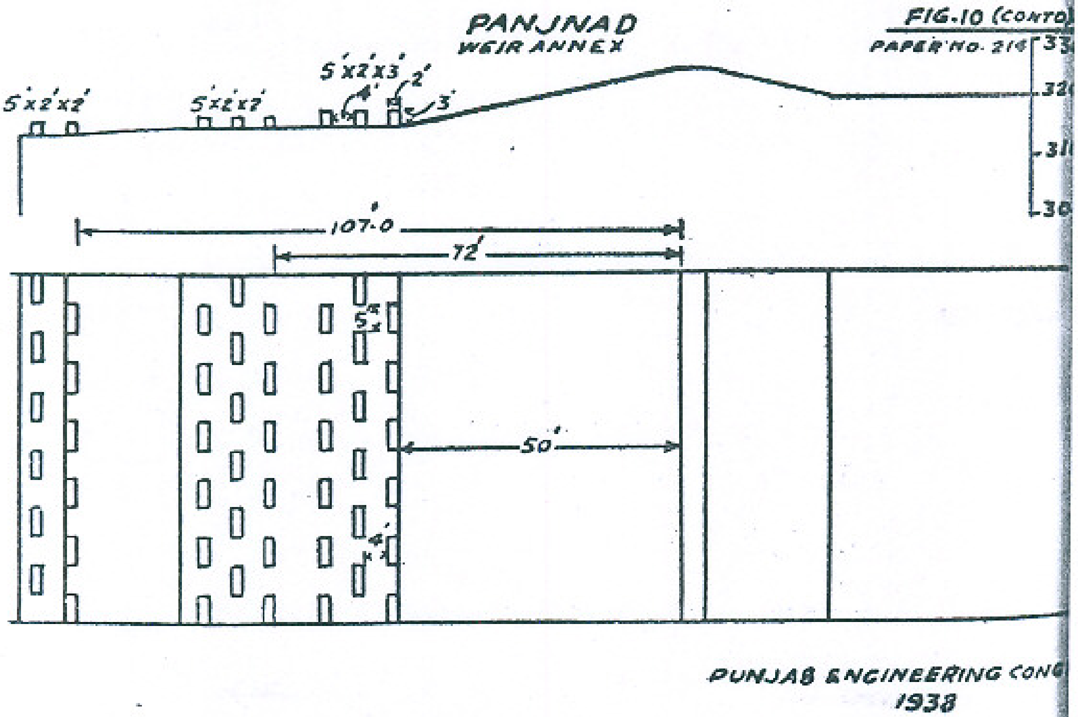

PANJNAD
WEIR ANNEX
FIG.10 (CONTD)
PAPER NO. 214
5'x2'x2'
5'x2'x2'
5'x2'x3'
107·0'
72'
50'
PUNJAB ENGINEERING CONG
1938

the reconditioning experiments and found to be satisfactory. Fig. 7 shows a model of Bay VIII of Khanki Weir fitted with arrows and blocks. The scour was appreciably reduced with the construction of arrows and blocks.

IV. *Blocks alone.*—The application of these devices was next extended to works having an ogee fall instead of straight glacis slope as hitherto examined. The model examined was that of Deg Diversion Fall on the Upper Chenab Canal and is shown in Fig. 8. Arrows and blocks were constructed downstream of the fall and their effect on the scour and the velocity distribution was examined. It was here that it was found that if an additional set of blocks similar to those at the downstream end was constructed just below the arrows, the results obtained were exceedingly better than those without the additional set of blocks. An examination of the maximum velocity line Fig. 8(*b*) showed that it was actually from the blocks just downstream of the arrows that it got a kick and was deflected towards the surface. The arrows were then taken out and it was found that the results obtained were none the worse. It was therefore considered worth the trouble to investigate the effect of blocks when they were substituted for the arrows. On a model of Panjnad Weir and Annexe detailed experiments were carried out in order to compare the effect of a combination of arrows and blocks with the blocks alone at both the places (eliminating the use of arrows). The tests were made with a number of discharges varying from a few thousands to several lacs cusecs. Some of the results obtained are plotted in Figs. 9 and 10. Statements showing the depth of line of maximum velocity from the water surface profile and the depth of scour with different devices were made and are given in Appendix II. From a comparison of the results obtained in the two cases it was shown that much better results were obtained in almost all cases when blocks were substituted for arrows. The blocks at both the positions were much more effective than a combination of blocks and arrows as shown in Figs. 9 and 10.

V. *Dentated sill*—In the next tests an examination of a dentated sill was made. On a model of Merala Weir the construction of a sill as designed by Rhebock was tested. All the necessary observations were taken. The sill was then removed and blocks were constructed in position. These tests showed a big differenee between the two experiments as illustrated in Plate I. When the sill was constructed no real standing wave was formed in the case of the maximum discharge. The scour, though reduced to some extent, extended to a great distance below the work. On the other hand the blocks caused a well defined standing wave to form on the glacis slope. The scour existed but was only local and was less than that obtained with the sill in position as shown in Plate I. Hence the blocks proved more effective than the dentated sill. *Blocks are better than a dentated sill.*

Fig. 11.

TYPE OF DEVICES EXAMINED

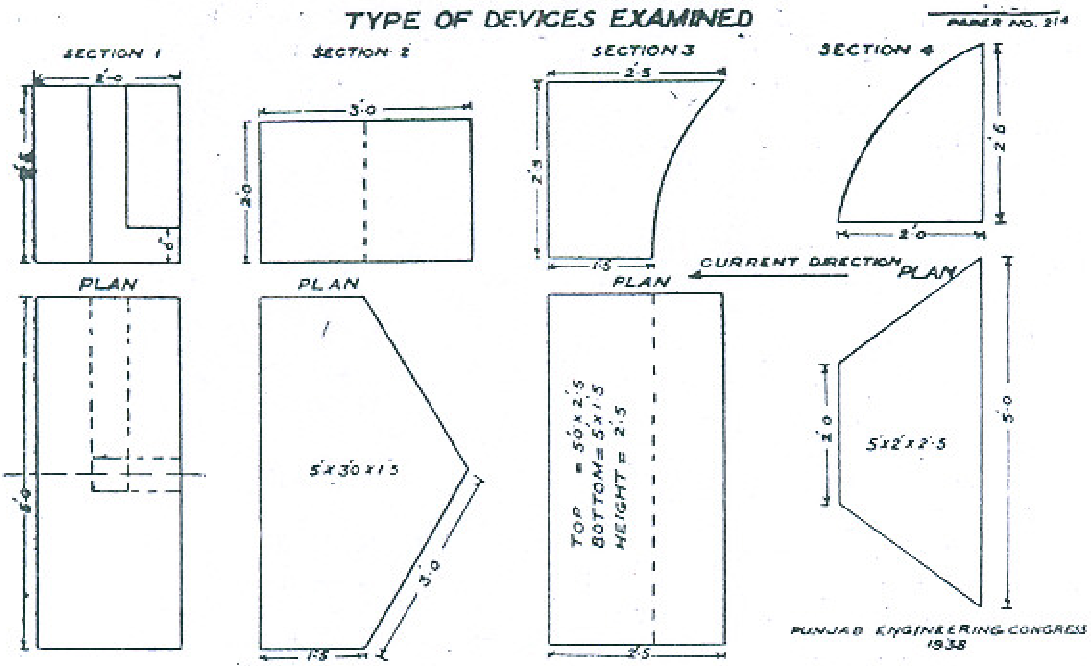


Fig. 11—contd.

TYPE OF DEVICES EXAMINED

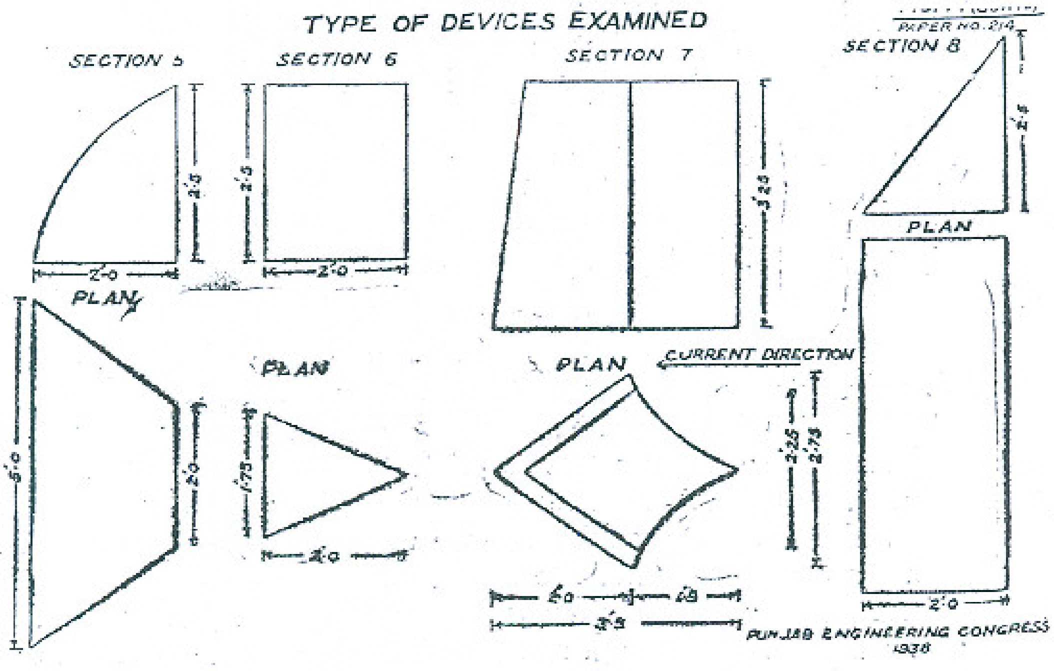


Fig. 11—contd

ARROWS

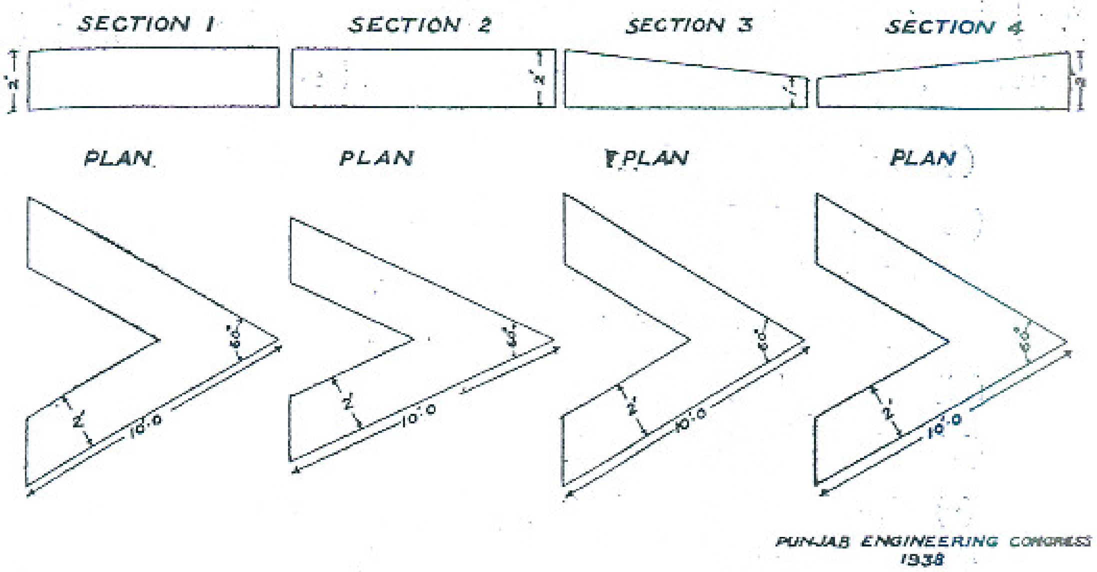
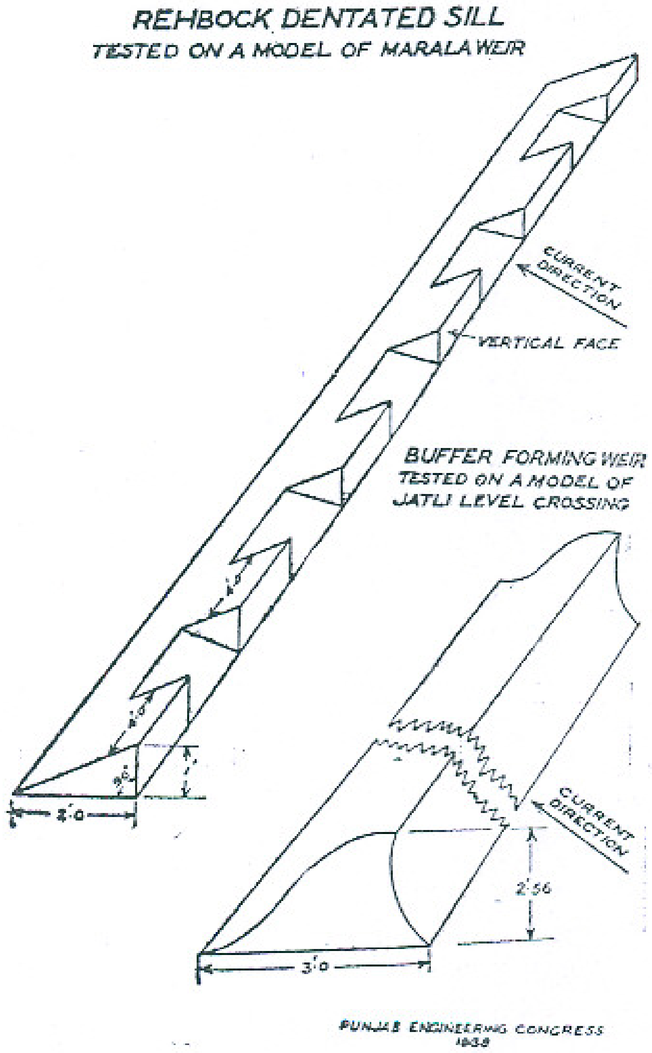


Fig. 11—contd.



