

Discussion.

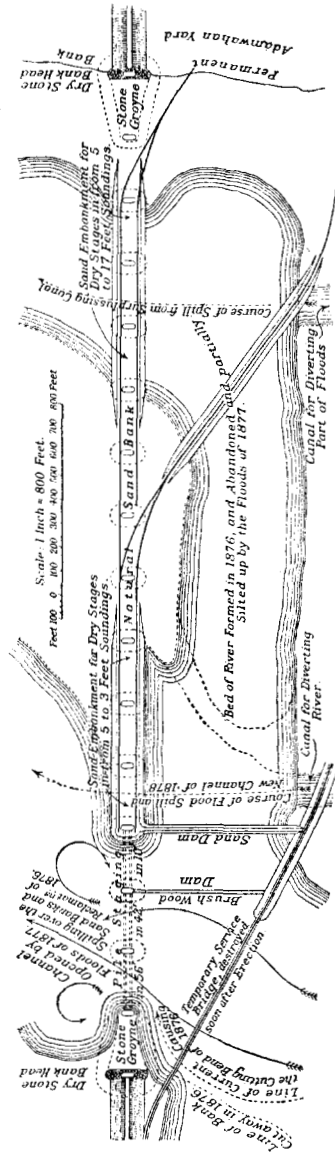
Sir CLEMENT HINDLEY remarked that when he had read Mr. Watson's Paper before its publication, he had suggested that it should be supplemented by a description of the river-training works, showing how it had been found possible to shorten the bridge to half its original length, and special thanks were due to Colonel Macrae for his Paper in which he had explained the whole history of this peculiarly interesting river crossing. In 1880 Mr. J. R. Bell had given The Institution a most interesting description¹ of the original construction of the Empress Bridge, and in 1903 Sir Francis Spring, in an Indian Technical Paper, had described the river-training work up to that date.² Those Papers were of special interest, as nearly sixty years had passed since the bridge problem was first studied, and Mr. Bell's Paper showed how the problem had been attacked with the somewhat limited experience then available. The idea at that time had been to bridge the river practically from one bank to the other, but it would be seen from Fig. 1, Plate 2, in Colonel Macrae's Paper that the Sutlej was a very troublesome river, as its course oscillated over a width of $3\frac{1}{4}$ miles between its permanent banks, and it was not therefore easy to bridge it in its entirety. Before Mr. Bell's project had been carried out Colonel Peile had suggested a site further upstream, and had recommended that not only should the whole of the river be bridged, but that there should be a number of land spans on each side to take any overflow there might be from the river. Such a form of construction would have resulted in disaster, because the river in one or other of its oscillations would have got behind the abutments. *Fig. 1*, p. 132, which had been prepared from Mr. Bell's Paper, was very striking, as it showed that the river was running parallel to the bridge. Mr. Bell had dismissed that extraordinary phenomenon in the brief statement that the piers were built parallel to the assumed axis of the river, but that such an assumption was unwarrantable, because in 1877 during the early part of the construction the river was found to be travelling parallel to the alignment of the bridge. That was one of the small difficulties with which engineers in those days had had

¹ J. R. Bell, on "The Empress Bridge over the Sutlej." Minutes of Proceedings Inst. C.E., vol. lxx, p. 242.

² F. J. E. Spring, "Indian Technical Paper No. 153," Chapter XIV. Simla, 1903.

Sir Clement Hindley.

Fig. 1.



