10TH MARCH, 1887.

W. D. CRUICKSHANK, PRESIDENT, in the Chair.

THE following Paper was read by Mr. Shellshear :—

ON THE APPLICATION OF THE CONVERGING JETTY SYSTEM.

For the Removal of Bars from the Entrances to the Rivers of New South Wales, with some remarks upon Hydraulic Dredging.

BY WALTER SHELLSHEAR, ASSOC. M. INST. C.E.

THE rapid development of our coasting trade, and the ever-increasing necessity for improving the navigation of our eastern rivers, and thus lessening the risk inseparable from the arduous duties of the mariner, has induced the author, at the request of several members of the Association, and others who are interested in this important subject, to prepare the following paper. In a communication to the Royal Society of New South Wales, in 1884, the author considered in general terms the principles on which our rivers could be improved, and in the paper read before this Association, on the 8th April, 1886, the construction of breakwaters and training jetties was considered. On the present occasion it is proposed to explain in detail the author's views as to the best plan of applying the converging jetty system to the improvement of the Richmond and Hastings rivers, and also to add a few remarks on hydraulic dredging.

The great importance ot the question of improving our river entrances, does not require to be enlarged upon in this paper, for it must be obvious to all that anything that can be done to improve these natural highways to so important a part of our territory, must enhance the value of property, and increase the national wealth.

The first matter to be studied is the cause of the formation of bars at our river entrances. A bar is a ridge or shoal across the navigable channel, at the mouth of a river, over which there is a less depth of water than in the adjacent portions of the channel.

The formation of bars may be attributed to two principal causes :—

(1) The tendency of the sea, or of waves driving along the shore by the prevailing winds, or of littoral currents, to heap up the beach in a continuous line along the shore, and close up the outlet of the river, which is only partially prevented by the scour of the tidal ebb and flow, and the discharge of inland waters.

(2) The deposit of material brought down by a river, when the velocity of the river is checked on entering the sea.

The formation of bars at the mouths of tidal rivers is mainly due to the first cause, whilst the action of the second cause is most clearly manifested at the deltas of rivers flowing into tideless seas.

The tendency of the waves to heap up the beach in a continuous line along the shore is well illustrated in the case of all our coast rivers. Thus at every inlet we see sand spits pushing across the entrance, and the direction of these sand spits is either north or south, according to the amount of protection they receive from the adjacent headlands. Thus at the Richmond River the tendency is for the sand spit to push to the north, by the action of the southerly wind, there being no headland to the south of the entrance. At the Clarence, the Hastings, the entrance to Lake Macquarie, and other entrances which are well protected on the south, we see the sand spits pushing southwards, by the action of the north-east winds.

Examining the charts of the coast of New South Wales, we see that the bar formation is merely local, and is confined to a tolerably narrow ridge across the entrances to the rivers, the depth rapidly increasing seawards, and at most places a depth of ten fathoms is reached within half a mile from the shore. This feature is of great importance in connection with the question of removing the bars, for it shows that if the bars could once be moved, there would be but little prospect of their re-forming, as is almost invariably the case when it is attempted to remove a bar from a river entrance where the sea is shallow for a great distance from the shore.

Of the different systems of improving river entrances, the converging jetty system has proved more uniformally successful than any other system; and there are few rivers in the world that offer greater facilities for the successful application of this system than the rivers of New South Wales.

In considering any scheme for lowering or removing bars, the following points must be kept in view:—Firstly, that, although as a rule the sea along the coast of New South Wales is moderately smooth, yet at times storms of considerable violence occur. Secondly, the necessity of making provision for the proper discharge of flood waters under the exceptional characteristics of the country, as all the rivers are liable to floods of considerable magnitude. And lastly, the *sine quâ non* that the cost of carrying out the proposed works must be kept down to the lowest possible figure.

The object aimed at in the construction of training jetties is, to concentrate the tidal and upland water flow in a definite channel, and to protect the channel from the inroads of sand as it tends to push its way across the entrance by the action of the waves.

The rise and fall of tide along the coast is from three to five feet, and although this is only a moderate range, most of the rivers have a large tidal capacity, and the amount of tidal water entering and leaving the rivers is quite sufficient to maintain a good channel over the bars if the flow was well directed by judiciously planned works; and many examples of successful training works could be cited where the range of tide is even less than the range available in the case of our rivers.

