible for them.

42. The direct communication between the Superintendent and myself would be of an unofficial and confidential character; where circumstances require official communication, it should be carried on through the Government.

From the above it will be seen that the duties which I ask the Government to confide to me are those of general control over the undertaking, based upon continuous study of circumstances as they arise. There would be a constant interchange of views between the Superintendent and myself, so that each would be informed of the proceedings of the other; but I should interfere only where some point affecting the general principles of the design was involved, and then only through, and with the sanction of, the Government. The correspondence which has been carried on between us for the last three or four years, the identity of our present views, and the strong desire of both Mr. Price and Lieutenant Merewether for some such arrangement as this, assure me that it would work advantageously for the undertaking.

W. PARKES.

Bombay, 10th August 1868.

POSTSCRIPT.

On my submitting my report in draft to the Governor of Bombay, His Excellency suggested objections to two of my proposals in reference to the future Engineering control of the undertaking. Upon these points I wish to offer some further explanation.

2. The first is as to my being consulted upon the appointment of successors to Mr. Price, Lieutenant Merewether, or Mr. Humby, in the event of either of those gentlemen withdrawing from his present duties. My only motive in making the proposal was to provide what appeared to me a simple means of ensuring an important object. If that means be inadmissible, my end will be equally attained by my setting forth the object, and leaving it to the Government to provide the means for its attainment.

3. It is clear that the efficiency of my proposed services will be in great measure dependent upon the degree of promptness and fulness with which I am supplied with information by the Superintendent. Moreover, as it is important that our communications should be unofficial, in order that they may be unreserved, any default on his part would probably be of a negative character, so that in this respect there would be little control over him.

4. In a word, the success of the proposed organization depends on cordial co-operation and full understanding between the Superintendent and myself. If this is fully understood, and accepted as a condition of the appointment of a future Superintendent, there is no reason for my having any voice in it.

5. The other point to which exception was taken by His Excellency is as to the proposed transference of the duty of reporting on the effects produced by the works from the Superintendent to myself. Hitherto this has clearly been the duty of the Superintendent; henceforward, (if my proposals be accepted) it will as clearly be mine, whether the Superintendent continue his reports or not. My object in suggesting their discontinuance on his part was to prevent any small differences of opinion, or of mode of presenting the facts, from being made the ground of cavil. I have no wish to debar him from giving full information to the Government, but if the relations between us be of the character which I have described as essential, he will naturally be disposed to abstain from much independent expression of opinion. There can be no objection to his directing attention to any important results obtained when he forwards the charts to Government; but such communications should be considered as entirely subordinate to mine.

W. P.

APPENDIX.

*DESCRIPTION OF THE SEVERAL ATTEMPTS MADE BY THE
EBB TIDE SINCE 1863 TO FORM A DIRECT CHANNEL TO SEA.*

In the early part of 1863 the increased scour was brought to bear upon the Bar in its original state. The effect was to carry away the sea slope and the crest of the Bar, which were composed of very light and fine sand, while the new and coarser material brought down from the Harbour was deposited within the line of the original Bar. The Bar now lost its characteristic form, and presented that of a wide, shapeless shoal, the highest part of which was about 2 feet lower than that of the original Bar. Then, in the ensuing monsoon, the counteracting force came into play, and its effect was simply to re-arrange the particles of the shoal into the form which the original Bar had presented.

2. The scour of the following fair season had to renew its efforts against a more stubborn obstacle. The upper current set over the crest of the Bar, as before, straight out to sea, but the under current was diverted along the inner side of the Bar, and no material change was produced.

3. The monsoon of 1864 found the Bar already formed; but the heavy break upon it diverted the *whole* of the ebb tide into the East Channel, and the effect of thus increasing the scour upon the inner slope of the spit, was to cut it away, and deposit the material at its extremity, thus narrowing and lengthening the Bar. In addition to this result, however, we find that this year the whole Bar was moved bodily seaward nearly 200 feet, proving that the material of which it was composed must have been turned over and over by the action of the waves and currents, though the ultimate result shewed no preponderance of one force over the other.

4. During the fair season of 1864-65, the East Pier was constructed. The further increase of scour produced by this had little effect on the western part of the Bar; but, previous to the monsoon, the under current made a marked attempt to cut into the inner slope at about two-thirds of its length, throwing up a bank to the eastward. The action here manifested, however, was interrupted by the monsoon.

5. The effect of the monsoon of 1865 was very remarkable, and it brought the East Channel to a state from which it has not since materially changed. It was then, in fact, that the temporary choking of the entrance was overcome. The principal effect upon the Bar was at the eastern end or tail, which was pushed outwards and flattened, but the whole length was narrowed. The total bulk of the Bar was considerably reduced.

6. During the fair season of 1865-66 a marked effort was made to cut through the Bar at a point nearer to Manora Point than any that had hitherto been acted on. The whole force of the scour seemed to be concentrated on one point, and in May 1866, the width at 14 feet depth was reduced to 200 feet, or little more than half its width 12 months previously. The material scoured out was, however, deposited in the immediate vicinity.