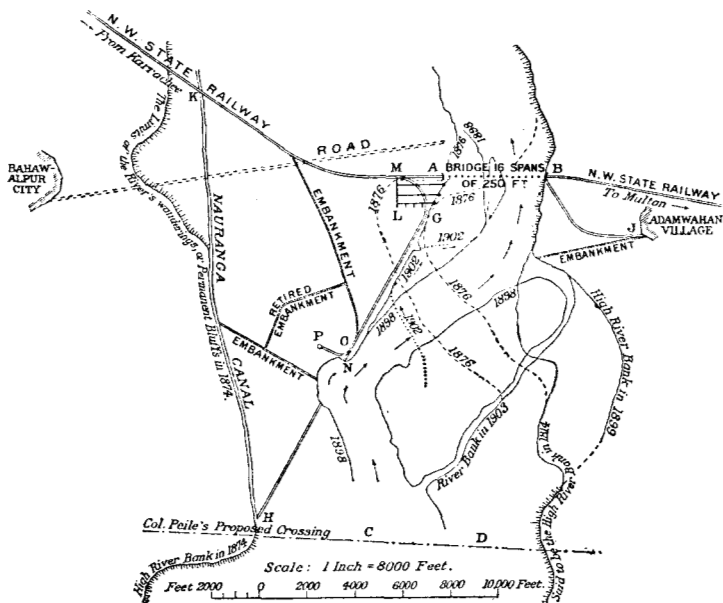
PLAN OF BRIDGE SITE DURING CONSTRUCTION.

to contend. But Mr. Bell had carried on undaunted and *Fig. 1* showed two canals which the engineers had constructed in order to bring the river back to its proper alignment. The formation of the abutment which Mr. Bell attributed to Mr. (afterwards

Sir Guilford) Molesworth was of interest and had been the best way they could devise of trying to keep the river within the channel. Sir Clement Hindley.

He thought that the history of the treatment of this particular river-crossing would be found to be synchronous with that of the development of river-training in the Punjab and the rest of India. Fig. 2, published by Sir Francis Spring in 1903, showed what had been done up to that date. It was impossible in a short descrip-

Fig. 2.



tion to follow through all the developments which had taken place in river-training during the intervening years. They had been fully set out by Sir Francis Spring's Paper, to which Colonel Macrae's Paper formed a very good supplement. Sir Francis Spring had tackled the whole question of river-training in a masterly way, and in giving the credit to Mr. J. R. Bell for having introduced the theory and practice of river-control by guide-banks, he had written: ¹ "Mr. J. R. Bell, utilizing others' and his own experiences of the river's attacks at Adamwahan, and the measures which accidentally

¹ Loc. cit., p. 77.

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or designedly availed to deal with them, and adding to these the experience which, as fully explained in Chapters XXVI and VII, he gained at Ferozepur and Sher Shah, found himself in a position to formulate the principles underlying the modern engineering practice of smooth-faced stone-protected guide-banks," and a few lines farther on, "The Adamwahan works are interesting as exhibiting an intelligent appreciation on their designers' part of several of the leading principles whose recognition led to the subsequent invention of the true guide-bank system with its more or less parallel embankments, well armoured and well aproned, everywhere accessible to stone-laden trains, terminating boldly in impregnable heads standing well out in the river bottom or *khadir*, with no attempt to abut on the bluffs, and each bending round, outwards, at its upper end to meet the current of the embayment that, sooner or later, is bound to come from the upstream side." That statement was particularly interesting because it showed that Mr. Bell, by his own and others' experience of that bridge, had formulated those important principles, and that what had been done since had enabled the engineers to carry out the two Bell bunds seen in Colonel Macrae's diagram, fitting almost exactly the principles laid down by Sir Francis Spring in 1903. The Institution was fortunate in having on its records these valuable Papers, spread over a period of 60 years, describing, by implication, the development of that valuable principle which, as Colonel Macrae said, was now universally adopted in the rivers of the Punjab. It would be seen how at last, after many struggles, the great river Sutlej was held in a fetter, and it was interesting to notice that Mr. Watson stated that the rivers of the Punjab were now much less apt to move about in their channels owing to many irrigation and bridge works which had influenced them.

The wrought-iron girders which had been put up in 1876-77 were now just as good as when they were put in. Eight spans had been taken away and used on the Amritsar-Narowal extension, and the others had been reconstructed and used on another branch-line. They might very well last for another 50 years. Bridge-builders owed a great debt to wrought iron, and they sometimes forgot what valuable service it had rendered.