The quantity of fresh water coming down the rivers is very variable. At times the rivers almost cease to flow, whereas in times of flood they bring enormous volumes down to the sea. Some estimate of this variation may be made when it is mentioned that the average rainfall for the coast district is something like 35 inches per annum, and this large amount is made up by a comparatively few days of excessive rain, followed by weeks, and even months of complete drought.

No general plan for improving our rivers could be given, as each case has to be dealt with according to its local characteristics. But to illustrate how the jetty system could be applied to our rivers, two very different cases will be considered. Firstly, the Richmond River (Plate 1), where the entrance is exposed to the full force of the southerly weather, and has only slight protection on the north. And secondly, the Hastings River (Plate 2), where the entrance is well protected on the south, but is exposed to the north-easterly weather.

The Richmond River (Plate I.) is a typical one, and perhaps no better example could be taken from the list of Australian rivers. This river rises on the Queensland border, and the main river, exclusive of its many branches, has a course of about 150 miles. The area of the watershed is about 2,660 square miles, and it falls into the Pacific Ocean. Its entrance is obstructed by one of the most dangerous bars on the coast, and has been the scene of a large number of shipping disasters; in fact, this entrance might appropriately be called a cemetery of wrecks. This river flows through one of the richest agricultural districts in the colony. The district is noted for its magnificent sugar cane plantations; and, from the great extent of splendid volcanic soil, there is every reason to expect that in a few years it will take one of the first places among the agricultural centres of New South Wales. There are also good indications of abundant mineral wealth in the district. The improving townships of Casino, Lismore, Coraki, Woodburn, Ballina and several others are on its banks. The main river is navigable for coasting vessels of light draught as far as Lismore—seventy-five miles from the entrance—and at present two lines of regular steamers run weekly trips to and from Sydney, in addition to a number of sailing vessels engaged in the timber trade. The entrance within late years has shifted through a range of about 6,000 feet. The navigable channel is constantly shifting, and at times the crossing is so bad that ships have repeatedly had to wait for weeks before they could cross in or out. The present channel is under the North Head, and is very narrow and tortuous. The bar is formed of fine white sand, easily set in motion by the current or waves, and to the north there are several patches of rock in the estuary. A branch of the river, called the North Creek, joins the main stream almost at the entrance, and the effect of the waters flowing from this branch must be taken into consideration in setting out any plan for improvement works. All the circumstances of the case point to the suitability of the converging jetty system for effecting permanent improvement to this entrance. The position marked in the detailed chart (Plate I.) appears to possess special advantages, for the reasons that the position of the proposed channel is so placed that the combined flood and tidal waters from the main channel and the subsidiary, or North Creek, have a straight run, and therefore their scouring action would have the maximum effect in deepening and maintaining the channel. The dangerous rocks near the North Head would be avoided; the entrance being nearly at right angles to the coast, the extent of bar to be acted upon is a minimum; and, lastly, the adoption of the curved form of jetties would deflect the current into the centre of the channel, and prevent the undermining of the works in times of heavy floods. This form of entrance, moreover, possesses in a marked degree the properties of a nozzle, and give the ebb tide and flood waters the best effect in deepening the centre of the channel and concentrating the scour of the issuing current on the bar.

The entrance to the Richmond River is in some respects similar on a small scale to the entrance to the Charleston Harbour, on the east coast of the United States, and the lines above proposed for the improvement works at the Richmond are similar to those at Charleston, where a very marked improvement has been effected by converging jetties, and every year since the commencement of these works the improvement in the channel has become more marked. The rise and fall of tide at Charleston is only slightly more than at the Richmond, and the two places are about equally exposed to the force of the sea, the Richmond has the great advantage however, that the sea is much deeper near the coast than is the case at Charleston, a depth of 10 fathoms being reached within half a mile of the shore line at the Richmond, whereas that depth is not reached for several miles in the case of Charleston. The tidal capacity of the Richmond is very considerable, and the large volume entering and leaving the river at every tide should be more than enough to maintain the entrance if its energy was well directed, without the assistance of the upland waters which are of themselves an important factor in connection with the scouring out of the bar. Having thus described what appears to the author the best lines on which to construct improvement works for the Richmond entrance, it is next proposed to consider the case of the Hastings River and then proceed to the question of the most suitable method of constructing training jetties with the material and labour available in this Colony.