VI. *Different Forms of Blocks.*—Having decided that blocks gave much better results than the arrows, in all further tests blocks were used. Different types of blocks were next investigated with a view to increasing their efficiency and reducing the cost of construction if possible. The following designs were tested :-

(i) Triangular blocks.

(ii) Trapezoidal blocks.

  (*a*) Larger side facing the current.

  (*b*) Smaller side facing the current.

(iii) Baffle piers.

(iv) Upstream face curved.

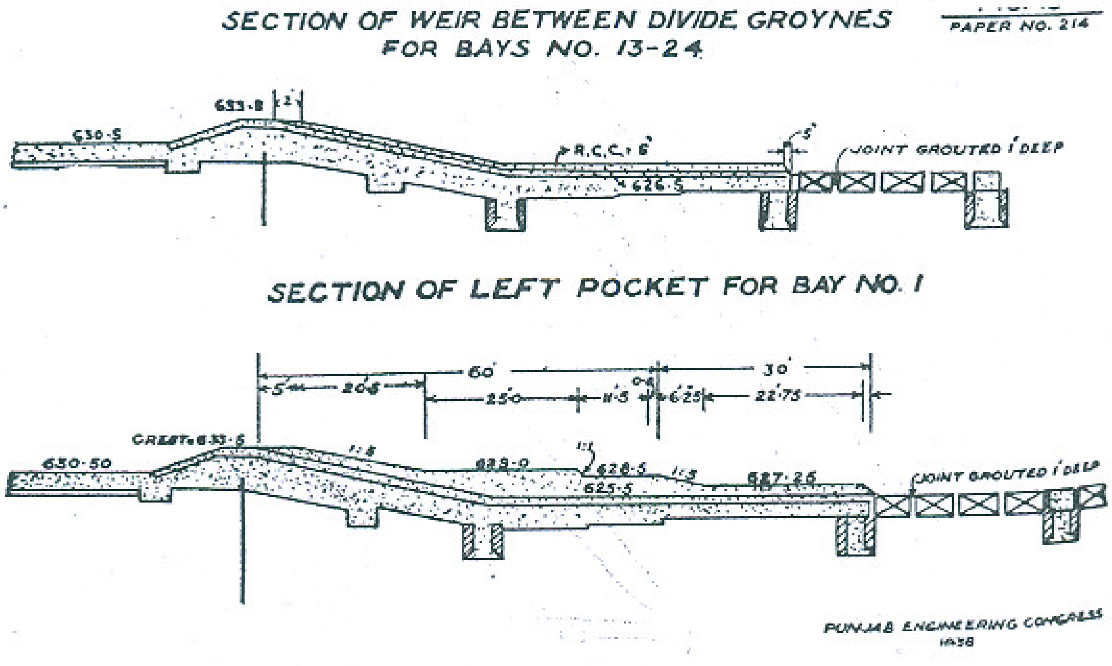
(v) Downstream side sloping.

(vi) Hollow blocks to allow the passage of water through them.

(vii) Rectangular blocks.

Different types investigated are illustrated in Fig. 11. All these tests were made on a model of Ferozepur Weir. The sections through the weir are shown in Fig. 12. The results obtained with the different devices are plotted in Fig. 13. A comparison of triangular

Fig. 12.



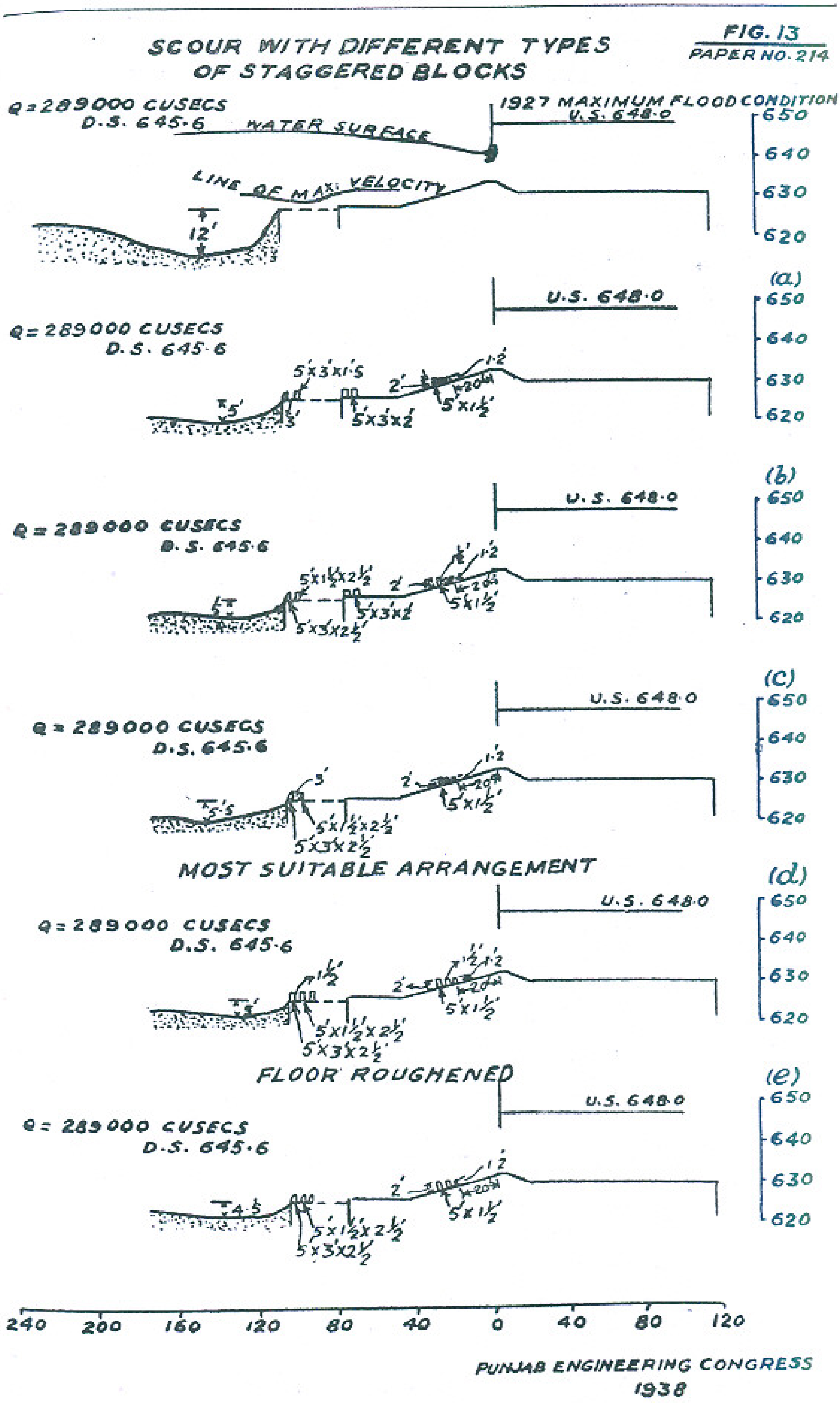

SCOUR WITH DIFFERENT TYPES OF STAGGERED BLOCKS
FIG. 13
PAPER NO. 214
Q=289000 CUSECS
D.S. 645·6
WATER SURFACE
1927 MAXIMUM FLOOD CONDITION
U.S. 648·0
LINE OF MAX: VELOCITY
12'
(a)
U.S. 648·0
5'x3'x1·5
5'x3'x2'
5'x1½'
(b)
U.S. 648·0
5'x1½'x2½'
5'x3'x2½'
5'x3'x2'
(c)
U.S. 648·0
5'x1½'x2½'
5'x3'x2½'
MOST SUITABLE ARRANGEMENT
(d)
U.S. 648·0
5'x1½'x2½'
5'x3'x2½'
FLOOR ROUGHENED
(e)
U.S. 648·0
5'x1½'x2½'
5'x3'x2½'
650
640
630
620
240 200 160 120 80 40 0 40 80 120
PUNJAB ENGINEERING CONGRESS
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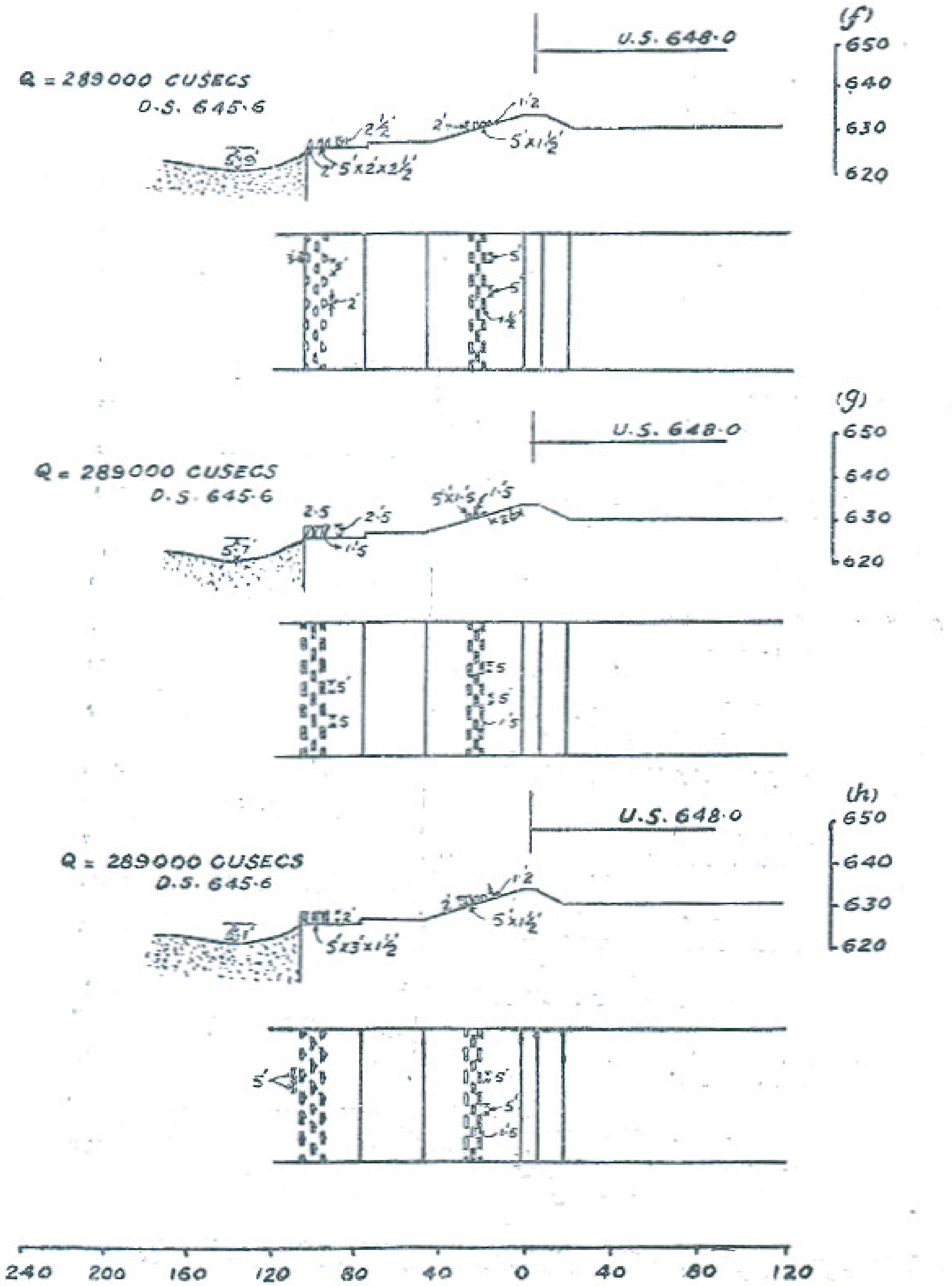
FIG. 13 (CONTD.)
PAPER NO. 214