7. The monsoon of 1866 broke with unusual violence, and its effects were very remarkable. The part of the Bar in which the indentation just mentioned had been formed was covered with a mass of sand apparently thrown up from the westward, and was considerably increased in bulk; it was likewise driven inwards, contracting the channel at that point. A little further to the eastward, however, the effect was reversed, here, *in the face of the monsoon sea*, the crest of the Bar was lowered 2 to 3 feet.

8. It is obvious that at this point the force of the scour had fairly overcome that of the surf, weakened as the latter was by the previous narrowing of the Bar. There was, in fact, an actual want of material for the formation of a ridge such as that into which the flat shoal of 1863 had been made. To the eastward of this there was a slight increase of bulk in the Bar, though no increase of length.

9. Here, then, we have, as the action of one monsoon on different parts of the Bar, a complete neutralization of the previous effect of the scour in one place, and probably assistance to it, by the lifting of the sand by the breakers, in another.

10. The depression in the crest of the Bar effected during this monsoon formed a convenient channel for small vessels.

11. The succeeding fair season (1866-67) produced a result upon this depression, which, at first sight, presented some similarity to the action of the monsoon of 1863. A narrow ridge of sand was deposited along the highest part of the Bar, across this depression, so as to narrow the opening. This was no doubt due to the eddy naturally formed between the direct *upper* current across the Bar, and the diverted *under* current through the East Channel.

12. During this fair season, 1866-67, the effects of the removal of Deep Water Point were exhibited. The early ebb tide, which had previously been diverted by it to the eastward, now set with considerable strength over its site, and the results are seen in the approach of the contour lines to the Manora shore.

13. The deep water has, in fact, a tendency to creep downwards towards the root of the Bar. The Bar itself also was lowered immediately under the Point; but this would seem to be due more to the flood tide than the ebb.

14. In the monsoon of 1867 this deepening near the root of the Bar became an important feature. The waves ceased to break on this part, and for the first time the surf of the Bar itself was completely detached from that which fringes the shore of Manora Point. This remarkable effect is continued in the present monsoon, and the entrance, as viewed from the top of Manora Point, has the appearance of being perfectly open for a width of 700 feet from the Point, with a shoal on which the waves break harmlessly to the eastward. The appearance, however, is delusive; the new entrance having only about 10 feet at low water, is available for light vessels, but that for deep ones remains to the eastward of the shoal. The effect of the monsoon of 1867 was also important on the other parts of the Bar. The part where the depression had been formed the previous year, was driven inwards, the depression itself being partially obliterated, but the tail of the Bar was forced outwards. The result of this change in the form of the Bar, combined with the increasing capacity of the eastern channel, was that the probability of any effectual action of the scour in cutting through the Bar was materially lessened. The angle between the upper current of the ebb tide and the line of the Bar having diminished, there was less resistance to the diversion of the under current, and if nature were left to herself, the probability is that the changes of many future years would be less than those of the last two or three.

15. From this general conclusion, I ought, perhaps, to except the new channel under Manora Point. This might be further developed, and become permanent; but I fear it would be at the cost of some advantages which have already been gained. The free admission of the waves into the Harbour causes an oblique break in the shore of Manora Point, by means of which sand is driven up to the site of Deep Water Point. The ultimate result of this would be the re-formation of that obstruction, the consequent diversion of the ebb tide, and the movement to and fro of a quantity of sand.

W. PARKES.

Bombay, 10th August 1868.



KURRACHEE HARBOUR.