It was interesting to compare Mr. Watson's Paper with Mr. Bell's. Mr. Watson said: "Much of the heavy plant employed is of a type commonly used by bridge-engineers and warrants no description." Mr. Bell, on the other hand, had given a most meticulous description of his dredgers and methods of well-sinking. Plant such as Mr. Watson's had been absolutely unheard-of in Mr. Bell's days, and would have astounded him. Mr. Watson had pneumatic riveting, but Mr. Bell had had a lot of trouble with his riveters, and had

written : "Allowing for sick and disabled men, the riveting work required close on three hundred gangs, and these were with difficulty collected from all parts of India, as far as Bombay and Calcutta. But the men were mostly unequal to knocking down a 1-inch rivet ; and even after the sturdier well-sinkers and erectors (mostly boatmen by profession) were taught to do the work with heavy hammers, the waste of rivets was about 50 per cent. instead of 20, as usual. The best gangs rarely put in one hundred good rivets in a day, and the average was not much more than thirty. The rate paid (Rs. 9 per hundred 1-inch rivets) for labour only was about double the price in England. Bad as were the hammermen, the holders up were worse ; and a man too listless to hold up for two minutes would spend an hour, if unwatched, in caulking a slack rivet to pass it off as sound."

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Mr. Bell had remarked that the piers could have been built up for a double track, but that that would probably never be needed. They were anxious in 1877 to complete the bridge quickly in order to get the guns and supplies across for the Kandahar column then on its way to Afghanistan, and were successful ; but they did not imagine that a double line of railway could ever be wanted on the bridge ; as Colonel Macrae pointed out, they had not realized the possibilities of irrigation all over the Punjab, and the enormous increase of business which had resulted ; but a double line was in fact necessary. As Mr. Bell's work had lasted for 60 years the new heavy standards adopted in designing the girders might very well last for another 60 years. Mr. Watson compared the types of staff and labour employed in Mr. Bell's time and his time. Mr. Bell had employed a large number of Europeans on the work, but Mr. Watson had done his work with two European engineers—the only Europeans present—and had paid a special tribute to the bridge inspector, an Indian. Mr. F. C. Pavry, M. Inst. C.E., the chief engineer of the North-Western Railway during the recent work, who had laid down the instructions for the river-training works, was also an Indian. The 60 years which had passed had completely revolutionized the execution of such work in India, and it was interesting to see that Indians were taking their place in work of this heavy kind.

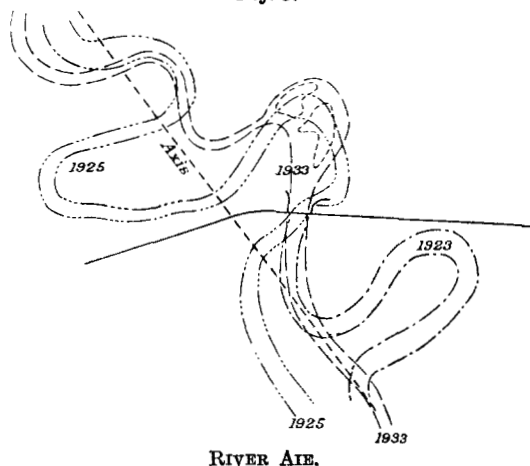
Colonel Sir GORDON HEARN, R.E., said that Mr. Watson's remarks about the European staff were interesting. He noticed that, in spite of what nowadays would be considered an excessive number of Europeans employed on the job, the original cost of the bridge, without the training works, had been only Rs.100 per foot. True, the value of the rupee had been 1s. 8d. in those days, but he was sure present-day engineers would be very pleased to see bridges built now

Colonel Sir
Gordon Hearn.

Colonel Sir
Gordon Hearn

for anywhere near that figure. The second Paper dealt with a subject which was seldom discussed and which was not yet perhaps thoroughly understood. Apart from the inadequacy of the Molesworth groynes, it was quite probable that they would cause great scour, and Mr. Mair's Paper on the Willingdon Bridge¹ showed what the result of stone between piers had been at the Hooghly Bridge at Naihati. It was interesting to note that the guide-banks in the original Adamwahan Bridge had been placed at 60 degrees to the bridge, the modern fashion being to run them practically at right angles to it. The river had been practically uncontrolled, but it never appeared to have seriously attacked those bunds, at all events within

Fig. 3.