SCOUR WITH DIFFERENT TYPES OF STAGGERED BLOCKS



PUNJAB ENGINEERING CONGRESS
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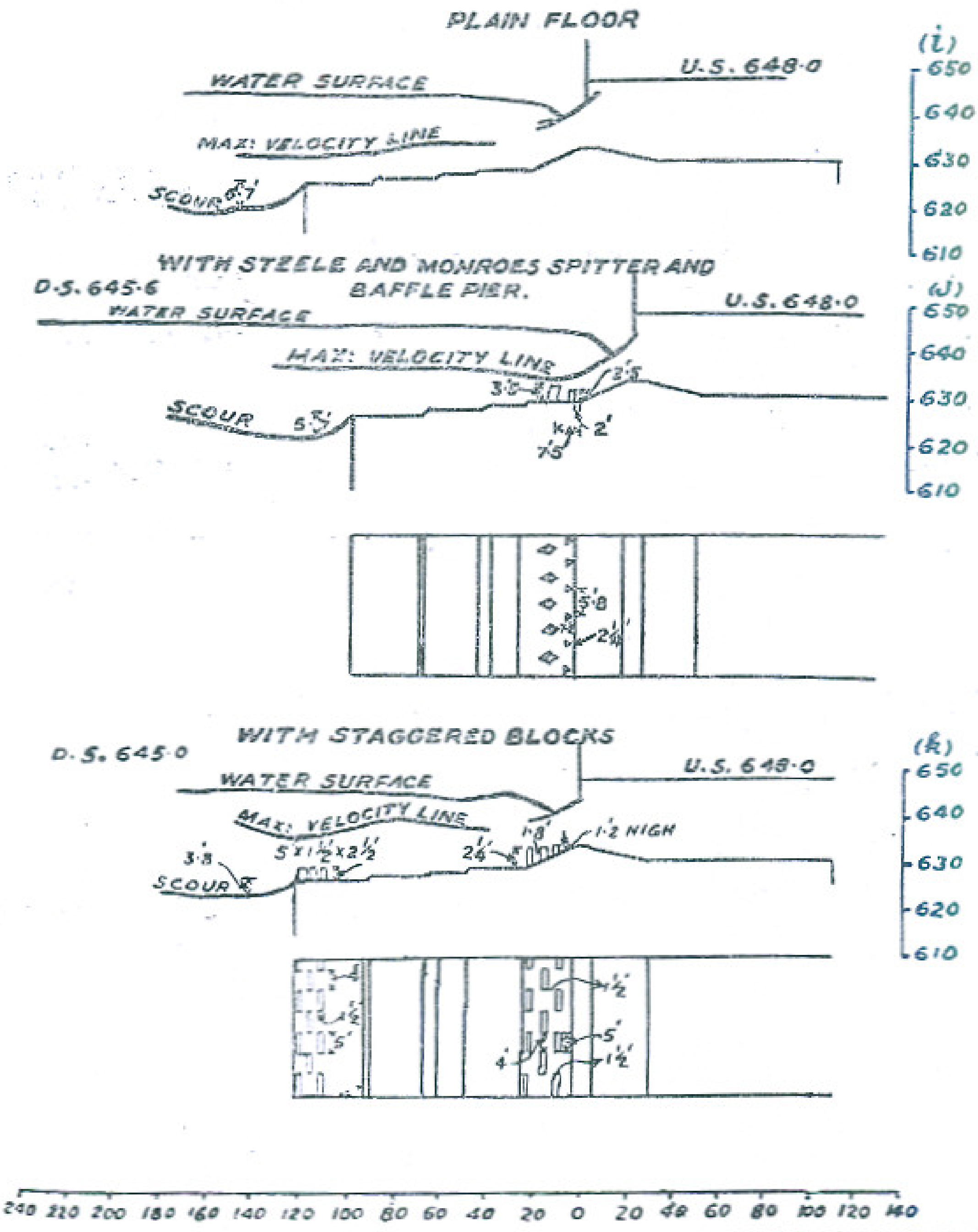
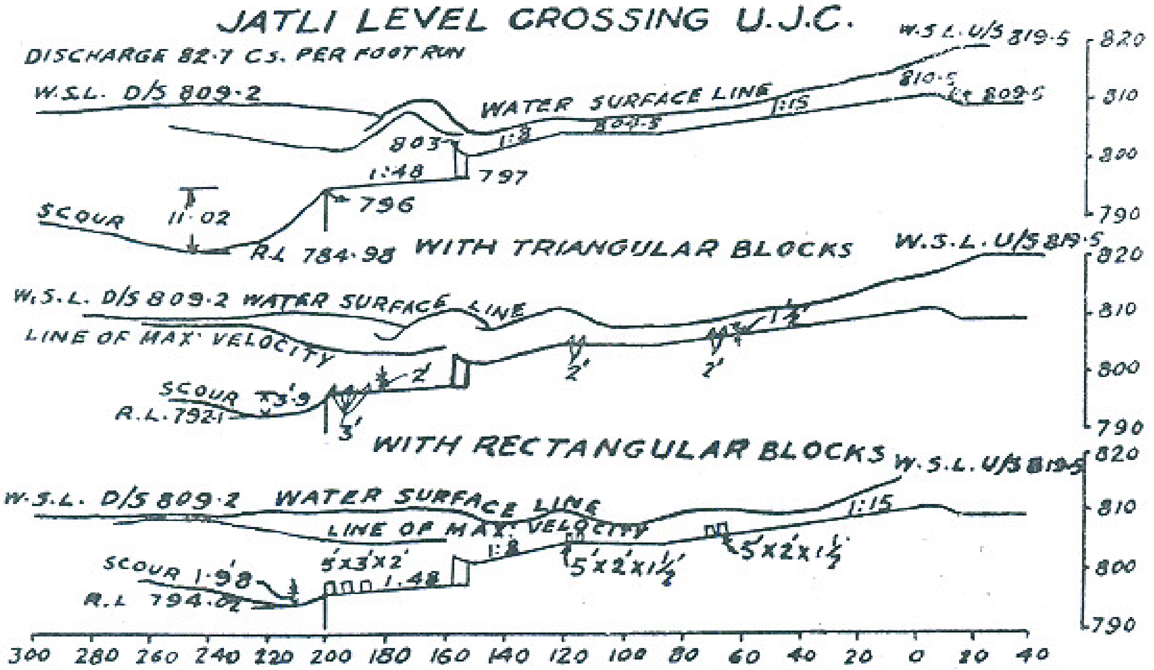
FIG. 13 (CONTD) PAPER NO. 214

FEROZEPUR WEIR



PUNJAB ENGINEERING CONGRESS 1938

FIG. 13 (CONTD)
PAPER NO 214



PUNJAB ENGINEERING CONGRESS
1938

blocks with the rectangular blocks was made on a model of Jatli level crossing and is also shown in Fig. 13.

A survey of these tests showed that rectangular blocks were the best means of dissipation of energy and of prevention of scour below work. Minimum scour occurred when the rectangular blocks were constructed.

The arrangement consisted of 2 rows of blocks. The first row consisting of 3 lines of blocks graded was constructed near about the toe of the glacis. The second row comprised 3 lines of blocks constructed at the end of the pucca floor. The arrangement of the blocks in the rows was adopted after a number of tests. It is shown in Fig. 14. The action of a satisfactory arrangement is illustrated in Fig. 13(*d*). It will be seen that the largest velocities are deflected on to the surface and the bed velocities are diminished by the blocks.

The investigations of individual cases of models of works have been discussed in detail. It is difficult to suggest a universal arrangement for all types of works. Complicated forms might necessitate an examination of their models. However, certain rules derived from experiments have been put forth which it is hoped will prove useful for designing the protection.

5. The Optimum Height and the Optimum Position of the Blocks.

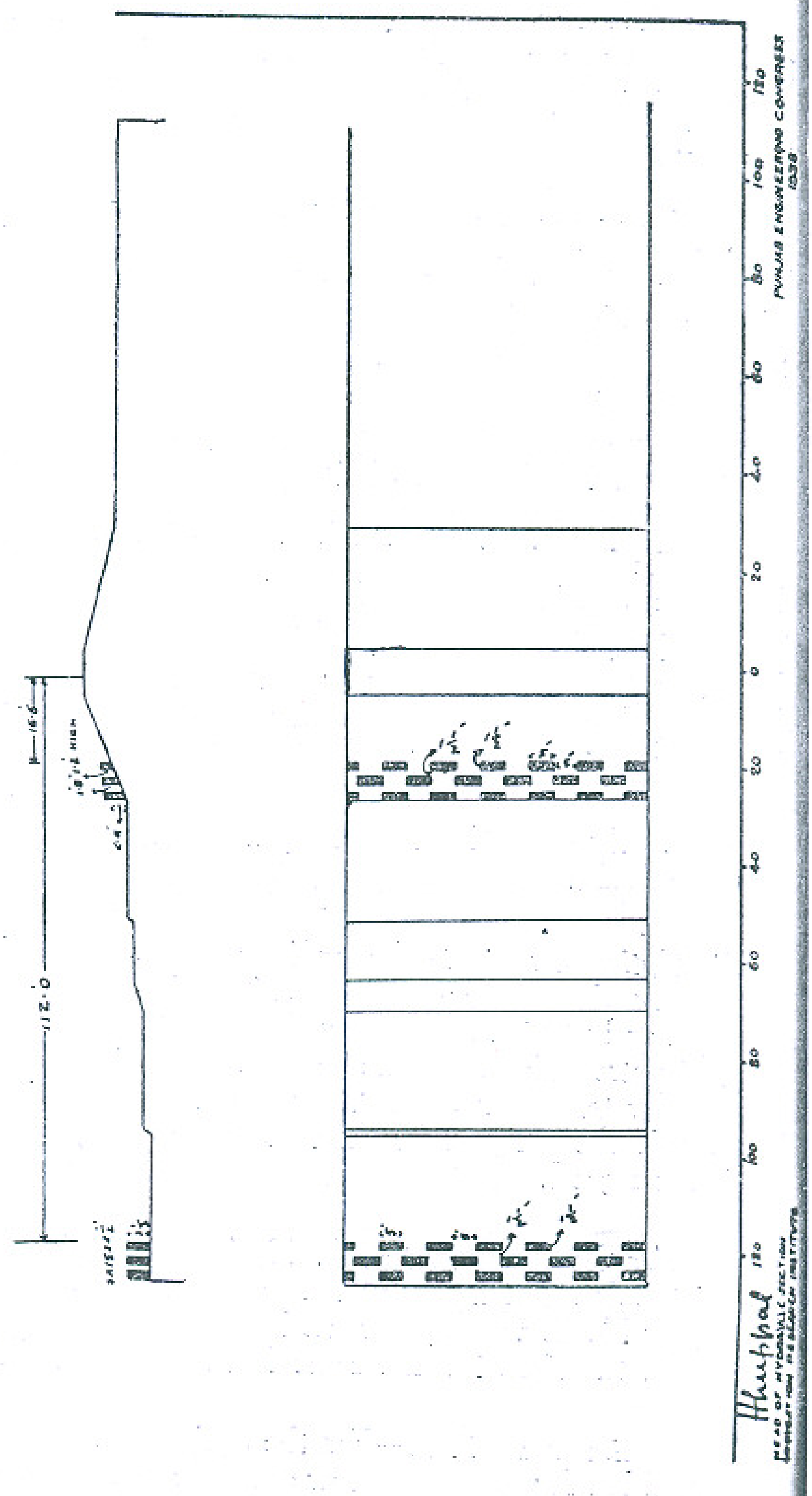
Optimum Height.—Regarding the optimum height of the blocks several experiments were carried out in which the height varied between 0·5 feet and 5·0 feet. As a result of these tests it was found that for the downstream blocks or the second row a height equal to $\frac{1}{8}$th-$\frac{1}{10}$th the depth of water on the downstream floor for the maximum discharge was most suitable. Higher blocks than these cause huge surface pulsation and are no good.

For the first row, *i.e.*, the blocks on the glacis slope, a height of $\frac{1}{4}$ to $\frac{1}{5}$ the depth of water on the glacis at that position was effective. If higher blocks were constructed they increased the afflux over the weir and therefore for the same head decreased the discharge.

Optimum Position.—For the optimum position of the blocks the best position for the second row of blocks was at the end of pucca floor. When constructed in three rows the staggered blocks at this position gave very good results. The scour was in fact mostly controlled by these blocks.

Fig. 14.
PAPER No. 213.

SHOWING THE MOST SUITABLE ARRANGEMENT OF STAGGERED BLOCKS FOR BAY.1



The most suitable position for the first row of blocks was on the glacis of the work. Blocks placed on the glacis at a distance of 2 feet to 3 feet from the toe of the glacis gave very satisfactory results. This holds good for all glacis slope between 1 in 3 and 1 in 6. The arrangement shown in Fig. 15 is adopted generally. The length of each

Fig. 15(*a*).
Paper No. 214.

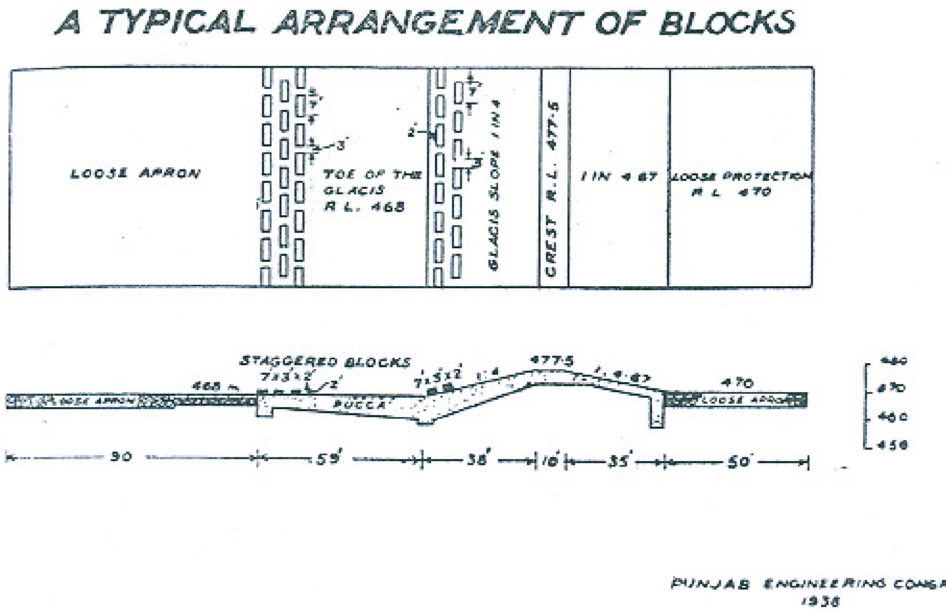


Fig. 15(*b*).