M E M O I R

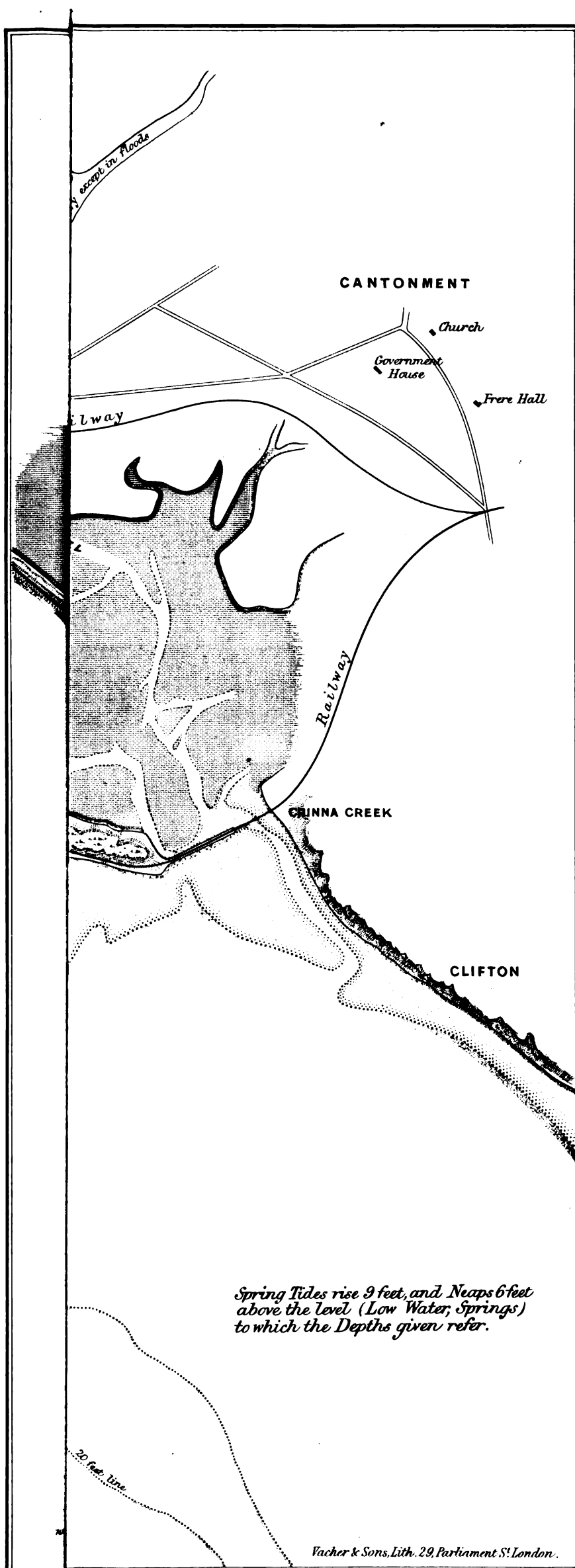
BY

WILLIAM PARKES, M. Inst. C.E.,
CONSULTING ENGINEER TO THE HARBOUR IMPROVEMENT WORKS.

**BY AUTHORITY OF THE SECRETARY OF STATE IN COUNCIL
OF INDIA.**

22.)

Bombay 2a 4



Introductory remarks.

Mr. Walker's first report. Harbour Works Correspondence, Vol. I., p. 8.

Mr. Parkes' survey, 1857-8.

Mr. Walker's second report. Harbour Works Correspondence, Vol. I., p. 16.

KURRACHEE HARBOUR.

MEMOIR, &c.



THE papers on the Kurrachee Harbour Works have become so voluminous as to render it difficult for any one not familiarly acquainted with the subject to obtain a connected idea of its history. While disputed questions remained undetermined by the Government, the *resumés* of the whole subject which were put forth almost necessarily either bore the character of *ex parte* statements, or, if impartiality was aimed at, the attempt to present the conflicting views in a concise form resulted only in confusion and unintentional misrepresentation of one or both sides. *Introductory remarks.*

2. Now, however, that the Government has decided on carrying out the policy with which I have been identified, a sketch of the whole subject from my point of view can hardly be considered as *ex parte* in an objectionable sense. The sketch would be manifestly incomplete without allusion to the proceedings and objections which have served for so many years to retard the prosecution of the undertaking, but in alluding to them now it is unnecessary for me to attempt to present the views of those who differ from me as consistent wholes. My only concern is with those parts which especially conflicted with the principles of the positive recommendations made either by Mr. Walker or myself. I trust I have not *misrepresented* any one, but I make no pretence to have given a complete view of principles in which I do not concur. I have, however, given full references to the documents in which those principles are set forth at length. I may further add that I have not thought it necessary or desirable to confine myself to such views of certain parts of the subject as the Government as a body, and still less individual members of the Government, may be prepared to endorse.

3. The late Mr. James Walker was first consulted as to the improvement of the harbour of Kurrachee in the year 1856, and he made a preliminary report on the 8th September of that year. *Mr. Walker's first report. Harbour Works Correspondence, Vol. I., p. 8.*

The opinions expressed in that report were based on a survey then recently completed by Lieutenant Grieve, I.N., and on information furnished by several gentlemen acquainted with the locality then in England. Mr. Walker's conclusion was that, through the application of proper means, the "deepening or even entire removal of the bar and the general improvement of the harbour" might certainly be accomplished.

Rather by way of illustration than as pledging himself to any particular plan, he suggested a system of works which he thought would be suitable for the purpose. He at the same time recommended that an engineer should be sent out to make the necessary surveys and examinations on the spot, and report to him previous to his making a complete design.

4. I was appointed to this service, on Mr. Walker's recommendation, by the Court of Directors of the East India Company in the latter part of 1857, and after spending five months at Kurrachee, I returned to England and reported to Mr. Walker in June 1858. *Mr. Parkes' survey, 1857-8.*

5. Mr. Walker's second report, with which mine to him was combined, was made in October of that year. In it he confirmed the general principles which he had laid down in his former report, and repeated his recommendations as to the works to be executed, with little variation from his original suggestions. *Mr. Walker's second report. Harbour Works Correspondence, Vol. I., p. 16.*

Those works, which are shown on the accompanying plan, were, shortly, as under:

1. A breakwater in a direction S. by E. for 1,500 feet from Manora Point. (Estimate 110,000*l.*)
2. A stone bank or groyne from the western end of Keamaree Island to opposite Manora Point, so as to confine the whole of the ebbing and flowing waters to the main channel of the harbour for a length of about two miles, and the entrance to a width of about 2,000 feet. (Estimate 42,000*l.*, and east pier extension, if required, 40,000*l.*)
3. The diversion of the tidal water which ebbed and flowed through the Chinna Creek into the harbour itself, by closing the creek (9,000*l.*); removing a portion of the Napier Mole, and carrying a bridge on piles over the opening (40,000*l.*); excavating a channel into which the tide waters would be collected and conducted into the harbour (18,000*l.*); and the formation of a jetty ("Native Jetty"), for further guiding them, which would be also used for wharfage (28,000*l.*, or for the whole of this series of works, 95,000*l.*).