The Hastings River (Plate 2) rises in the mountains about forty-five miles from the coast and after following a circuitous course receiving on its way to the sea numerous tributaries, falls into the ocean at Port Macquarie, the area of its water shed is about twelve hundred square miles. The river as it approaches the ocean takes a northerly direction and then an abrupt turn to the south widening out into a broad sheet of shallow water, turning eastwards as it enters the ocean at Port Macquarie. The entrance to this river unlike the Richmond is well protected by nature from the southerly weather and the variation in its entrance channels are caused by the action of the north easterly weather, in this case the rocky South Head on which the town of Port Macquarie is built, forms a natural protection work extending into deep water on the side from which the heaviest weather breaks on the coast, all that is required therefore is the construction of a training jetty from the northern sand spit in an easterly direction, to protect the entrance from the inroad of sand from the north, and to permanently fix the channel so that the tidal action may be concentrated and used to the best advantage in clearing and maintaining a fixed channel; after a careful study of the tidal capacity of the river and taking into consideration the position of the outlying rocks on the south side, the most suitable position for the northern jetty in the author's opinion is that shown on the detailed chart of the entrance.

The next question to be considered is the best method of constructing training jetties: the author has already described at some length the various systems of constructing training jetties in a previous paper, and it is now proposed to describe what in his opinion is the most economical method of construction in the case of our rivers. In connection with this point the following considerations must be borne in mind. Firstly, the fineness of the sand renders it absolutely necessary that the site of the jetties should be protected for a considerable distance in advance of the works whilst in progress, otherwise the scouring current round the end of the advancing works would cause such changes in the bottom that vast quantities of material would be wasted in filling up the holes and trenches scoured out by this action. Two plans of protecting the bottom at the site of works of this class have been successfully used in other parts of the world. The first is to pave the site with small stone thrown in from a staging or from barges, and distributed evenly over the bottom to the depth of two or three feet for a considerable width on either side of the centre line of the works. The second is by the use of fascine mattresses. The works at the Sulina mouth of the Danube, and the breakwaters at the entrance of the Amsterdam ship canal, are good examples of the first method, and the jetties at the Charleston Harbour and the mouth of the river Maas are good examples of the second plan.

Either of these plans could be used with advantage on our coast, but the price of labour, and the probable difficulty of getting suitable material would militate against the use of the fascine mattresses. A paving of stone would therefore appear to be the best for our case. In the construction of training jetties, the rate of progress is a question of importance, for the more rapidly the works can be pushed forward the less will be the effect of temporary local changes on the site. From this fact, and also from the circumstance that timber of great strength and considerable durability is abundant on all the eastern rivers, a modification of the ngenious system of construction employed by Sir Charles A. Hartly at the Sulina Mouth of the Danube seems peculiarly suitable.

The force of the sea being greater in the case under consideration, a greater height for the platform would be necessary, and in the more exposed parts of the works it would be advisable to cut off the sheet piling at about half tidal mark, so that the crests of the waves in times of storm might pass over without bringing an undue shock on the works. The back lash of the waves being most injurious to the rubble foundations where a solid structure is taken up above high water mark, and as the jetties under consideration are for the purpose of directing and concentrating the tidal currents rather than for the complete breaking up of the waves, their efficiency would not be impaired by a reduction in height of the solid part of the works; moreover, by cutting off the sheet piling at the height proposed, relief would be furnished in times of floods and exceptionally high tides; and at the same time the best effect of the tidal scour from the latter half of the ebb would be retained. No doubt a considerable quantity of sand would be thrown over the works in times of storm, but the well-directed ebb current would be more than able to roll this out to sea, where beyond the jetties it would encounter the littoral ebb-current, and be moved from the entrance with a velocity accelerated by the storm.

The figure (Plate 3) shows the construction of the form of jetty proposed. The method of construction would be as follows: The open work of the jetty would be urged forward as rapidly as possible, the piles being protected by a paving of small stones spread over the bottom for about thirty feet on each side of the centre line. This material could be deposited either from barges or by a travelling crane from the pier. By a suitable pile engine, each succeeding bay of piling could be driven from the end of the completed pier; and as the open work progresses the sheeting could be advanced and the necessary protecting rubble deposited. After a time, when the rubble mound had become well consolidated, which would be greatly helped by oysters, coral, and other calcarious insects, the works could, like those at the Danube, be rendered permanent with a concrete top at a moderate cost. It would be necessary to protect the rubble mound in the more exposed portions of the works by depositing large blocks of stone or concrete on the slope, but the extent to which this would be necessary could be settled as the works progressed.