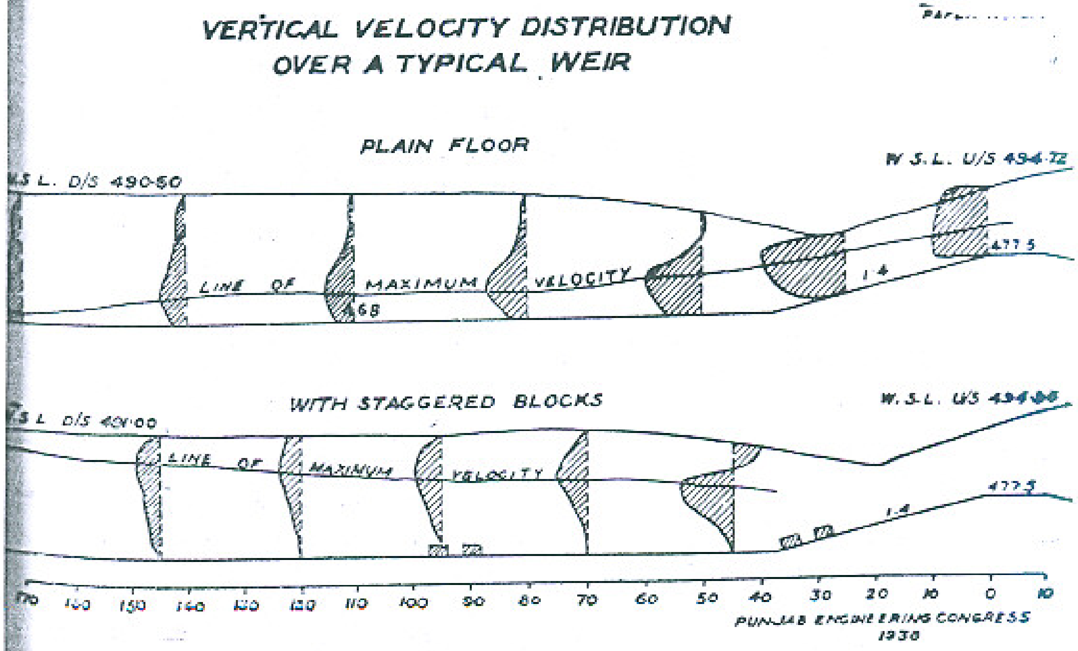
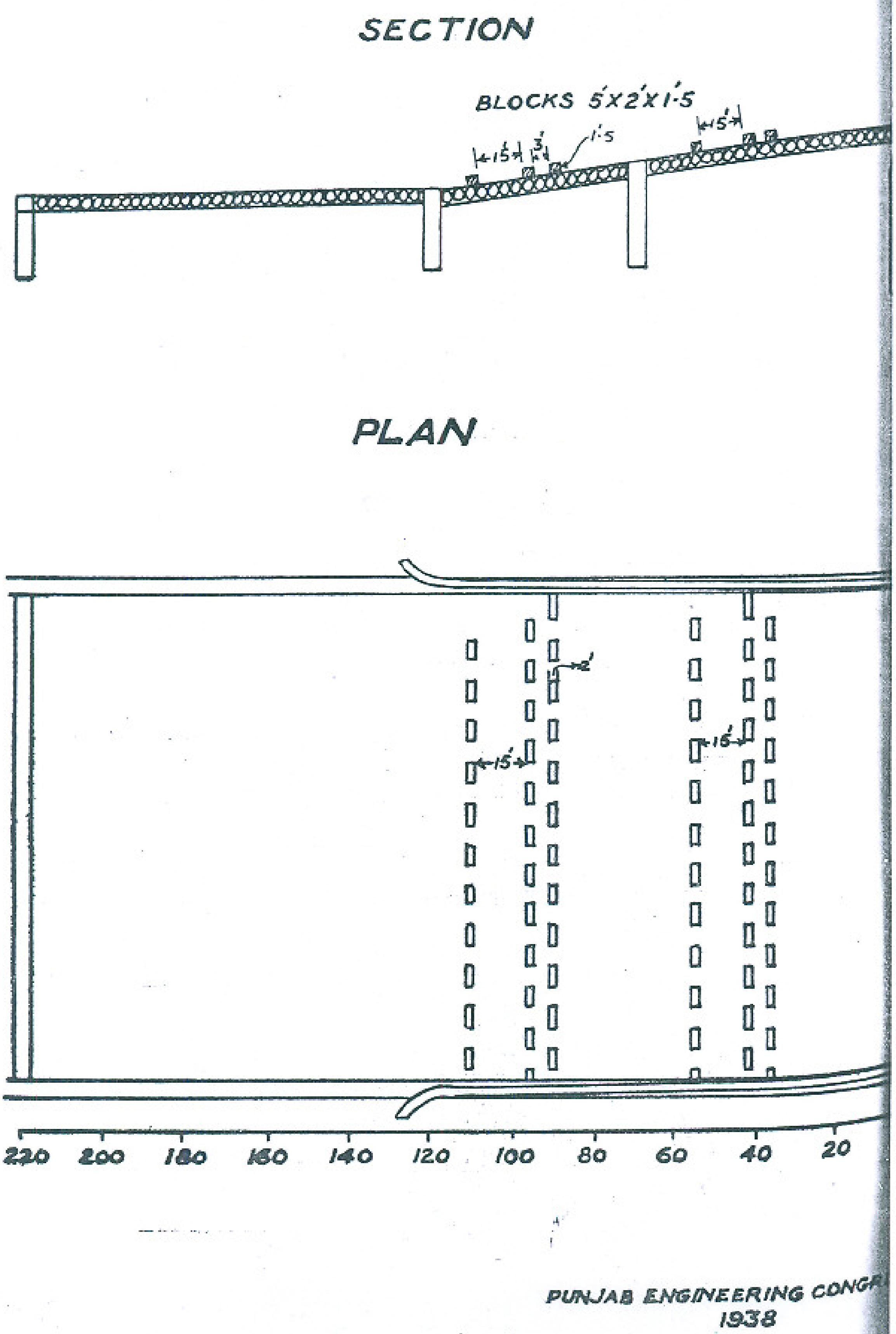


FIG. 16
PAPER NO. 21[illegible]

RAPID NO. 17 U.B.D.C.
ARRANGEMENT OF STAGGERED BLOCKS



: is 5 feet and thickness of 2·0 to 2·5 feet is found to be good enough ıigh discharges. For glacis slopes between 1 in 6 and 1 in 10 the row of 2 lines of blocks is shifted upstream on the glacis such that distance between the toe of the glacis and the second line of blocks feet.

For the examination of works having flat slopes the experiments 'e carried out on rapids and level crossings such as :—

(*i*) Salampur Feeder, Rapids Nos. 7 and 8,
(*ii*) Jaba Level Crossing,
(*iii*) Upper Bari Doab Canal Main Line, Rapid No. 17.

(*i*) *The Investigation of a Model of Rapids 7 and 8, Salampur Feeder, . B. D. C.*—On the Upper Bari Doab Canal there are a large number rapids, the annual repairs of which cost approximately Rs. 30,000. In ·der to prevent the action downstream, these rapids have been periodi- ılly extended. In spite of this, the scour downstream has persisted. ı model of Rapid No. 8 was constructed in the flume and the conditions xamined. It was found that no standing wave was formed and hat considerable scour took place downstream of the model as is shown n Plate II. Various arrangements of blocks were tested on the model ınd it was found that the arrangements shown in Plate II resulted in :he complete elimination of the scour. The arrangement caused the standing wave to be formed on the glacis as shown in Plate II at the second line of blocks and also resulted in the even distribution of the water at the downstream end of the work.

(*ii*) *Jaba Level Crossing.*—The Jaba Level Crossing on the Upper Jhelum Canal carries a torrent over that canal. The maximum discharge of this crossing was taken to be 56,000 cusecs. Considerable action had taken place downstream of the work and it was desired to obtain a protection which would control the standing wave and prevent action downstream.

A model to the scale of 1/40 was constructed and various devices examined. From the experiments it was found that three rows of staggered blocks constructed on the glacis as shown in Plate III controlled the standing wave most satisfactorily and resulted in a minimum action downstream of the work.

(*iii*) *Investigation of a Model of Rapid No. 17, Main line, U. B. D.C.*—Like the rapids on the Salampur Feeder the Main Line rapids have also been scouring badly. A model of Rapid No. 17 was investigated and a system of staggered blocks as shown in Fig. 16 was recommended for adoption.

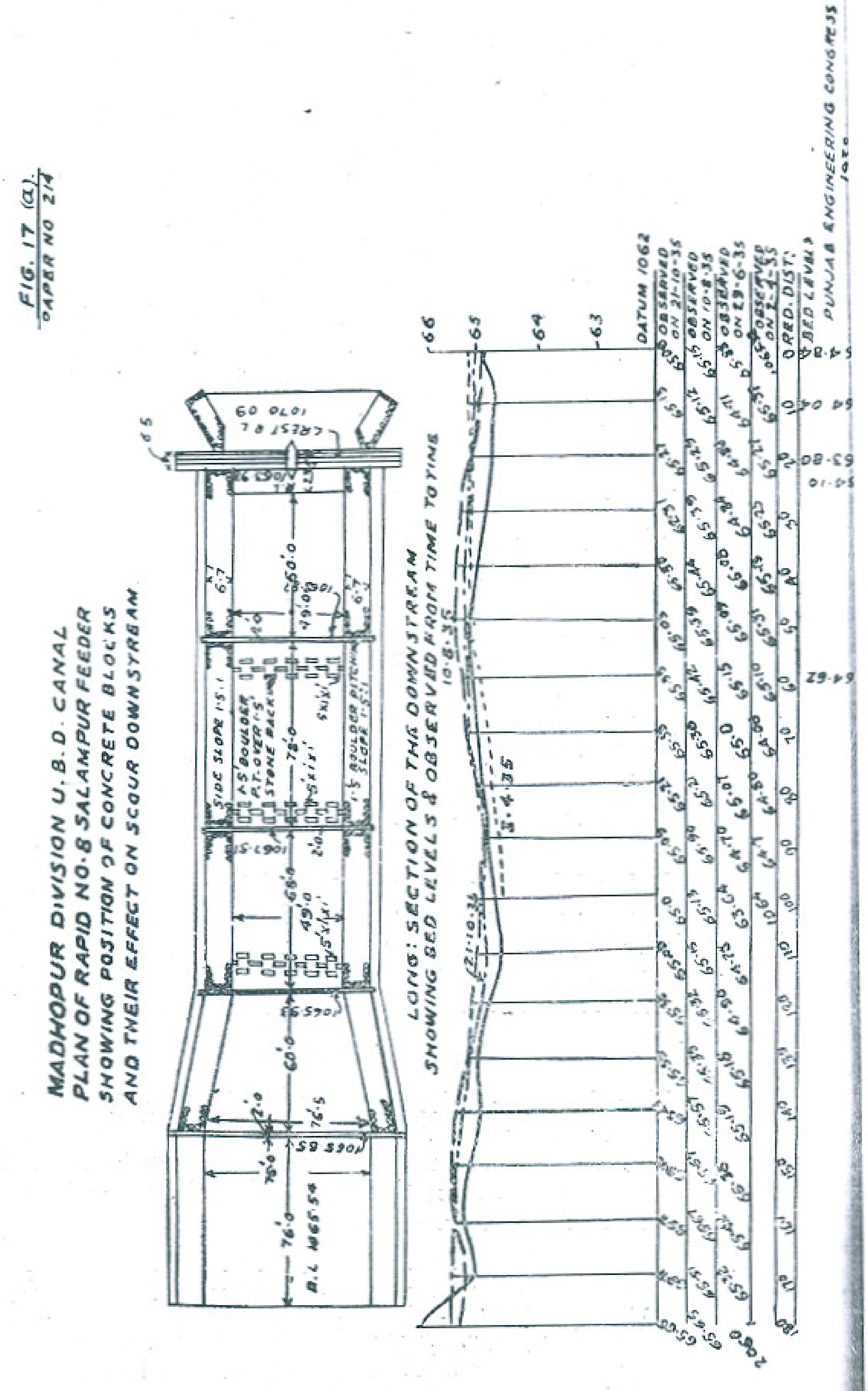


FIG. 17 (a).
PAPER NO 214
MADHOPUR DIVISION U.B.D. CANAL
PLAN OF RAPID NO. 8 SALAMPUR FEEDER
SHOWING POSITION OF CONCRETE BLOCKS
AND THEIR EFFECT ON SCOUR DOWNSTREAM
LONG: SECTION OF THE DOWNSTREAM
SHOWING BED LEVELS & OBSERVED FROM TIME TO TIME
DATUM 1062
OBSERVED ON 21-10-35
OBSERVED ON 10-8-35
OBSERVED ON 29-6-35
OBSERVED ON 3-4-35
RED. DIST.
BED LEVELS
PUNJAB ENGINEERING CONGRESS