8,500 feet of the bridge on the left bank, as had been shown in *Fig. 2*, p. 133. Mr. Watson stated that irrigation in the Punjab had had a regulating effect on the rivers. His own experience did not bear that out, because with a smaller volume a greater sinuosity of oscillation was produced, as he had remarked in the correspondence on an earlier Paper.²

Turning to the opinion that Bell bunds tended to stabilize rivers, he did not think anybody who had seen on the map the courses of the Thames and the Seine below London and Paris respectively would agree that the restriction of a river for a certain length caused it to run straighter. *Figs. 3 and 4* showed the vagaries of the Aie (Assam) and

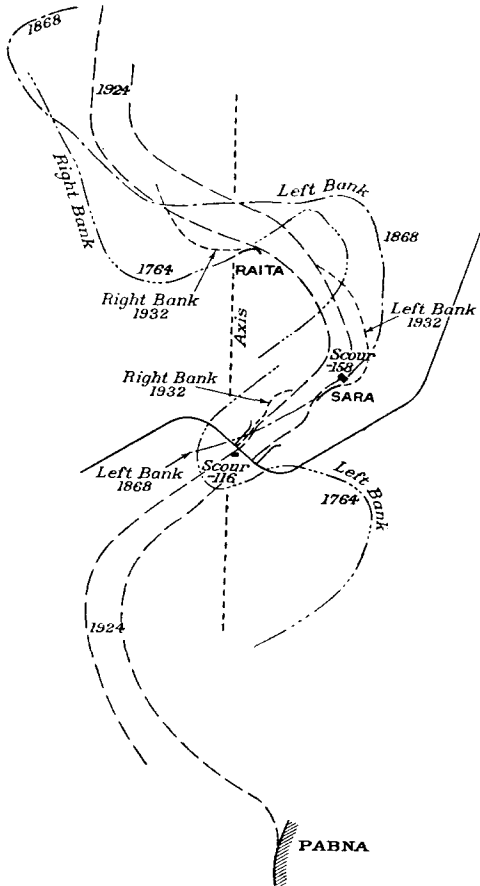
¹ Minutes of Proceedings Inst. C.E., vol. 235, pp. 96, 101, 104.

² *Ibid.*, vol. 223, p. 288.

Ganges rivers over a series of years. For the information he was indebted to engineers who had formerly served under him. The Aie had a discharge of 16,000 cusecs, while that of the Ganges had been estimated by Sir Robert Gales as attaining 2½ million cusecs, but they

Colonel Sir Gordon Hearn.

Fig. 4.



RIVER GANGES.

had features in common. Downstream, a cut-off in the Aie had caused the course to swing away, but it now appeared to be swinging back. In the Ganges, the great bend mapped in 1764 had not reappeared, but the river in 1925 set strongly against the town of Pabna, in the manner observed at Clay Point below the bridge at Adamwahan. Upstream in the Aie river a loop attack on the left

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Gordon Hearn.