Thus the estimate for the improvement of the harbour (exclusive of docks and basins, for which Mr. Walker indicated the best sites and arrangements) was, in round numbers, 300,000*l.*

ated result
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6. As the result of these works, Mr. Walker anticipated that a depth of at least 20 feet at low water of spring tides, giving 29 feet at high water of spring tides, and 25 feet at that of neap tides, with ample width for navigation sheltered from the worst winds, might be depended on.

The groyne, besides bringing the whole scouring power of the harbour to bear upon the entrance, was also calculated to enlarge and improve the anchorage; and the diversion of the Chinna Creek waters, besides further increasing the scour on the entrance, would form and maintain a channel of sufficient capacity for the passage of the largest native craft up to the proposed new jetty near the town and the offices and warehouses of the merchants.

y of
Walker's
maintained,
standing
on.

7. It is worthy of remark that although Mr. Walker's proposals have been met by strong opposition from many quarters, and every detail has been subjected to the severest criticism, only one specific proposal of any other system of improvement (that of Lieutenant Taylor, I.N., in 1860) has since been made, and that has not been pressed.

Thus the only recommendation ever prominently brought before the Government or the public has been to carry out Mr. Walker's plans in their integrity. All the opposition has been of a negative character. No one has denied the capability of the harbour for improvement; no one (with the one exception above named) has proposed any plan of improvement to supersede Mr. Walker's. Nor, it may be added, has the close observation of local phenomena and changes which has been made both by supporters and opponents of the works during eight years, resulted in the establishment of any fact which suggests material modification from the details of the plan as originally designed. I am aware that this statement may appear inconsistent with the existence of the strenuous opposition led by General Tremenhare, but a careful examination of the papers will show that that opposition is entirely of the above negative character. The policy of improving Kurrachee Harbour at all therefore is, by the absence of any other proposal, identified with Mr. Walker's plans for accomplishing it. This ought to afford a strong presumption in favour of the general soundness and comprehensive character of his views.

on of
Break-
ostponed.

8. Mr. Walker's plans, submitted, as above stated, in October 1858, having been considered by the Government, it was decided on financial grounds that it was undesirable to give immediate sanction to the expenditure of so large a sum as 300,000*l.*, and it was therefore determined, with the very qualified and reluctant concurrence of Mr. Walker, to defer the sanction of the execution of the Manora Breakwater. He afterwards (in April 1861) took an opportunity of formally expressing his regret at this decision.

r Works
ondence,
p. 68.

n given to
ing works

9. In February 1859, then, the Keamaree Groyne and the system of works connected with the diversion of the Chinna Creek waters, at an aggregate estimated

cost of 137,000*l.*, were sanctioned. It was decided to place their execution in charge of the officers of the Public Works Department, under the general superintendence of Colonel Turner, R.E., then chief engineer in Sind, and who, having been in England and having frequently conferred with Mr. Walker during the preparation of the design, concurred in his recommendations. Mr. Walker, however, had further recommended that tenders for the execution of the whole of the sanctioned works should be asked for from responsible contractors, but this recommendation was not adopted.

*to be executed by
Public Works
Department.*

10. Colonel Turner, however, appears to have had the intention of making a local contract for the whole of the works, for at his request Mr. Walker prepared for him detailed plans and specifications with a view to such a contract.

*Mr. Walker pre-
pared plans and
specifications for
a contract.*

It should be stated that I took no part in the preparation of these plans and specifications, considering that the engineer who was to have local charge of the works should have the sole responsibility in their adaptation to local circumstances.

No contract was ever based upon these plans and specification, but the works were from the first carried on departmentally, and the specification used as a code of instructions to the engineers in charge, a purpose for which it was not intended or adapted.

With the exception of a reply to a reference to him of Lieutenant Taylor's scheme in 1861, the preparation of these plans and specification was the last service which Mr. Walker or his firm performed in connexion with Kurrachee Harbour. He died in October 1862.

11. Orders were given for the commencement of the works early in 1860, Mr. Price, C.E., having been appointed superintendent, under the general direction and control of Colonel Turner, chief engineer in Sind. In May 1861, Colonel Turner was succeeded by Colonel Tremenhoe, so that the works had not made sufficient progress to show material results before his connexion with them ceased. Colonel Tremenhoe from the first took an unfavourable view of Mr. Walker's plans, both in their principles and in every detail, and persistently urged their abandonment upon the Government.

*Commencement of
works under
Col. Turner and
Mr. Price.
Col. Turner
succeeded by
Col. Tremenhoe.*

12. In the early part of 1862 a revised estimate was made of the probable cost of the works as they were being executed on the departmental system, the amount of which was very much in excess of that of Mr. Walker's. In the absence of explanation this result appeared to tell unfavourably against either the sufficiency of the original estimate or the economy of the execution.