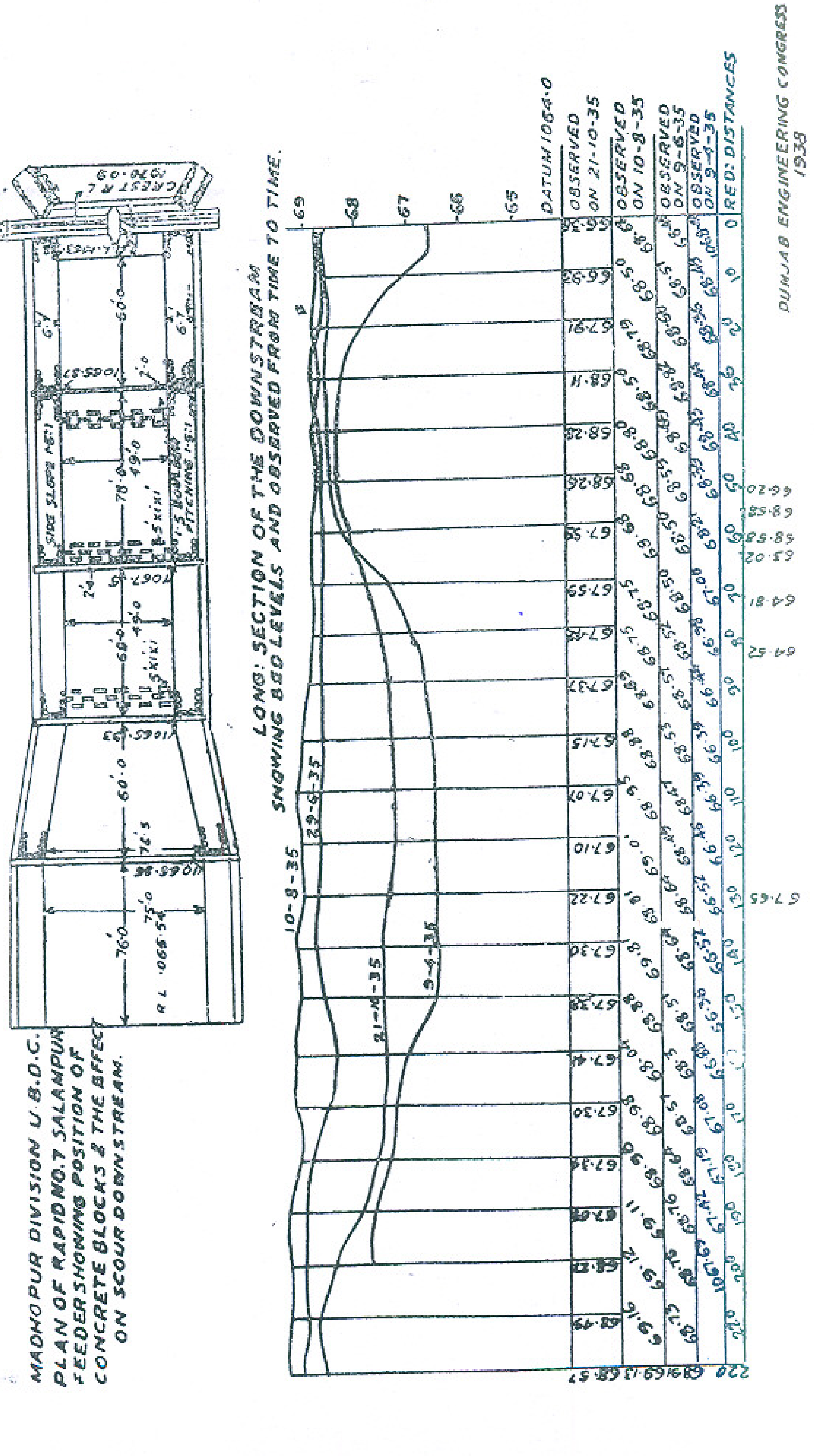


FIG. 19 (6)
PAPER NO. 214
MADHOPUR DIVISION U.B.D.C.
PLAN OF RAPID NO.7 SALAMPUR FEEDER SHOWING POSITION OF CONCRETE BLOCKS & THE EFFECT ON SCOUR DOWNSTREAM.
LONG: SECTION OF THE DOWNSTREAM SHOWING BED LEVELS AND OBSERVED FROM TIME TO TIME.
DATUM 1064.0
OBSERVED ON 21-10-35
OBSERVED ON 10-8-35
OBSERVED ON 9-6-35
OBSERVED ON 9-4-35
RED: DISTANCES
PUNJAB ENGINEERING CONGRESS 1938

It will be seen from a study of these models that the most satisfactory arrangement for reducing the scour below the pucca end of works having flat glacis slopes is the construction of staggered blocks similar to those adopted for works with steep slopes.

In the case of rapids or other similar works three to four rows of staggered blocks are constructed on the floor of the work 20 feet apart from each other. Each row consists usually of 2 lines of blocks (sometimes three) the arrangement of the blocks in the row being the same as adopted before. The last row is always constructed at the end of the pucca and the most suitable place for the first row is 25 feet downstream of the end of the crest.

The system of blocks as developed in the laboratory on model tests was constructed practically at Khanki Weir in 1934, Salampur Feeder rapids in 1935, Jaba Level crossing in 1935, Panjnad Weir in 1936 and Merala Weir in 1937. The blocks are made of cement concrete and are tied down on to the floor at their respective places.

The observations made on the actual works after the construction of the blocks have confirmed in a fine measure the favourable results of the experiments on models. The effect of the blocks in some cases was even better than was indicated by the experiments.

6. Field Results.

A brief mention is made below of the results obtained from some of the works.

Salampur Feeder Rapids 7 and 8.—Surveys of the bed were taken after every two months' running of the Feeder. The plotting of the survey as sent by Mr. Jaini, the then Executive Engineer, Gurdaspur are shown in Fig. 17. It will be seen from an examination of these figures that the rapids silted up at the downstream end after the construction of the blocks. Where, before the construction of the blocks, scour existed to a depth of 12 feet to 15 feet and no standing wave was formed, now silting took place and a well defined standing wave occurred after the blocks were laid in position.

The experiments were so successful that the Superintending Engineer, Upper Bari Doab Canal, decided to construct similar blocks on all the rapids of the Salampur Feeder. The annual repairs amounting to Rs. 30,000 were thus reduced to nothing.

Jaba Level Crossing.—The blocks were constructed at site in 1935. Reports received from the Superintending Engineer, Upper Jhelum Canal, show that the blocks are giving satisfactory results. They have proved efficient as energy dissipators. The high velocity jet is split up and is thrown on to the top by the presence of the blocks. Plate III shows the position of the standing wave as observed on the actual. The position of the standing wave on the model obtained by constructing the blocks compares very well with that on the actual. It will be seen therefore that on this work too the blocks have worked very efficiently in throwing the high velocity jet to the top and in reducing the scour.

Khanki Weir.—Soundings taken downstream of the bays of Khanki Weir on which blocks and arrows (in this case) were constructed have shown that not a stone moved from the loose protection. It may be mentioned here that deep scour holes formed before the protecting devices were constructed and huge sums were spent on annual repairs.

The best proof of the effectiveness of the staggered blocks will however be found in the Administration Report of the Government of the Punjab, P. W. D., Irrigation Branch for the year 1933-34, page 8, para 16.

"Nevertheless most valuable work has been carried out during the year in connection with subsoil water flow and uplift pressures under the Khanki Weir at present in course of construction. *The* **Energy Disssipator Blocks** *constructed downstream of the crest of the above weir, the dimensions and position of which were fixed on the direct results of model experiments in the laboratory,* **have proved an unqualified success.**"

7. Conclusions.

1. A number of models of works have been investigated with a view to studying the action at the downstream end of the *pucca*. As a result of that it has been found essential to construct some sort of devices in order to protect the work.

2. A number of different types of devices have been examined and it has been found that the staggered block arrangement gives the best results. The scour is considerably reduced and the high velocity jet is thrown on to the top. The baffle and Rehbock sill are inferior to blocks.

3. It is difficult to give a general arrangement for all works but usually the arrangement consists of constructing two rows of blocks; one row consisting of two lines (sometimes three) of blocks on the glacis 2 ft. to 5 ft. upstream of the toe, and the second row of three lines of blocks at the end of the pucca.

4. For rapids or similar other works three to four rows of blocks (depending upon the length of the work) are constructed. Each row consisting of two line of blocks is placed 20 ft. apart. The last row is generally placed at the end of the work and has three lines of blocks. In some complicated forms, models of works have got to be examined.

5. Sloping aprons at the downstream end of the work should be avoided. They induce scour and create greater action. Level portions are the best.

6. Extensions in the length of the downstream aprons are expensive and do not materially reduce the depth of scour.

The Authors wish to thank Dr. E. Mckenzie Taylor, Director, Irrigation Research Institute for his invaluable guidance and help during the course of this investigation.

Our thanks are also due to Mr. D. D. Jaini, I. S. E., Executive Engineer for supplying the information regarding the Salampur Feeder and to Mr. Nazir Ahmad, M. Sc., Research Assistant for his valuable help during the course of certain parts of this investigation, the electrical arrangement for recording the water level having been set up by him.

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APPENDIX I (*a*).
OPEN WEIR (KHANKI).

Serial No.	Length of Protection.	Arrows.					Control Blocks.		Pond Level	Maximum Flood.	
		Height.	Length.	Trans-verse Spacing.	Axial Spacing.	Distance from shutter line.	Height.	Distance from Shutter line.	Scour.	Scour.	Depth to max. velocity
	1	2	3	4	5	6	7	8	9	10	
1	..	..	..	..	..	..	..	..	9·8′	15·3′	22·5
2	..	1	12′	..	..	49′	..	..	9·0′	14·7′	22·3
3	..	1	12′	11¼′	18½′	76′	..	..	8·0′	12·5′	15·4
4	30 ft.	..	..	..	..	..	..	..	16·0′	10·5′	16·5
5	Do.	1	12′	..	..	76′	..	..	9·0′	10·4′	15·0
6	Do.	1	12′	..	..	76′	1′	126	5·6′	7·8′	19·5
7	Do.	1	12′	..	..	76′	1·25′	126	4·1′	7·5′	15·9
8	Do.	1	12′	..	..	76′	1·5′	126	3·6′	6·9′	11·8
9	Do.	1	10′	9¾′	18½′	83′	1·5′	126	4·0′	6·5′	9·5
10	Do.	1·5′	8′	..	..	87′	1·5′	126	4·4′	6·4′	4·0
11	Do.	..	..	..	..	..	1·5′	126	6·1′	7·3′	13·8
12	Do.	..	..	..	..	..	1·5′	111	6·2′	9·2′	16·0
13	Do.	·5′	8′	..	..	87′	1·5′	126	3·0′	7·0′	14·0
14	Do.	·5′	8′	..	..	87′	1·5′	134	3·2′	5·8′	16·5
15	Do.	·5′	8′	..	..	87′	¾′	131	5·3′	..	..
16	Do.	1′	12′	11¼	18½′	76′	0·75′	126	2·6′	8·0′	16·0
17	55 ft.	..	..	..	..	..	..	..	15·9′	9·5′	1·2
18	Do.	1′	10′	9¾′	18½′	83′	..	..	6·0′	10·0′	13·5
19	Do.	1′	10′	..	..	83′	1·5′	151	4·0′	5·8′	16·0
20	Do.	1′	10′	..	..	83′	1·5′	141	..	6·4′	13·7
21	Do.	1′	10′	..	..	111′	1′	151	4·2′	6·7′	11·5
22	Do.	1′	10′	..	..	83′	1′	151	4·0′	6·8′	16·2
23	Do.	1′	8′	8′	18½′	87′	1′	151	4·3′	6·4′	10·6
24	Do.	1′	8′	..	..	87′	1·5′	151	3·2′	5·7′	16·6
25	*Nil.*	1′	8′	6′	15′	87′	1′	151	2·7′	6·6′	1·6

APPENDIX I (*b*).

UNDERSLUICED WEIR (KHANKI).

Serial No.	Length of Protection.	Arrows.			Control Blocks.		Pond Level.		Maximum Flood.	
		Height.	Length.	Dist. from the crest.	Height.	Dist. from the crest.	Scour.	Depth to maximum velocity.	Scour.	Depth to maximum velocity.
1	..	..	..	..	..	..	19·2′	12·0′	19·4′	12·5′
2	30′	..	..	..	..	..	14·6′	10·0′	18·5′	19·0′
3	50′	..	..	..	..	..	12·0′	7·5′	16·5′	18·7′
4	Do.	2′	12′	45′	..	..	6·5′	5·5′	11·8′	7·5′
5	Do.	,,	,,	45′	2 rows 1·5′	133′	6·2′	3·0′	11·4′	7·0′
6	Do.	,,	,,	45′	4 rows 1·5′	133′	5·7′	2·0′	10·1′	2·7′
7	30′	,,	,,	45′	..	..	8·5′	5·2′	13·0′	3·5′
8	Do,	,,	,,	45′	2 rows 1·5′	123′	6·5′	3·5′	12·0′	7·0′
9	Do.	,,	,,	45′	2 rows 1·5′	103′	6·6′	..	12·1′	2·5′
10	Do.	,,	,,	45′	4 rows 1·5′	113′	7·0′	5·8′	12·2′	5·0′
11	Do.	rows 1st 1·5′ 2nd 2·0′ 3rd 2·5′	..	45′	..	..	..	..	12·0′	8·0′
12	Do.	Do.	Do.	40′	2 rows 1·5′	123′	6·0′	3·2′	10·8′	17·5′
13	Do.	Do.	Do.	40′	3 rows 1st 2·5′ 2nd 2·0′ 3rd 1·5′	118′	7·5′	3·5′	9·0′	18·5′
14	Do.	rows 1st 2·0′ 2nd 2·0′ 3rd 2·5′	.	40′	Do.	118′	6·0′	2·6′	10·0′	1·4′
15	Do.	2.0′	12′	40′	Do.	118′	5·0′	6·0′	10·4′	1·4′
16	Do.	3 rows of 2′ blocks		40′	Do.	118′	..	..	10·8′	2·4′
17	Do.	3 rows of 2′ arrows		40′	2 rows 1·5′	123′	7·0′	5·8′	10·7′	8·0′

APPENDIX II (*a*)

PANJNAD WEIR ANNEXE.