bank had developed, in twenty years or so, until the head of the straight guide-bank was destroyed in 1925. It had been restored with considerable difficulty and replaced by a curved bank, which had stood well until 1929, when it caused a cut-off to develop. All cut-offs in this river seemed to develop when the longer axis of the loop became two or three times the length across the neck. It was to be noticed that the alignments of the bridges over both rivers were at an angle to the general course, indicated by a dotted line. This seemed to invite severe loop attack on the "refused" side. There were signs of a cut-off in the Ganges above Raita and a return to the course of 1909. The bank at Raita was curved and had given no trouble, although there was deep water along it. On the other bank, the comparatively straight Sara guide-bank had been severely attacked. There was now a scour-hole upstream of the bank 158 feet below low water, as shown in *Fig. 4*, the greatest bend scour anticipated¹ was 100 feet. The slope to the scour-hole was at 1 vertical to 1½ horizontal. He preferred this method of expressing slope to that adopted by Colonel Macrae. Sir Robert Gales, who had designed and built the Hardinge bridge, was in India investigating the present conditions in the Ganges, and it was to be hoped that he would communicate his opinions to the Institution. Meanwhile some facts might be of interest. He had expressed previously his opinion that the Hardinge bridge was from two to four spans too long, and at the present time six spans were completely silted up at low water. There was an island extending about a mile upstream of the bridge. The spans on the Calcutta side, which had never been scoured up to 1925, had now been nearly all scoured out. The deepest scour under the bridge was 70 feet below low-water level, and at high water the depth there was 101 feet, though previously it has not been more than 90 feet. At pier No. 2 on that side there was a hole 350 feet above the bridge, scoured 76 feet below low water. Pier No. 3 had been heavily armoured some time ago, he did not know why, and 300 feet below that pier there was now a scour-hole of 116 feet below low-water, as shown in *Fig. 4*; the bottom of the pier, however, was still 39 feet deeper than that hole. He endorsed Colonel Macrae's method of stepping-up the apron, leaving the stone which was wanted down at the toe before it was cut away. The trouble had actually started, at the Sara bund, by the pitching not sliding down on the face of the bund. This had caused a chink in the armour, and the water had begun to scour away the clay, which it had always been considered was un-erodible.

¹ Sir Robert Gales, "The Hardinge Bridge over the Lower Ganges at Sara," Minutes of Proceedings Inst. C.E., vol. ccv, p. 18.

Mr. B. B. HASKEW would have liked Mr. Watson to have given Mr. Haskew further details about the work, and particularly of costs and weights of spans, as the Paper would then have been much more valuable. Judging from his own experience, the provision of piled staging seemed to have been extremely lavish. He had just built a bridge in Northern Ireland with five spans each of 131 feet, carrying a roadway on top and a railway below. The weight of steel in each span was 450 tons, and that which had to be carried by falsework was about 350 tons. The spans had been erected by the cantilever method, but in order to get an anchorage the first span had been piled. 350 tons was carried on seven bents of five piles each, driven 15 feet into the bed of the river, which consisted of sand and gravel. Actually twenty-eight of those piles were carrying a load of about $12\frac{1}{2}$ tons each. Mr. Watson had not given the weight of the 258-foot spans, but judging from similar spans Mr. Haskew estimated their weight to be about 620 tons, the staging weighing probably another 300 tons. Figs. 4 and 8, Plate 1, showed that twenty bents of ten piles, each 20 feet long, had been used. His own experience would have indicated that a hundred piles would have been ample for carrying that load, and he would like to know why the extra piles had been provided. No doubt there were special reasons for their use, but the bearing capacity he thought must have been extremely small. Sir Clement Hindley had said that the old spans were in perfect condition and had been used again. He wondered if tests had been made of the material in them, because it had been brought to his notice that before the recent replacement of the Khedive Ismail bridge at Cairo, which had been built in 1872 of wrought iron by a Belgian firm, the Public Works Department of Egypt had had tests made on its material and had found that the wrought iron had become crystalline and had snapped off without any elongation at a tensile stress of about 21.6 tons per square inch. It was therefore doubtful whether wrought iron could be relied on, without making tests, after it had been in service for a long time.

Mr. J. M. LACEY said that 40 years ago it had been his good fortune Mr. Lacey to be indirectly associated with Mr. J. R. Bell when he was Engineer-in-Chief of the East Coast Railway and was revising the design of the railway bridge over the Godavery river at Rajahmundry. Engineers had learned a great deal regarding the flow of the large rivers of India from him.

Through the courtesy of the Editor of *The Engineer*, Mr. Lacey was able to give diagrams and certain information which had appeared in that journal.¹ Fig. 5 showed the survey of the

¹ "Flowing Water III.," *The Engineer*, p. 218, vol. 150, 1930.

Mr. Lacey.