*Revised estimate.
Harbour Works
Correspondence,
Vol. I., p. 114.*

Much of this discrepancy, however, was in fact due to misapplication and misunderstanding of the plans and specification which Mr. Walker had furnished to Colonel Turner, arising from a want of communication between Mr. Walker and the engineers in charge while the works were in progress. A considerable economy was ultimately made upon the revised estimates, but the greater part of the unnecessary expenditure had been incurred before the character of it was pointed out. These remarks apply only to the Napier Mole Bridge, Native Jetty, and New Channel, which (estimated originally at 86,000*l.*) have cost 170,000*l.* The Keamaree Groyne and East Pier, so far as executed, have cost less than the estimate. The details of the works themselves were executed with every regard to economy and reflect much credit on the engineers in charge.

*Causes of excess
over original
estimate.
Harbour Works
Correspondence,
Vol. I., p. 113,
Col. Tremenhoe;
p. 122, Mr. Parkes;
p. 93, Mr. Parkes.*

13. The Keamaree Groyne was commenced in November 1861, and was completed in April 1863 to the length included in the intended contract, viz., about a mile and half. There were no special physical reasons for the termination of the groyne at this particular length. It was no doubt assumed that before that length should have been completed, new materials for deciding the questions of its extension and of the principles of its construction at the outer end would have been collected, and that if an extension should appear desirable it would be proceeded with without interruption. Mr. Price did in fact recommend such an extension early in 1863, and his recommendation was supported by General Scott, chief engineer of the Bombay Presidency, but being opposed by Colonel Tremenhoe, it was not prominently brought before the Government.

Keamaree Groyne.

14. About the same time, that is in 1863, the works necessary for the diversion of the Chinna Creek waters were so far advanced that preparations were made for

*Intended diversion
of Chinna Creek
waters in 1863.*

closing the creek and removing the dam which separates the Chinna Creek marsh from that of the harbour.

*Reference to
Mr. Parkes.
Report on state of
Entrance, 28 Oct.
1863.
Harbour Works
Correspondence,
Vol. I., p. 86.*

15. Such was the state of the undertaking when in October 1863 I was instructed by the Secretary of State, at the request of the Bombay Government, to give my opinion whether any of the facts noticed by Colonel Tremenneere in certain reports made by him to the Government "rendered a change in any part of the plans" of the harbour works advisable."

16. The facts so brought to my notice were the effects produced by the action of the groyne upon the scour of the harbour, as shown by surveys made in January and April 1863. Those effects may be described, shortly, as follows:—

1. A very large quantity of sand ($23\frac{1}{2}$ millions of cubic feet) had been washed out from the harbour channel, thereby increasing the water space of that portion of the harbour about 9 per cent. But of the sand so washed out a portion, though a very small one, had been deposited in the line of navigation between the end of the groyne and the sea. Moreover, the action of the scour extending to the bar at the entrance, which consisted of a very fine light sand, had completely deranged the form of equilibrium which the contending actions of the scour of the tidal waters in their original volume, and the surf raised by the south-west monsoons, had impressed upon the material of the bar. Portions which were formerly deep had been filled up, while other parts had been lowered. The effect on the whole was encouraging as to the ultimately beneficial action of the increased scour, which had already carried so large a quantity of sand clear away to sea, but the immediate effect was injurious to the navigation of the entrance.

*Recommendation
to defer diversion
of Chinna Creek
waters.*

17. In view of these facts, I expressed a confident opinion that the actually injurious action was only temporary, and that the evil would cure itself, but that as to any recommendations for further works which might be advisable for reducing the temporary evil to a minimum, or obtaining the maximum of ultimate advantage, I wished before making them to see what had been the effect of the monsoon then just over. My definite recommendations, therefore, were confined to one point, viz., that the diversion of the Chinna Creek waters then about to be carried out should be postponed. I advised this in the belief that the temporary evil then affecting the entrance was due to an excess of scour too hastily thrown into the channel, and that a further addition of scour, in the then condition of the entrance, would aggravate the evil. At a future time, when the channel should have recovered itself, and with certain precautions, I considered that the diversion might be carried out with much advantage.

*Mr. Parkes' visit
to Kurrachee in
1864.*

18. Shortly after the delivery of this report I was instructed to visit Kurrachee, and, after making a full investigation into the whole subject, to report to the Bombay Government.

*Conferences with
Col. Tremenneere.*

With this view I arrived at Kurrachee early in January 1864, and remained there for two months. I had then the advantage of meeting Colonel Tremenneere, and of discussing the whole question with him. I informed him unreservedly of all my conclusions, and he did the same to me except upon one point, which he afterwards brought very prominently forward, and which gave rise to much correspondence.

*Effects produced
by monsoon of
1868.*

19. The effects produced during the monsoon were principally the following:—

- 1st. The characteristic form of the bar was restored, a high bank of sand being piled up as a barrier immediately in front of the entrance, while the circuitous channel round the tail of this bank was reopened to the same depth as formerly, but to a less width (and consequently less depth available for navigation).
- 2nd. A considerable quantity of sand was washed into the harbour channel, partially replacing that which had been washed out previous to the monsoon.