Serial No.	Arrows. Spacing { Transverse.—15′·0, Axial.— 8·5′ }: No. of Rows.	Height.	Length of Arms.	Distance from the down-stream end of the crest.	Control Blocks. Spacing { Transverse.—5′·0, Axial.—4′·0 }: No. of Rows.	Size.	Distance from the down-stream end of the crest.	Pond. Scour.	Pond. Depth of point of Maximum Velocity from the water surface.	Maximum Flood. Scour.	Maximum Flood. Depth of point of Maximum V[illegible]
1			..		..	..	..	11·0′	15·7′	18·0′	20[illegible]
2				..	3 2 2	5′×2′×3′ 5′×2′×2′ 5′×2′×2′	50′ 72′ 107′	3·7′	7·8′	8·3′	14[illegible]
3	3	2′	10′	41·4′	3 2	5′×2′×2′ 5′×2′×1′	72′ 109′	5·4′	5·6′	11·5′	13·[illegible]
4	3	2′	10′	41·4′	3	5′×2′×2′	72′	6·6′	7·1′	11·1′	15·[illegible]
5	3	2′	10′	41·4′	2	5′×2′×2′	109′	6·9′	11·0′	10·1′	16[illegible]
6	3	2′	10′	69·0′	3	5′×2′×2′	103′	6·6′	10·8′	10·3′	15[illegible]
7			..	..	3 2 2	5′×2′×2′ 5′×2′×2′ 5′×2′×2′	50·0′ 70·0′ 109·0′	7·0′	10·0′	9·3′	12[illegible]
8	3	2·5′	10′	60·0′	1 2	5′×2′×2½′ 5′×2′×2′	93·0′ 99·0′	7·5′	10·5′	10·2′	13·[illegible]
9	3	2·5′	10′	69·0′	1 2	5′×2′×2½′ 5′×2′×2′	103·0′ 109·0′	6·8′	12·6′	10·2′	14·[illegible]
10	3	1·5′	10′	41·4′	3	5′×2′×2′	103′	8·0′	10·7′	8·5′	14[illegible]
11	3	2′	10′	32·8′	3	5′×2′×2′	103′	6·0′	15·5′	9·9′	11[illegible]
12			..	..	3 3	5′×2′×2′ 5′×2′×2′	50′ 103′	5·6′	10·1′	9·6′	1·[illegible]
13			..	..	3 3 3	5′×2′×4′ 5′×2′×2′ 5×2′×1′	50′ 72′ 107′	3·9′	4.0	8·0′	11·[illegible]
14			..	..	3 3	5′×2′×4′ 5′×2′×1′	50′ 103′	4·9′	5.0′	9·4′	10·[illegible]
15	3	2′	10′	41·4′	2	5′×2′×2′	72′	7·8′	10.3′	12·3′	1[illegible]
16	..		..	..	3 2 2	5′×2′×3′ 5′×2′×2′ 5′×2′×2′	38′ 78′ 107′	3·7′	3.1′	The same as No. [illegible]	

*Axial spacing of blocks at the downstream end of pucca 2 feet.

APPENDIX II (*b*).
CONTROL BLOCKS.

Arrows — Spacing { Transverse.—15·0′. Axial.—8·5′.				Spacing { Transverse.—5·0′. Axial.—4·0′.			Pond.		Maximum Flood.	
No. of Rows.	Height.	Length of Arms	Distance from Shutter Line.	No. of Rows.	Size.	Distance from Shutter Line.	Scour.	Depth of point of maximum velocity from the water surface.	Scour.	Depth of point of maximum velocity from the water surface.
..	..	..	..	..	..	..	8·0′	13·0′	16·8′	17·4′
3	2′	10′	41·4′	2	5′×2′×2′	109′	7·5′	10·4′	10·5′	14·2′
3	2′	10′	69·0′	3	5′×2′×2′	103′	..	..	9·3′	14·7′
3	2′	10′	41·4′	{ 3	5′×2′×2′	72′	..	..	11·0′	14·2′*
				2	5′×2′×1′	109′				
..	..	..	..	{ 2	5′×2′×3′	50′	..	..	9·6′	14·7′
				2	5′×2′×2′	78′				
				2	5′×2′×2′	107′				
3	2′	10′	41·4′	2	5′×2′×2′	109′	7·5′	10·4′	..	..

* Axial spacing of blocks at downstream end of pucca 2 feet.

Block and the well portions of the bed made flush with the horizontal ucca floor.

APPENDIX II (c)

PANJNAD WEIR PROPER.

Arrows. Spacing { Transverse. 15·0'. Axial. 8·5'					Control Blocks. Spacing { Transverse.—5·0'. Axial.— 4·0'.			Pond.		Maximum Flood.	
Serial No.	No. of Rows.	Height.	Length of Arms.	Distance from the downstream end of the crest.	No. of Rows.	Size.	Distance from the downstream end of the crest.	Scour.	Depth of point of maximum velocity from water surface.	Scour.	Depth of point of maximum velocity from water surface.
1	..	..	..	..	..	..	..	10·9'	16·5'	13·4'	19·0'
2	3	2'	10'	72'	3	5'×2'×2'	105'	5·4'	9·9'	8·3'	14·4'
3	..	..	..	..	3	5'×2'×3'	45'	4·9'	6·2'	7·5'	10·1'
					3	5'×2'×3'	75'				
					3	5'×2'×2'	105'				
4	3	2'	10'	36.4'	3	5'×2'×2'	72'	5·6'	9'	7·5'	10' *
					2	5'×2'×1'	113'				

* Axial spacing of blocks at downstream end of pucca 2 feet.

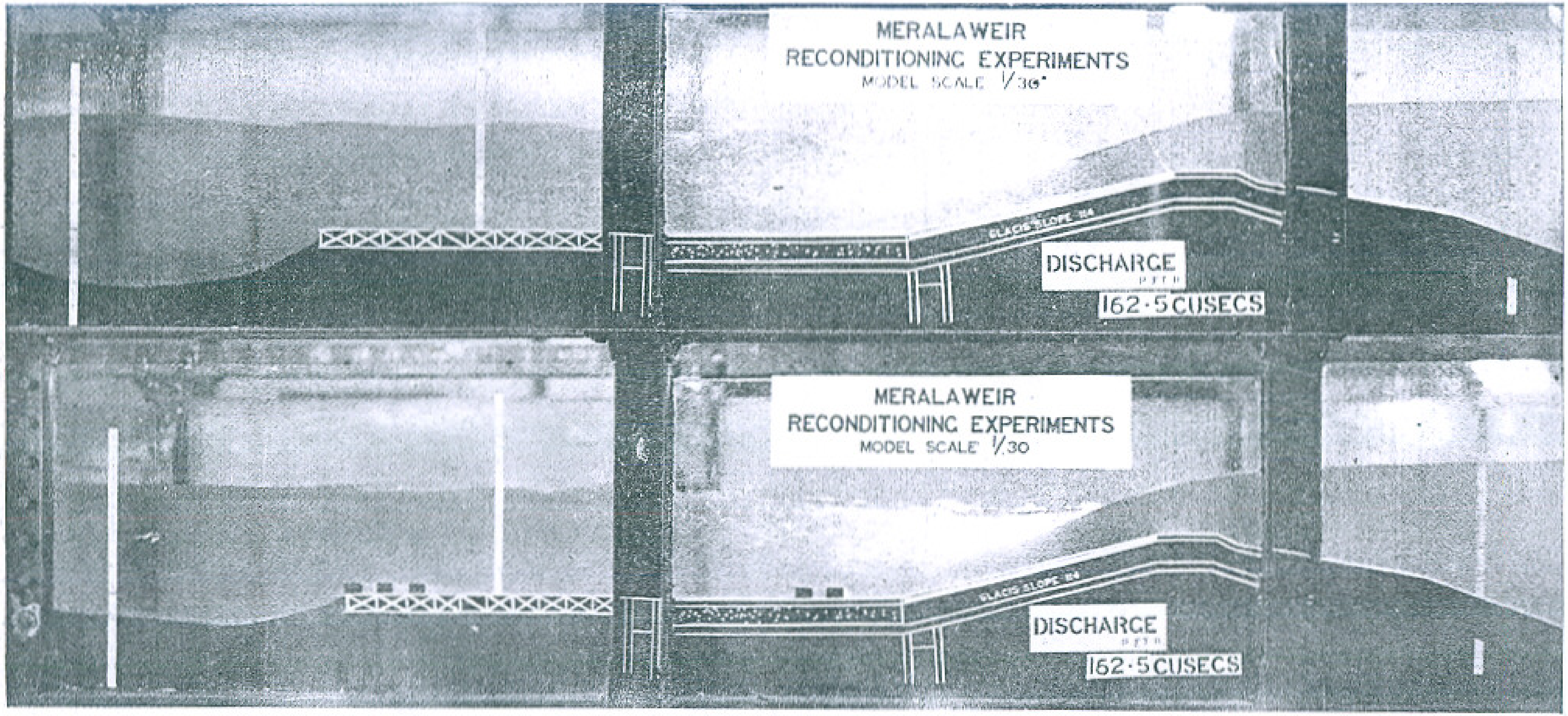


Photo No. III.—Without blocks (above) and with blocks (below).

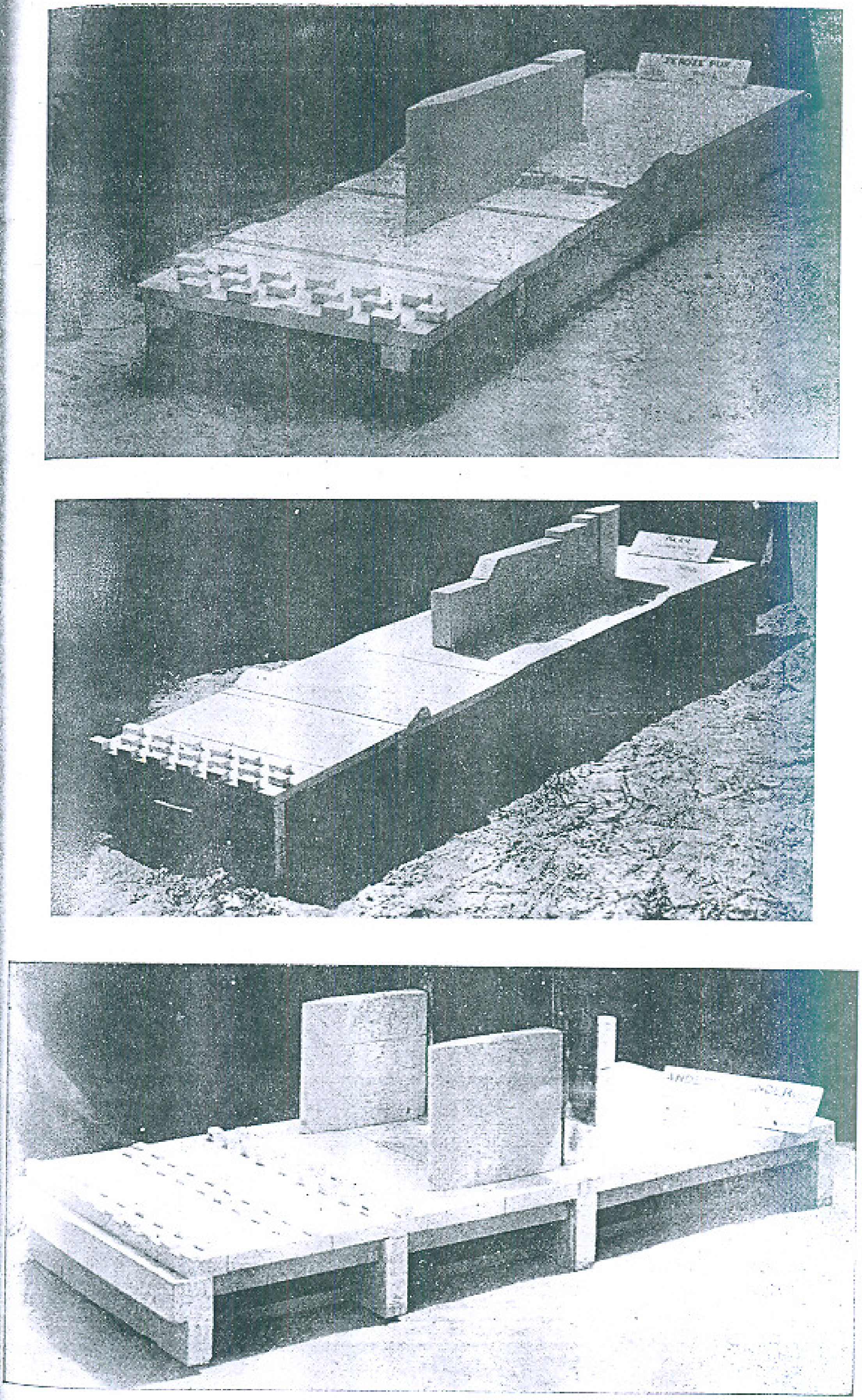


Photo No. IV.—Some of the models fitted with Blocks.