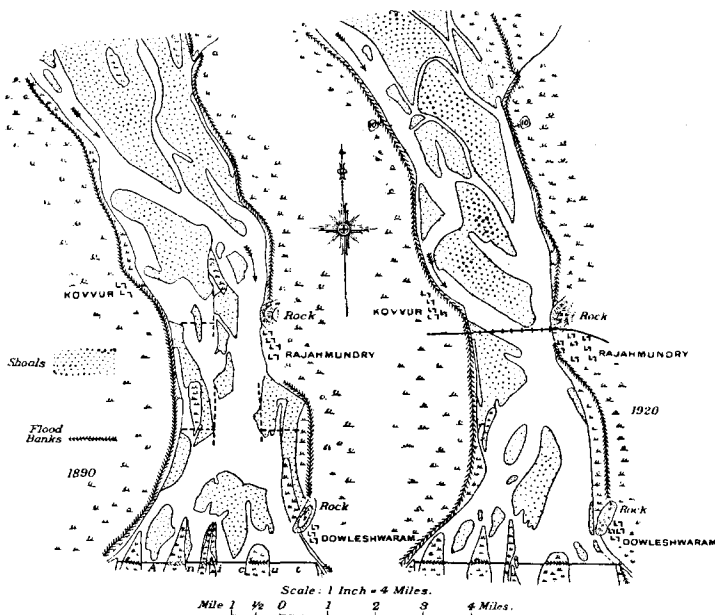
Godavery river above the Dowleshwaram anicut taken in the cold weather of 1890-91 during the low-water season, when the water-level was at anicut crest, which was about 8 feet above mean river bed. In 1890-91 the "line-channel" of the river flowed down the eastern or Rajahmundry margin of the river, the channel at Kovvur being its concomitant creek. At Rajahmundry the river always adhered to the rocky flank there where the depth at low water was 28 to 30 feet. In flood the bed of that channel was cleaned to rock. The river rose in flood, and when the "line-channel" could carry no more it spilt over, and eventually spread over the whole sandy bed of the river between the high alluvial margins. In very high floods the river would spill over those margins as well unless confined by flood-banks. The internal spills from the "line-channel" carried the surplus flow to the "creek," which eventually joined the river lower down.¹ Mr. Bell considered that the "line-channel" carried roughly two-thirds of the flood-discharge when fully scoured, and the "creek" the remainder. If therefore the actual width of a well-defined "line-channel" could be ascertained for a maximum flood, it should be possible to guide the whole discharge of the river into a single channel half as wide again, provided there was no restriction to the free scouring of the river bed. The original proposal was to construct the bridge at the Rajahmundry flank of the river, using the rock as the eastern bund. Mr. Bell was opposed to that site, as he considered that the river was making a determined set on the right margin, and he anticipated that eventually the "line" or main channel of the river would flow down the Kovvur creek, and if opposed by the railway embankment might make a set against the right flood-bank and endanger the low-lying lands on the west. At Dowleshwaram, the head of the delta, the river ran on the crest of a great natural embankment having a transverse slope of about 3 feet per mile towards the east, and a slope of about 8 feet per mile towards the west, and Mr. Bell was afraid of a breakthrough in that direction. From charts of the river above the anicut taken from 1864 onwards, Mr. Bell pointed out that at the "gut," about two miles down-stream from Rajahmundry, where the river divided into its branches, the position of the deep-water channel was more or less constant, and he selected that site for his bridge. The positions the two designs would have occupied were shown in dotted lines in *Fig. 5*. Mr. Bell proposed to throttle the waterway to 5,000 feet, and, allowing for a depth of 50 feet in the "bridge pit," he proposed to pass the maximum flood of the river through that contracted waterway. In high flood the river rose some 23 feet

¹ Minutes of Proceedings Inst. C.E., vol. ccxvi, pp. 156 *et seq.*

above the anicut crest, and in such high floods little afflux was observed above the anicut. Considerable opposition to Mr. Bell's site was raised; it was not thought possible that the mighty Godavery river, which in flood extended four miles across from bank to bank, could be throttled to 5,000 feet. There was also apprehension that the contraction of the waterway and excessive scour might shoal the heads of the irrigation canal; also that the afflux above the contracted waterway, necessary to attain the requisite scour through the bridge, might endanger the flood-banks.¹ The con-

Fig. 5.