*Mr. Parkes' report
of March 1864.
Harbour Works
Correspondence,
Vol. I., p. 126.*

20. In view of these facts, I repeated my previously expressed conviction that where actual injury to the navigation had been produced, it was only of a temporary character, and would disappear as the principles of the design were carried out.

The accumulation of sand in the harbour channel I believed to be due in great measure to exceptional causes, though I was not prepared to explain the whole action. I thought, however, that certain obvious evils were caused by the position of the end of the groyne, and recommended its immediate extension for 1,500 feet; also that some assistance should be given to the natural scour for the removal of the opposite shore of Deep Water Point, so as to bring the force of the current nearer to the Manora shore.

With respect to the monsoon action on the bar, I cited it as a confirmation of the opinion originally expressed by Mr. Walker and myself, that the south-west seas were an active agent in its formation and maintenance, and that it must be sheltered from them before any material measure of improvement of the entrance could be looked for. I therefore recommended the immediate construction of the Manora breakwater as laid down by Mr. Walker, but without pledging myself to its sufficiency.

21. On receipt of this report the Bombay Government immediately sanctioned the extension of the groyne and the removal of hard material from Deep Water Point, which works were duly completed in the course of the following year (1865). *Sanction given to portion of recommendations.*

The construction of the breakwater (of which the estimated cost was about 120,000*l.*) was recommended to the Secretary of State for his sanction.

22. In the meantime Colonel Tremenheere, with my report before him, prepared an elaborate statement of his views, which he embodied in a report to the Commissioner in Sind, dated 19th May 1864. *Col. Tremenheere's report of May 1864.*

In it he gives the following summary of his opinions:—

- 1st. The peculiar position of the harbour with reference to the monsoon surf acting on the shallow coast has not hitherto met with sufficient consideration.
- 2ndly. The increased velocity given to the tides by the construction of the groyne, has increased the size and height of the bar, instead of opening a passage through it, or scouring it into deeper water, as was intended.
- 3rdly. The tidal water to fill the harbour being now drawn from the vicinity of the breakers on the bar, and carried at a high velocity through a narrow deep funnel, is much more laden with sand, silt, and mud than it was formerly, and the amount of such sedimentary matter brought in by the flood during the monsoon, much exceeds what can be lifted and carried out by the ebb tides, so that the amount of deposit within the harbour must annually increase.
- 4thly. The result of extending the groyne still further must be to draw water during the flood tide still more heavily charged with sand, and to cause still more rapid injury to the harbour.
- 5thly. The bar has increased both in length and width and height since the works were commenced, and the depth of water in the entrance channels has been materially reduced.
- 6thly. We find both within and outside the harbour the preservation of the general form, combined with a change of material from very light to heavy sand, a result which it should be an engineer's object to avoid.
- 7thly. The proposed breakwater would not afford any effectual shelter to that part of the bar which Mr. Parkes wishes to scour away, and it is very improbable that a deep channel could be formed in that direction.

Harbour Works Correspondence, Vol. I., p. 156.

23. It may be at once stated that the 2nd, 3rd, 4th, 5th, and 6th of these conclusions have been brought to the test of experience, and not one of them has been confirmed. They are based entirely on the observation of effects which have since disappeared, and the only yet remaining injurious effect of the works in their incomplete state is the lengthening of the bar to the eastward. Though longer, however, the bar is both narrower and lower than formerly, and the channel round its end is as deep and twice as wide as it was originally. With respect to the *interior* of the harbour the improvement is indisputable. These five objections therefore may be considered as removed from the pale of discussion. *Injurious effects have now passed away.*

Coast current theory.

24. The first objection is supported by a theory for the first time promulgated in this report, and as to which Colonel Tremenheere was silent in his previous communications with me, viz., that there is during the monsoons (when direct observations are impracticable) a coast current produced by the action of the waves running from the mouth of the Indus towards Kurrachee. The theory is supported by the fact (disputed by some persons, though I believe admitted by the majority) of the existence of minerals, especially mica, peculiar to the valley of the Indus, in the mud of Kurrachee Harbour, and still more directly by the results of an experiment made by Colonel Tremenheere during the monsoon of 1865, in which out of a number of bottles set afloat at the mouth of the Indus a considerable proportion were found on the beach a few miles to the eastward of Kurrachee Harbour. Colonel Tremenheere attributes the existence of the current to the supposed oblique action of the surf on the sandy coast, but in this part of his argument he is believed to stand absolutely alone in the support of some of the more important of his alleged facts and his inferences.

Discussion on coast current theory.

Harbour Works Correspondence, Col. Tremenheere, Vol. I., pp. 158, 162, 163.
Col. Kennedy, Vol. I., pp. 176, 178.
Captain Giles, Vol. I., pp. 178, 179, 180-184.
Col. Tremenheere, Vol. I., pp. 184-192, 192, 193.
Sir Bartle Frere, Vol. I., pp. 196-200.
Government resolution, Vol. I., pp. 200-202.

25. This coast current theory has been made the subject of a great deal of discussion, and has been contested from many points of view, but so far as it regards the design for the harbour improvements the discussion may be concentrated in two simple questions.

1st. If such a current exists, where is the evidence of its deteriorating effects upon a harbour of such acknowledged vitality as Kurrachee?