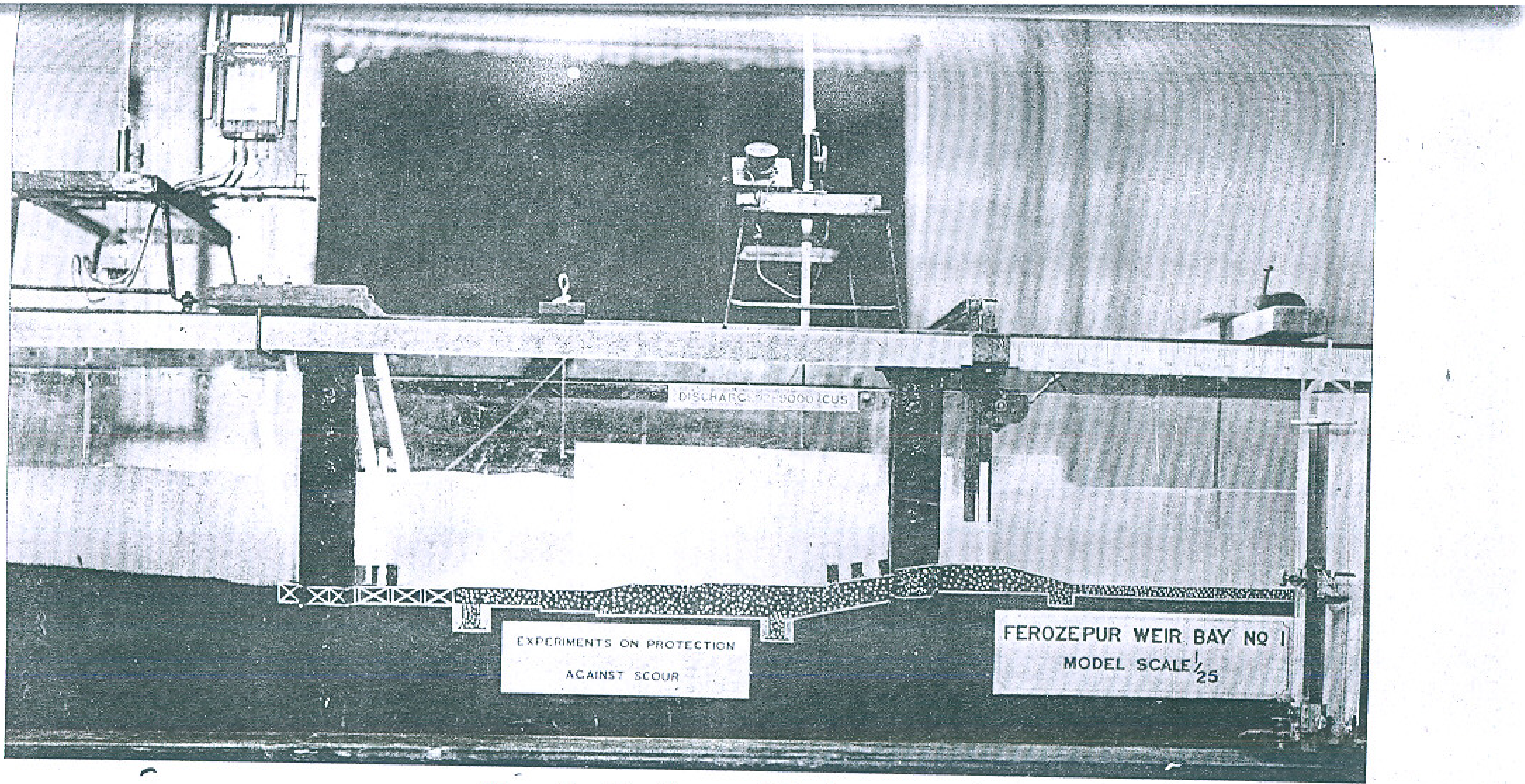


Photo No. V.—Staggered Blocks in Action.

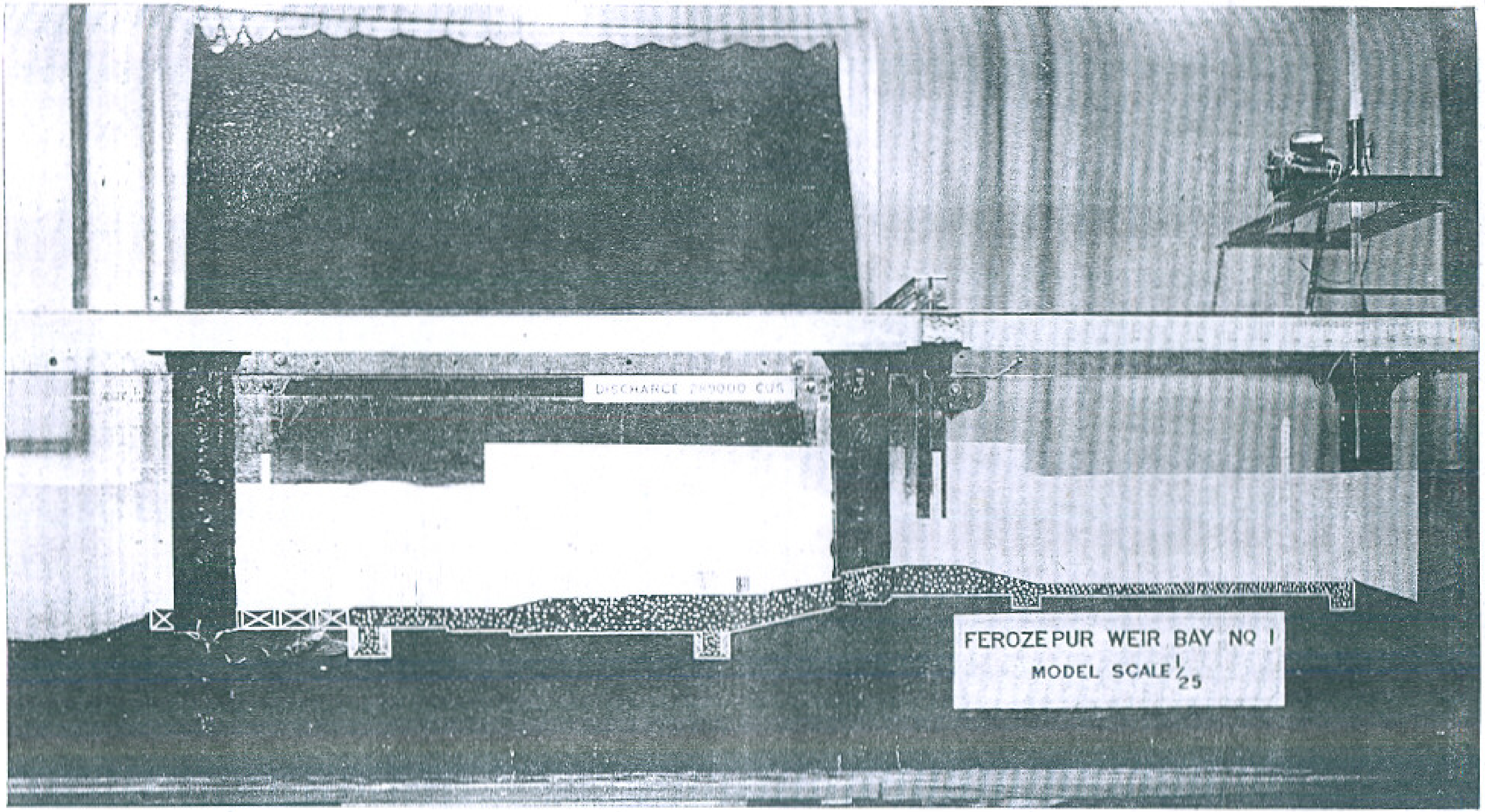


Photo No. VI.--Splitters and Baffle Piers.

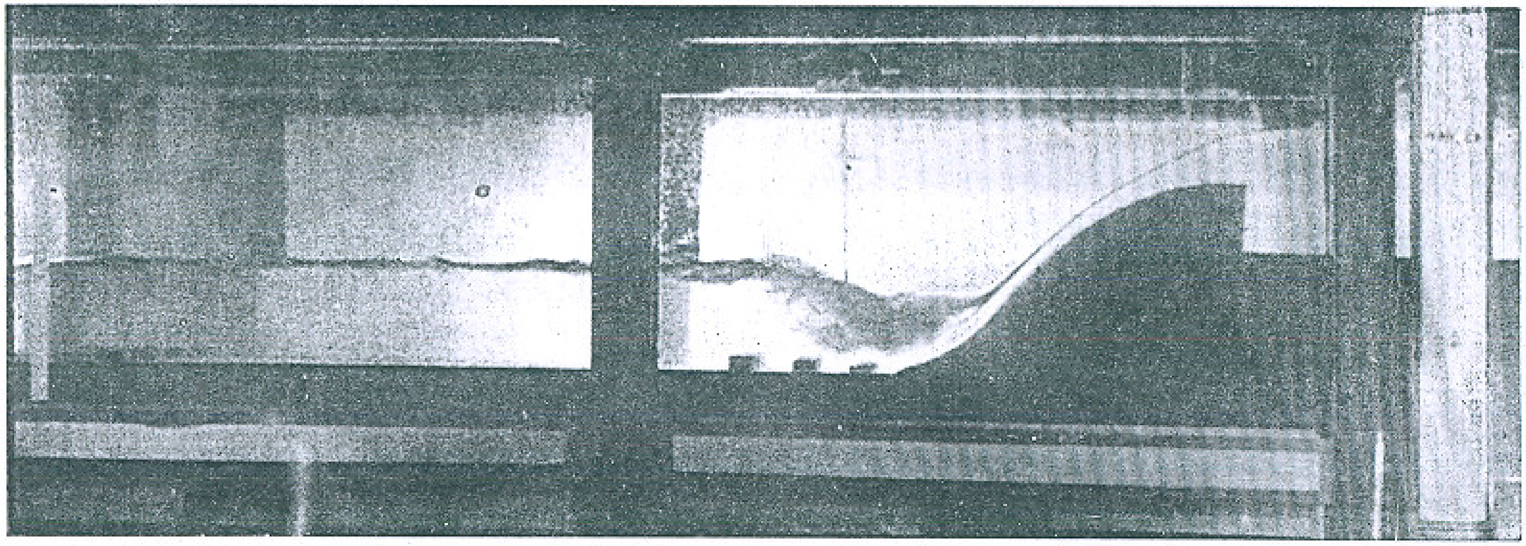
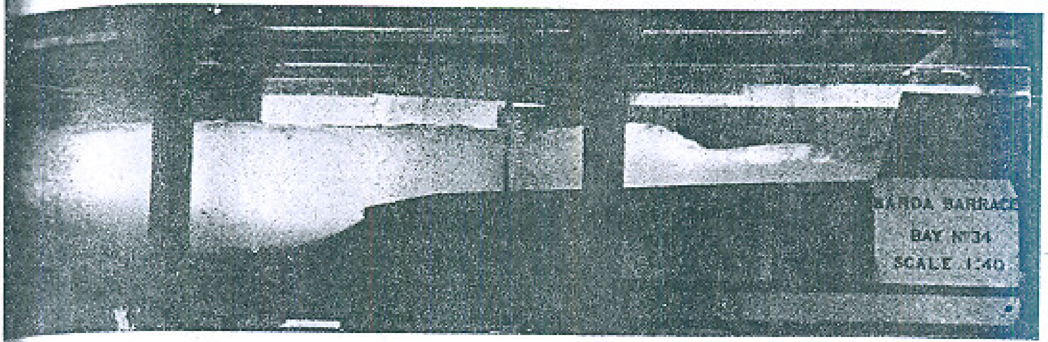


Photo No. VII. Blocks in Action. The Blocks throw the high velocity jet on the top.

SARDA BARRAGE.



Deep Scour.

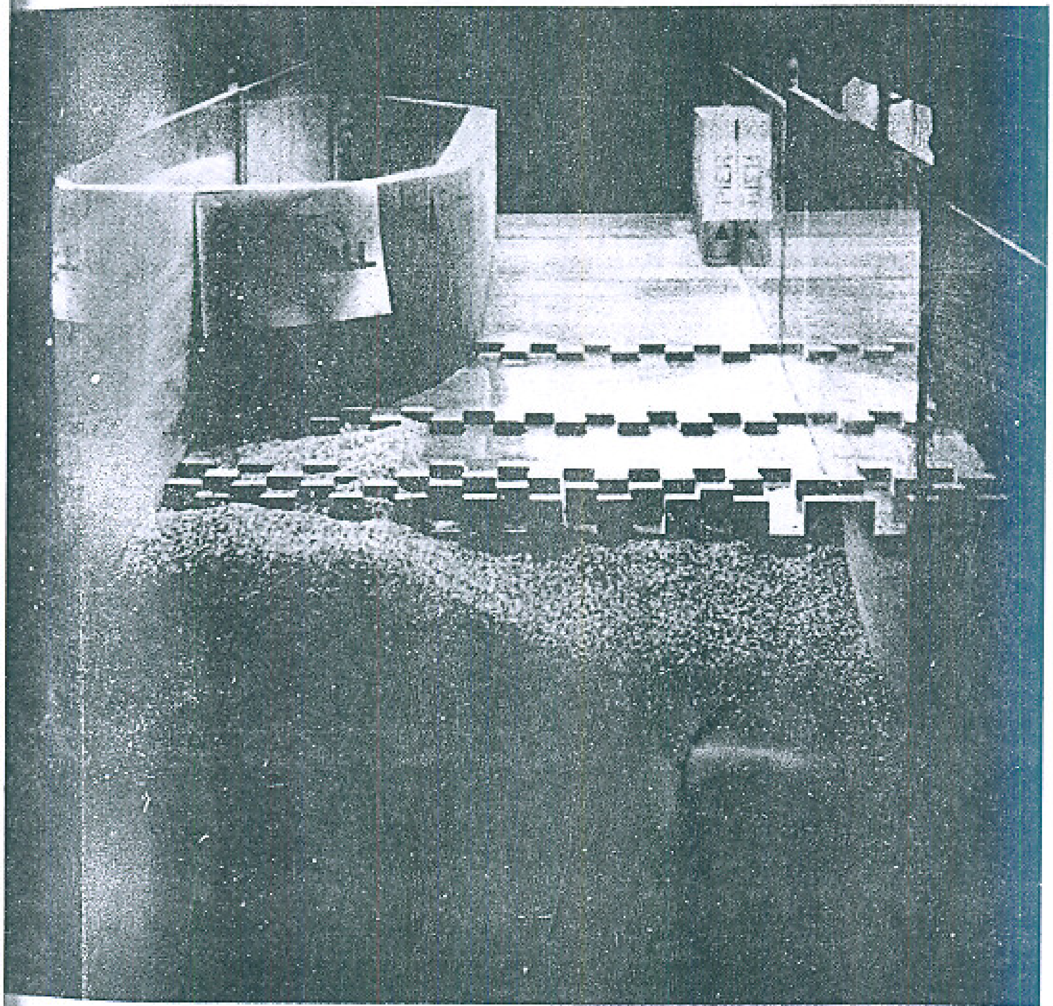


Photo No. VIII.—Practically No Scour.