The last part of my subject will now be considered, namely, Hydraulic Dredging.

The economical removal of sand from the entrance channels of our rivers is a very important question, for if the sand could by any means be removed it would often afford great assistance to the navigation, even if the circumstances of the port did not warrant a large expenditure on permanent works; the system of bucket-dredging, so useful in the upper parts of a river, and for deepening the interior of a harbour, is too slow and costly for the work under consideration, and the question naturally arises, is there no other system that could be used in cases like that under discussion? As pointed out in the earlier part of this paper, the bar formation at the entrances to our rivers is confined to a tolerably narrow ridge at the entrance to the rivers, and that deep sea water is found at a very short distance from the shore, it therefore follows that if during the periods of ebb tide the sand in the entrance channel could be set in motion, much of it would be carried away into deep water, and for a time at least would not obstruct the navigation. It is obvious that without protection works this deepening process would not be permanent, but even temporary improvements would be of great value in opening up the port after a heavy storm, when the depth over the bar had been reduced so as to obstruct navigation. Within the last few years the Americans have devoted much attention to the question of removing shoals and sand banks by hydraulic scour, and it is proposed to describe one or two of the plans adopted.

Major T. M. Mansfield, of the United States, invented a very useful Hydraulic Excavating Machine (Plate III.), a full account of which is published in the annual report of the Chief of

Engineers of the United States Army for 1884, page 1302. This machine consists of an ordinary screw steamer, fitted up with a powerful set of pumps and a kind of hydraulic raker; this is connected to the pumps by suitable flexible pipes, and is hung over the stern of the steamer by a pair of shear legs. Each of the branches of the rake is fitted with a nozzle, which direct a powerful jet of water against the bottom. The methed of working this apparatus is as follows:—The steamer is anchored by cables on lines running aft from the bow on both sides for a distance, say 1000 feet, each of which lines should be provided with two anchors connected as shown on the figure. Two cables are also passed forward from the bow and anchored as shown. By this arrangement the steamer is pivoted, as it were, at the bow, and by means of the rudder at the stern it may be made to travel on an arc whose chord is the desired width of channel. When the steamer is placed in position, and the anchors placed as above described, the stern of the steamer being down stream, the water jet or hydraulic rake is turned on, and the propeller started to go ahead, the rudder being alternately turned to port and starboard. The water jet disturbs the material at the bottom, which is thoroughly mixed with the water by the combined action of the propeller and water jets, and is sent seaward by the ebb current, assisted by the current produced by the propeller; the steamer is gradually hauled back by the stern cables, and a channel is rapidly cut through the sand bank. This form of dredging machine, besides being simple in construction and most effective in operation, is specially adapted to the removal of river bars when the material is to be transported short distances to the pools below, but more especially is it adapted for service upon exposed ocean bars, where the sea is rough and where the ordinary form of dredger is inapplicable. Very effective work can be done by simply mooring a screw steamer in the way above described and trimming her a little by the stern, so as to get the propeller shaft slightly inclined, and setting the propeller ahead, slowly drawing the vessel astern by the stern cables, at the same time moving the stern from side to side by the action of the rudder.

This method of dredging—or, as it is more properly called, propeller-sluicing—has been used in America with great success. In a recent volume of the "Minutes of the Institution of Civil Engineers," Vol. 83, p. 386, the results of some important work are published in a paper by Mr. Harry Harngood, Assoc. M. Inst, C.E. From this paper it appears that at the Saint Helen's bar, on the Columbia River, Oregon, U.S.A., a channel 1,200 feet long, 200 feet wide, was deepened six feet in three days in 1882. When the great depth of the sea at a short distance from the bars at our river entrances is considered, it must be evident how peculiarly suitable this method of sluicing is for temporarily improving the entrance channels; and what great assistance this system of sluicing would afford in securing a permanent channel when used in combination with suitably planned improvement works.

The questions treated of in the foregoing are ones that have been perplexing the colony for some time past, and the devising of some *speedy* and *economical* scheme for opening up the rivers on the banks of which some of the finest land in the colony is to be found, is a much wished for desideratum. The suggestions above are merely thrown out as the outlines of what might be done to dissipate this barrier to the full development of the resources of the country through which the rivers flow.