2nd. Even if it be calculated to injure the harbour, what can better mitigate the evil than the Keamaree Groyne, which provides in the angle between it and Keamaree Island a trap for all silt brought from the eastward, from whatever source, and prevents its entering the harbour?

After the lapse of four years no facts or arguments have been brought forward which suggest replies to either of these questions.

Short reply to Col. Tremenheere's objections to the breakwater.

26. With reference to Colonel Tremenheere's seventh conclusion, it appears to have been based on an imperfect conception of the objects which it was hoped would be effected by the breakwater, and upon a theory as to the improbability of the scour taking a certain direction, of which it may now be confidently said that it has been disproved by experience.

These points are more fully discussed in my report of the 10th August 1868.

Colonel Tremenheere concludes by a recommendation that the whole question should be referred for the opinion of scientific men.

Reference to Messrs. Stevenson.

27. This report, as above stated, was dated May 1864. In September 1865, sixteen months later, the Government of India recommended that the questions at issue between Colonel Tremenheere and myself should be referred to some independent engineer for his opinion, and in accordance with this recommendation Messrs. D. and T. Stevenson, of Edinburgh, were instructed by the Secretary of State to report on the following questions:—

1st. The validity or otherwise of Colonel Tremenheere's objections, and the consequent expediency or otherwise of stopping the works.

2nd. The amount of probability on general considerations, that Mr. Walker's plans, if prosecuted to completion, will effect an improvement of the harbour commensurate with their cost.

Their report.
Harbour Works Correspondence, Vol. I., p. 289.

28. Messrs. Stevenson's report was presented on the 26th February 1866. Although the form of their conclusion is favourable to Colonel Tremenheere's objections, yet their line of argument shows no one point of contact with Colonel Tremenheere's. Of the various questions at issue between him and myself many are not mentioned; a decision is not even pretended to be given upon any one. They state that they hold one opinion even more strongly than Colonel Tremenheere and myself, though there is nothing in Colonel Tremenheere's report to show that he holds it at all, viz., the necessity of protection from the sea; and upon the alleged ground that Mr. Walker's breakwater is insufficient for this purpose, they conclude that "Colonel Tremenheere's fears as to the success of Mr. Walker's plans are well founded." It will be observed that the sufficiency of Mr. Walker's

breakwater was an open question with me in 1864, and Messrs. Stevenson lay down no principle for the determination of what the extent should be. They do, indeed, say that the whole of the extensive sandbank called the Bar must be thrown completely under shelter, but this is a condition which may be interpreted with great latitude, and in a very reasonable sense may be met even by Mr. Walker's short breakwater.

On the whole, it may be said that Messrs. Stevenson's report served to obstruct the progress of the works as designed by Mr. Walker, but did not give the slightest clue to the principles on which an improved design might be based.

29. Messrs. Stevenson's report was made the ground of an order by the Secretary of State, issued in April 1866, to "stop the works." There were no works at that time in progress, all those already sanctioned having been completed, but the order of course involved the refusal to the sanction of any new works.

Works stopped by order of Secretary of State.
Harbour Works Correspondence, Vol. I., p. 288.

30. The Government of India acquiesced in this decision, considering that, though the improvement of Kurrachee Harbour was an object of great importance it would be better to wait till some plan commanding general confidence should be proposed.

Acquiescence by Government of India.
Harbour Works Correspondence, Vol. I., p. 286.

31. The Government of Bombay pointed out the inconsistent character of Messrs. Stevenson's conclusions, and suggested a further reference to them for explanations, to be followed, in the event of this second reference not resulting in a withdrawal of their unfavourable decision, by a still further reference to some engineer whose authority would justify the summary condemnation of Mr. Walker's designs.

Dissent by Government of Bombay.
Harbour Works Correspondence, Vol. I., p. 293.

32. Lord Cranborne, then Secretary of State, did not adopt this suggestion, but in January 1867 he practically admitted an appeal from the previous decision by referring the question to Sir Seymour Fitzgerald, then just appointed to the Government of Bombay.

Reference to Sir Seymour Fitzgerald.

Owing first to the monsoon, and then to the pressure of business connected with the Abyssinian expedition, His Excellency was unable to visit Kurrachee till January 1868. In that month, however, he did so, accompanied by General Tremenneere, and after a full investigation of the whole matter and of General Tremenneere's objections, he transmitted to Sir Stafford Northcote a strong recommendation for the immediate resumption of the works as designed by Mr. Walker.

33. In the following June, under instructions from the Secretary of State, I proceeded to India, and, after full reconsideration of the whole subject in conjunction with the local authorities and officers, I reported my conclusions as to the effects of the works already executed and my recommendations as to future proceedings.

Mr. Parkes' visit to Kurrachee and report, 1868.

34. My conclusions may be summed up as follows :—

Conclusions.