Fig. 6.



troversy was never settled, and the bridge was eventually built about 1898, to the full width of the river at Rajahmundry. Fig. 6 showed the river chart taken in the cold weather of 1919-20. It would be seen that the "line-channel" had taken the course of the Kovvur creek, as anticipated by Mr. Bell, and the Rajahmundry channel had become the concomitant creek. The piers of that bridge at the Rajahmundry end were carried down to rock. "Bell bunds" were expensive, and it was a matter for consideration

¹ The sand of the Godavery river bed is very coarse, and at times shoals of small pebbles are carried down.

Mr. Lacey.

whether they were always desirable. The catchment area of the river Sutlej above the Empress Bridge and the anticipated maximum flood discharges were not given in the Paper. At the Kaisar-i-Hind Bridge at Ferozepur, about 200 miles upstream of the Empress Bridge, the maximum flood discharge of the Sutlej river had been stated¹ to be 400,000 cusecs. Colonel Macrae gave no reasons for contracting the waterway from 4,000 to 2,000 feet. Sir Francis Spring's book, quoted by Colonel Macrae, stated that Colonel Peile estimated the real river Sutlej at the site of the bridge to be of a width of 1,000 feet and a maximum depth of 37 to 40 feet, so that, applying Mr. Bell's approximate rule, a waterway of 1,500 feet would have been sufficient. The positions of the high alluvial margins were not shown. Fig. 1, Plate 2, showed the position of the main channel for eleven years. Was there any hard soil, or any other cause for the apparent node at the left margin of this river at the bridge site? Mr. C. S. Fahey had stated that the deep channel of the Indus oscillated in its sandy bed and took 20 years to perform the whole cycle from the time it commenced to attack the margin at a particular place, left it, and again attacked it.² Had any such observation been made on the Sutlej river?

Mr. Husbands.

Mr. H. W. S. HUSBANDS remarked that he would like to ask what had happened to the caisson which had been put in under the second span to hold the temporary girders, as there was no mention of its having been taken out, and it seemed rather an obstruction to leave it in the river. Had it been left in there, or cut off? Mr. Haskew had drawn attention to the great amount of staging used. It appeared from the Paper that a separate set of staging was employed for each span. Mr. Husbands would have imagined that that was not necessary, and that staging could be moved from one span to another, excepting, of course, the special staging under the second span where the deep-water channel was.

He would like Colonel Macrae to give more details of the work on the training bunds. It was mentioned that the original guide-banks had been pitched with 13-inch cubes of burnt brick, and it was stated further on that after a number of years those bunds had been quite good. As it appeared from the Paper that the stone at the bridge cost four times as much as it did at the quarry, it seemed to him that those brick cubes must have been very much cheaper, and if they were good enough for the job it was curious that they were not used again. Had they deteriorated very much, or had there been any other reason for not using them? As remarked by

¹ Minutes of Proceedings Inst. C.E., vol. cliv., p. 3.

² *Ibid.*, vol. lxxi, p. 289.

Colonel Macrae, Sir Francis Spring had stated that the radius of Mr. Husbands. the curves on the Bell bunds downstream needed only to be half that of those upstream. That seemed to be contrary to the usual experience in dealing with the flow of water; one would have expected it to be necessary to have curves of a larger radius down the stream than upstream as the amount of energy lost and the eddies formed were greater at a sudden enlargement than at a contraction.

Mr. A. STEWART BUCKLE said that it was the conjunction of Mr. Buckle. J. R. Bell and Sir Francis Spring that had made possible the shortening of the bridge described in the Papers. The Bell guide-bank method of training rivers was originated by Mr. Bell and developed by Sir Francis Spring. He had had the honour of knowing both those men. He remembered Mr. Bell telling him how a very important rajah had come from a great distance in order to see the opening of the bridge. Mr. Bell had asked the rajah why he had come such a great distance, and the rajah had replied, "Because this is the river that stopped Alexander the Great, and I am interested to see how you have beaten him." Sir Francis Spring had been a wonderful man in many ways, especially for the astonishing speed with which he built his bridges, all with departmental labour and without the intervention of any contractor. Not satisfied with his 34 years in the Public Works Department of India, Sir Francis had put in 15½ years more as Chief Engineer of Madras Harbour, making a total of 49½ years' work in India. Sir Francis had stayed in Madras until 70 years of age, having converted the Port of Madras from an open roadstead into as good a harbour as could be found anywhere in the world.