The fundamental principles the author considers to be kept in view in undertaking works for the removal of bars at the entrance to rivers similarly situated to those on the coast of New South Wales, where a practically unlimited depth of water is found so near the shore, is firstly to take the channel by as straight a course as possible seaward, so that the best effect can be obtained from the ebb tide and flood waters over the line of minimum obstruction,* at the same time protecting the channel from the

* It is interesting to note that during the late floods on our northern rivers the tendency was to cut straight channels through the sand spits, thus showing that when the river currents are at their maximum strength they are able for a time to overcome the action of the waves, and the rivers assume a straight course to sea. From this it must be evident that the most suitable lines for protecting works are those which provide the straightest possible channel to deep water.

inroad of sand from the beach by suitable works extending from shore into the deep water. Secondly, the works should be pushed forward as rapidly as possible, so that the effect of temporary local changes may be reduced; for if this be not done the scouring action at the advancing ends of the jetties will be so great that the cost of the works will be increased to a serious extent. Adequate provision must be made for the entrance of tidal waters, so that the tidal portion of the river may be properly filled at each tide, thus extending the tidal influence as far inland as possible; at the same time this would afford a free exit for the ebb tide and flood waters. As far as possible the lines of the works must be such that the tidal and flood waters will be deflected into the centre of the channel, so that the works will not be undermined.

The regulation of the river immediately above the entrance jetties could be best effected by dykes or groins. The efficiency and economy of this system of regulating channels is well illustrated by many successful applications in Europe and America.

When the growing importance of our coast districts, and the vast area of splendid land which is at present more or less closed by the uncertainty which exists in getting produce to market, and the large amount of property invested in shipping is considered, the question under discussion will be seen to be not merely of local but of national importance, and that any scheme which could be devised to remove the present obstruction to the full development of so important a part of our territory, will confer a lasting benefit on the colony.

That to accomplish this, the author is convinced, is a matter capable of determination by a close investigation of the local circumstances governing their existence and natural features, and an intelligent application of the best means that have been found to operate and overcome somewhat similar difficulties in other parts of the world.

Finally, it must be remembered that the science of harbour engineering is one based on experience, and it is only by a careful study of the works of others that we may hope to profit by their successes, and be warned by their failures.

ADDENDUM.

SOME doubts having been expressed as to the strength of the jetties proposed in the paper, it may therefore be of interest to point out that when low level works are constructed the full force of the sea is not developed against the works but the crests of the waves pass over the works without bringing their destructive force into play. The jetties at the mouth of the Mississippi are constructed of willow mattresses weighted down with small stone, and with a row of concrete blocks placed upon the top the jetties rising but little above the ordinary sea level, the effect of a great storm on these jetties, which are certainly not more substantial than those proposed, is thus described in the *Scientific American*, of January 27th, 1887:—"If a single fact, more than such as we know, was wanted to confirm the confidence now felt in the jetties, the late storm in the Gulf has supplied it. It has often been asked how the jetties would stand one of those overwhelming tempests that sweep over the Gulf at intervals of years. Such a tempest we have recently had, and the jetties came out of the conflict with which the hurricane force assailed them staunch and victorious. The storm went beyond any to which the jetties had been exposed, beyond even the noted hurricane of 1883. Not only did the jetties at the mouth of the Mississippi withstand the might of the storm, but those at the Labini, not half-finished, did the same. They are built on the same system as the Eads' jetties, and the might that held out the storm was the same fragile-looking willow mattresses that are used there. Major Heuer, who has supervision of the work, has carefully examined what effect it has had upon the unfinished work. The New Orleans *Picayune* reports that Major Heuer, '*found the Labini jetties entirely uninjured, and no material change in the depth of the channel between them. They had withstood the fury of a storm that had swept away every human structure upon the adjacent land.*'"

A groin constructed at Newhaven, on the English Channel, extending 500 feet seaward, which was constructed on the beach of timber piles protected with large masses of chalk and sandstone, withstood the force of the sea for thirty-six years, when it was removed on account of more extensive works being carried out.

The two things that have to be considered in this class of structure are, firstly, that the sand must be kept from getting away by a proper paving of small stone or willow mattresses, and secondly, the works must not be taken up much above the mean sea level, for the higher the solid works are raised the greater the shock with which the waves assail them.