That the works already executed had had a very beneficial effect on the interior of the harbour, expelling from it about two and a quarter millions of cubic yards of sand, by which the water space of the anchorage was increased 14 per cent. ; while, by rendering the courses of the tidal currents more regular, they had made it so much more secure that the number of ships capable of being moored was increased from 20 to 55, and those of a larger tonnage :

That the injurious effects produced upon the bar and entrance immediately after the completion of the groyne had disappeared, leaving the navigation practically what it was before the works were commenced :

That although no actual improvement of the entrance had been effected, certain conditions necessary for effecting improvements had been established, which would produce useful results when supplemented by other conditions not yet provided.

35. Upon these conclusions I based the following recommendations :—

Recommendations.

That the breakwater, nearly as originally laid down by Mr. Walker, should be constructed, and, with a view to directing the scour of the ebb tide into the most

advantageous line, the bar and some of the shoals in the lower part of the harbour should be dredged :

That the obstructions in the entrance originally caused by the too sudden addition of scour to the harbour having been now cleared away, there was no further necessity for delaying the admission of the Chinna Creek waters into the harbour, the scour of which would effect a great improvement in the channel up to the wharfs near the town :

That, in order to ensure unity of purpose in the further prosecution of the works, the general direction of them should be placed in my hands as consulting engineer, in direct communication with the officers of the Public Works Department now in charge of the works.

action of
recommendations
Secretary of
C.

36. These recommendations, having been duly considered by the Secretary of State and by the Governments of India and of Bombay, they were sanctioned by the former in the month of November last.

37. It may be useful, in conclusion, to state a few facts tending to show that the increase of capacity of the interior of the harbour effected by these works has been by no means premature.

cause of
shipping.

The following return furnished me by the Commissioners of Customs shows how the shipping frequenting the port is increasing :—

Year.	Square-rigged Vessels and Steamers.			
	Arrivals.		Departures.	
	Number.	Tonnage.	Number.	Tonnage.
1856-57	52	24,024	54	24,493
1857-58	87	49,830	75	41,450
1858-59	96	52,927	101	56,554
1859-60	101	60,994	101	60,033
1860-61	109	61,589	101	56,929
1861-62	110	56,829	115	58,094
1862-63	128	62,161	129	58,843
1863-64	155	74,252	155	75,019
1864-65	71	46,247	64	41,687
1865-66	118	66,377	116	66,280
1866-67	120	76,808	113	73,553
1867-68	170	111,648	171	111,798

These numbers are perhaps too fluctuating to justify more than a general conclusion, but a glance at them will show that anchorage space which may have been ample in 1857-8 would be liable to be insufficient at the present time, and the more so when it is considered that the average tonnage of the vessels has increased as well as their number.

case of trade.

38. A better estimate of the growing importance of the port may be formed from the returns of the values of the exports and imports compiled by the Commissioner of Customs, and published by the Chamber of Commerce; but this, if taken in the gross, would be liable to mislead owing to the exceptional character of some of the items of the returns during the last few years. The exceptional items are cotton and wool as exports, treasure as an import. In the following table these exceptional items have been excluded. It should be borne in mind, however, that apart from the circumstances which have caused the great fluctuations in the value of these items, they are and are likely to remain important branches of the commerce of the port. Wool especially was exported to an average annual value of 300,000*l.* between 1858 and 1861. The value then rose to 700,000*l.* in 1863-4, and has since fallen to 350,000*l.* The export of cotton was small till 1861-2, when it rose suddenly to 120,000*l.*, thence to 2,116,000*l.* in 1863-4, and it has since fallen to 400,000*l.* Some considerable addition therefore should be made to the figures in the table to include cotton and wool at their normal rates, and so exhibit the true value of the export trade of Kurrachee.

Year.	Imports except Treasure.	Exports except Cotton and Wool.	Sum of Exports and Imports.
	£	£	£
1847-48	287,657	136,571	424,228
1848-49	344,716	92,948	437,664
1849-50	418,284	91,903	510,187
1850-51	424,545	144,201	568,746
1851-52	487,810	168,016	655,826
1852-53	532,186	208,758	740,944
1853-54	505,777	195,438	701,215
1854-55	569,077	221,885	790,962
1855-56	599,776	381,595	981,371
1856-57	664,717	321,961	986,678
1857-58	914,791	680,382	1,595,173
1858-59	1,438,687	782,180	2,220,867
1859-60	1,594,526	632,172	2,226,698
1860-61	1,568,305	690,923	2,259,228
1861-62	1,549,761	736,585	2,286,346
1862-63	1,605,195	1,133,815	2,739,010
1863-64	1,699,528	1,410,936	3,110,464
1864-65	1,882,727	1,276,599	3,159,326
1865-66	1,867,824	1,185,573	3,053,397
1866-67	2,096,337	1,281,012	3,377,349
1867-68	2,244,810	1,242,583	3,487,393

39. It will thus be seen that the value of the imports has gone on steadily and rapidly increasing, with little fluctuation. That of the exports attained a maximum in 1863-4, which, however, has been since almost maintained. Taking the exports and imports together, and considering the general stagnation of trade for the last few years, it cannot, I think, be said that these returns exhibit any symptoms of a falling off in the rate of increase of the trade of the port.

KURRACHEE HARBOUR.

MEMOIR

BY

WILLIAM PARKES, M. Inst. C.E.
CONSULTING ENGINEER TO THE HARBOUR
IMPROVEMENT WORKS.

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