Mr. C. T. A. HANSSSEN remarked upon the extensive use which Mr. Hanssen. Mr. Watson had made of compressed air for many purposes. The air-compressor used was stated to have a capacity of 1,200 cubic feet of free air per minute, but the air-pressure was not given. Was it 100 lbs. or 80 lbs. per square inch? He had had a great deal of experience with compressed-air machinery, and he thought that for many purposes it was really more convenient than electric power, especially where a reciprocating motion was required. For distances not exceeding 6 or 7 miles compressed air was almost as cheap as electricity, and was very much more convenient.

Lieut.-Colonel E. P. ANDERSON thought he might be able to throw Lieut.-Colonel Anderson. a little light on one or two points in connection with this bridge, particularly in regard to Colonel Macrae's Paper. As Deputy Chief Engineer of the North Western Railway he had had charge of the bridge during the hot weather of 1928. At that time the need for construction of the left guide-bank had been definitely settled, and before Mr. Pavry had gone on leave he had given orders for the

Lieut.-Colonel
Anderson.

necessary preparations to be made ; Colonel Anderson had therefore taken steps to carry on the work of preparation. They had assumed initially that there would, as before, be deep water roughly along the site of the new left guide-bank, and any one who had had experience of Indian rivers would realize the pleasure with which it had been found that as the floods dropped the channel had shifted, and that it would be possible to make practically the whole of the left guide-bank on dry land in the cold weather. But to his astonishment he had been sent for one day before the river had fallen low enough for work to start, and had been told that the first squall of the economic blizzard had started, and that this was one of the works which had to be stopped. He had shortly afterwards left India for good. Mr. Pavry had subsequently told him that on returning to duty he had succeeded in diverting funds from track renewals on other parts of the North Western Railway, in order to have enough money to carry out this work. Another point whose importance had not been made clear was the existence of an inundation-canal which was shown at the bottom of Fig. 1, Plate 2. The main line crossed it close to mile 515. That canal belonged to the Bahawalpur State, and for a very long time those who were responsible for the maintenance of the bridge had a good deal of anxiety lest its training works should so upset the regime of the river as to affect the flow of water in that canal. He might explain that the inundation-canal had no headworks with gates, such as were seen in other parts of India, and it only flowed when the river had risen to a sufficiently high state of flood to take water down it. The protection of the main line south-west of Clay Point had also caused anxiety at that time. During the hot weather to which he had referred very heavy erosion had been going on at the end of the armoured nose which was indicated on Fig. 1, Plate 2, and there had been at one time a serious risk of a breach of the main line occurring near mile 512. It was therefore of very great interest to him to see that, as the result of the carrying out of the training works, the channel of 1931 was shown as having left that Clay Point bank, though what happened to it where it now came in close to the line again, near mile 511, was not quite clear ; perhaps Colonel Macrae would give further information on that point in his reply to the discussion. It occurred to him that possibly the existence of the inundation-canal, the value of which to Bahawalpur State was very great, and the position of its intake, might have had something to do with the refusal of the higher authorities to sanction the crossing of the river at the place originally proposed by Colonel Peile, but he had no means of verifying that. Perhaps Colonel Macrae could do so. Two speakers had remarked on the pile staging used. He thought that in this case

Mr. Everall, who had been the bridge engineer responsible for the design of all work on the spot, had adopted there, as elsewhere, his usual principle of making the staging strong enough to carry not merely the dead load of both the old and new girders but also the whole live load of the train. That had been done again and again in similar reconstruction jobs in India, and had saved a great deal of time. Speed of working was essential, because once the river rose all temporary works in its bed were bound to be washed away, and therefore sufficient equipment and staging must be available to permit of working simultaneously at a number of spans in order to complete the job in the time available.

* * * The Authors' replies will be found at pp. 154 and 156.—SEC. INSTR. C.E.