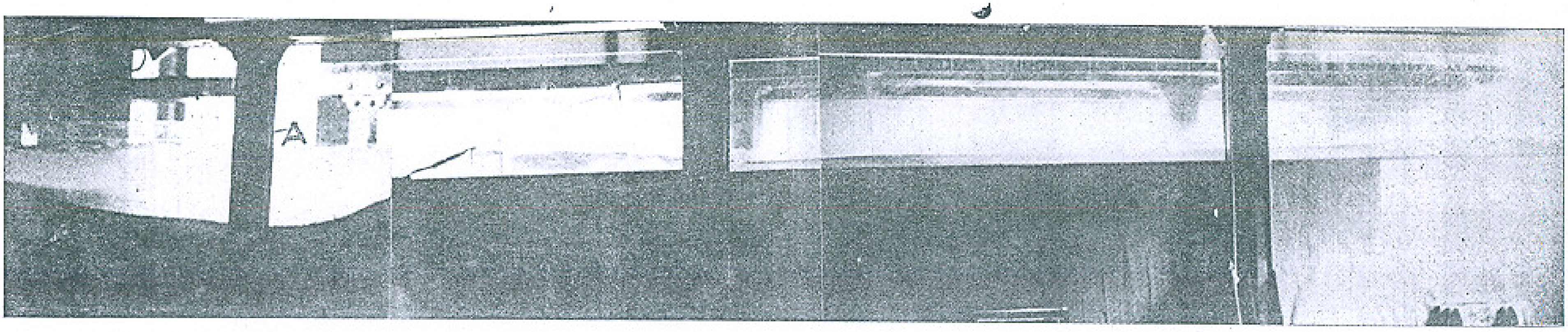
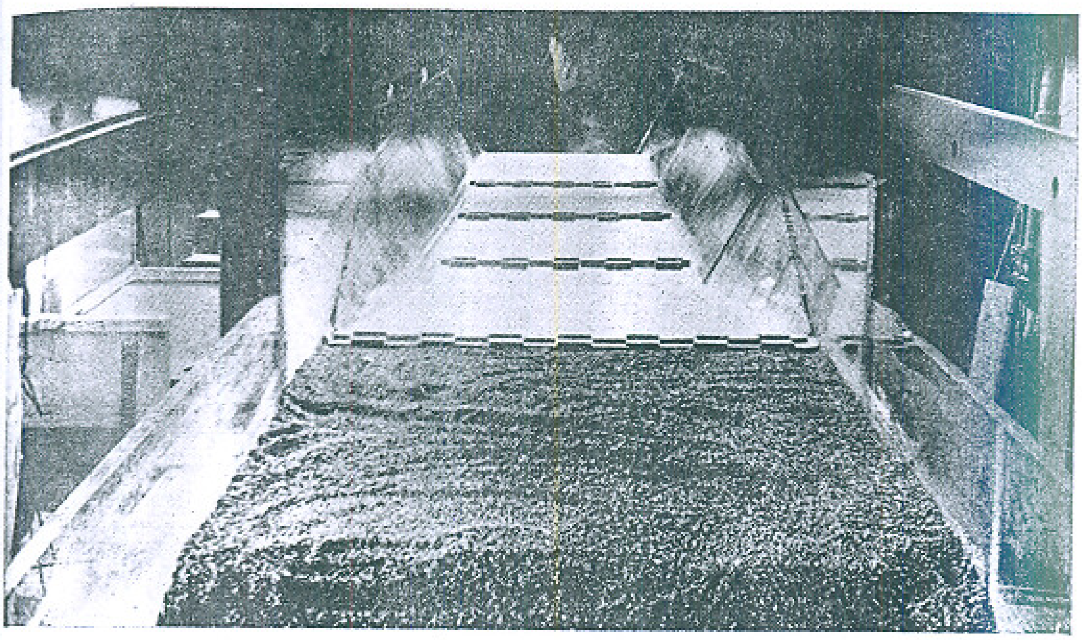
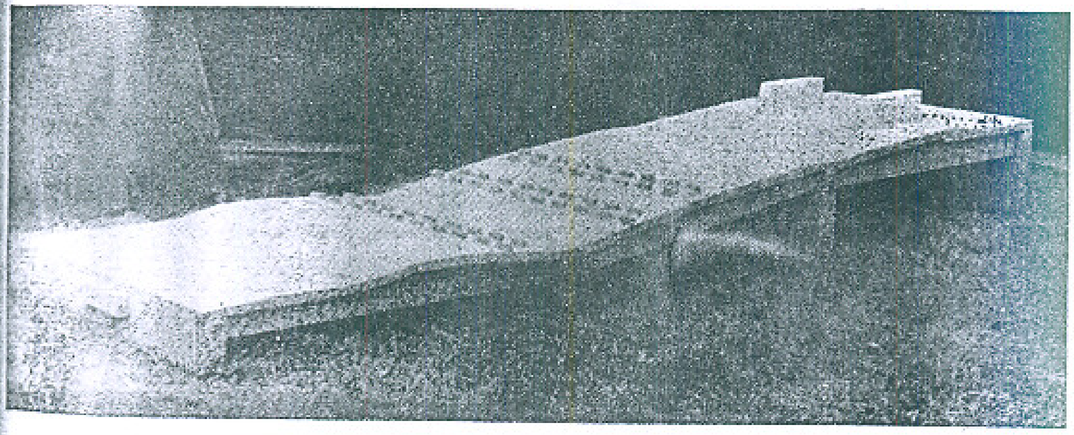


Photo No. IX. Salampur Feeder Rapid No. 8. Note the deep scour hole at "A."

Arrangement of staggered Blocks.



Salampur Feeder.



Jaba-level crossing.

Photo No. X.

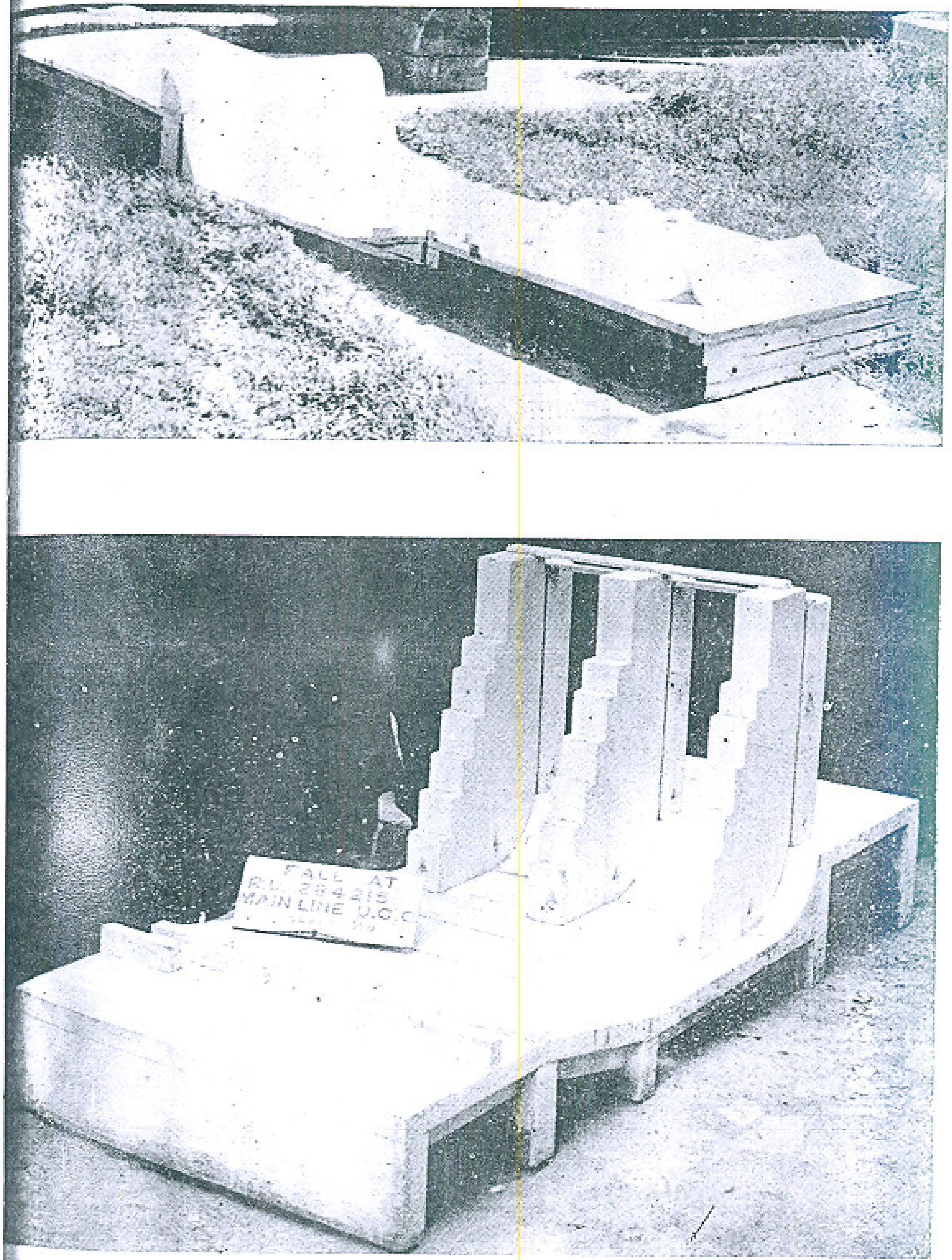


Photo No. XI.—Deg Diversion Fall and Fall at R. D. 2,84,215.
Main Line, U.C.C.

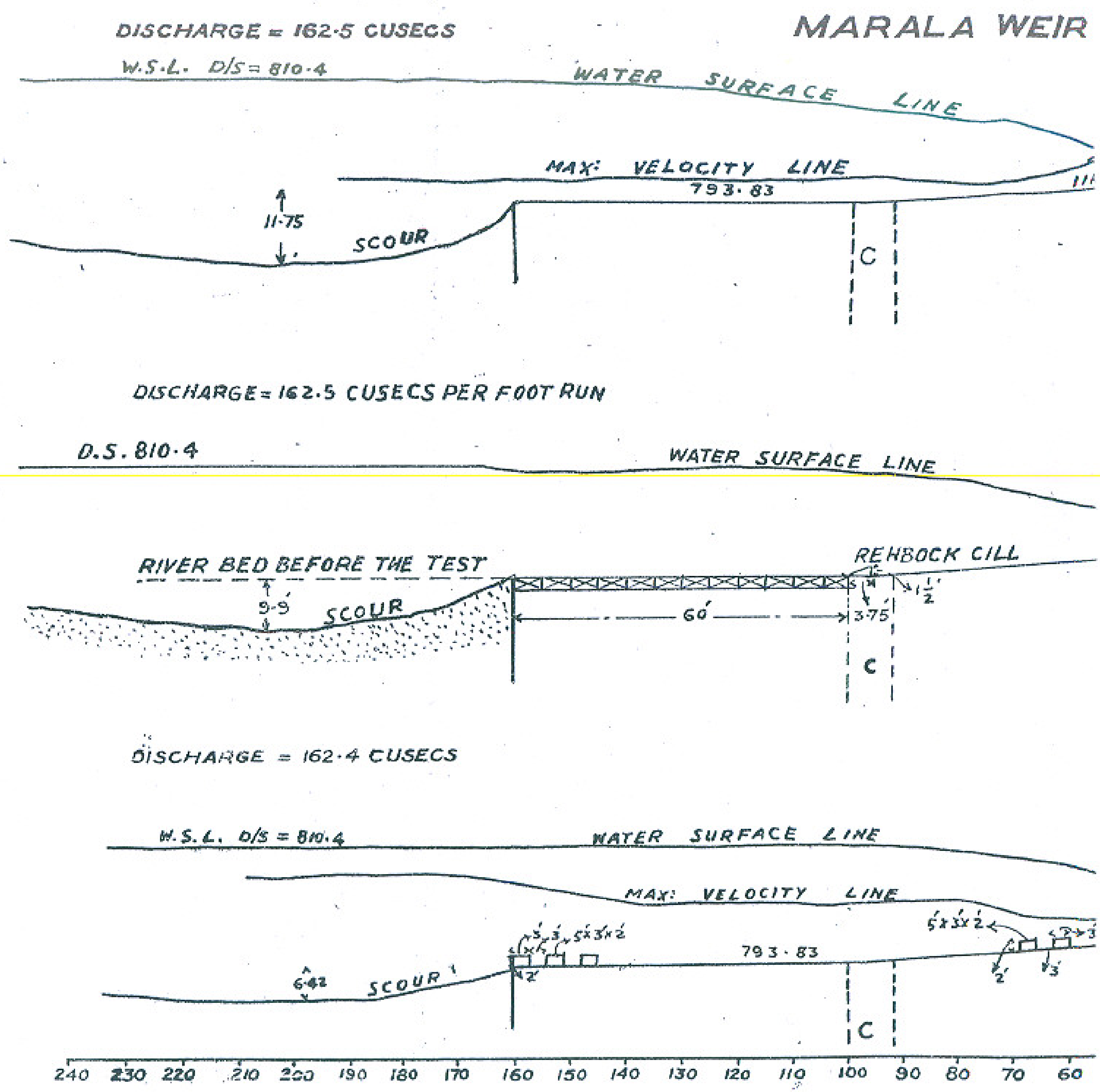
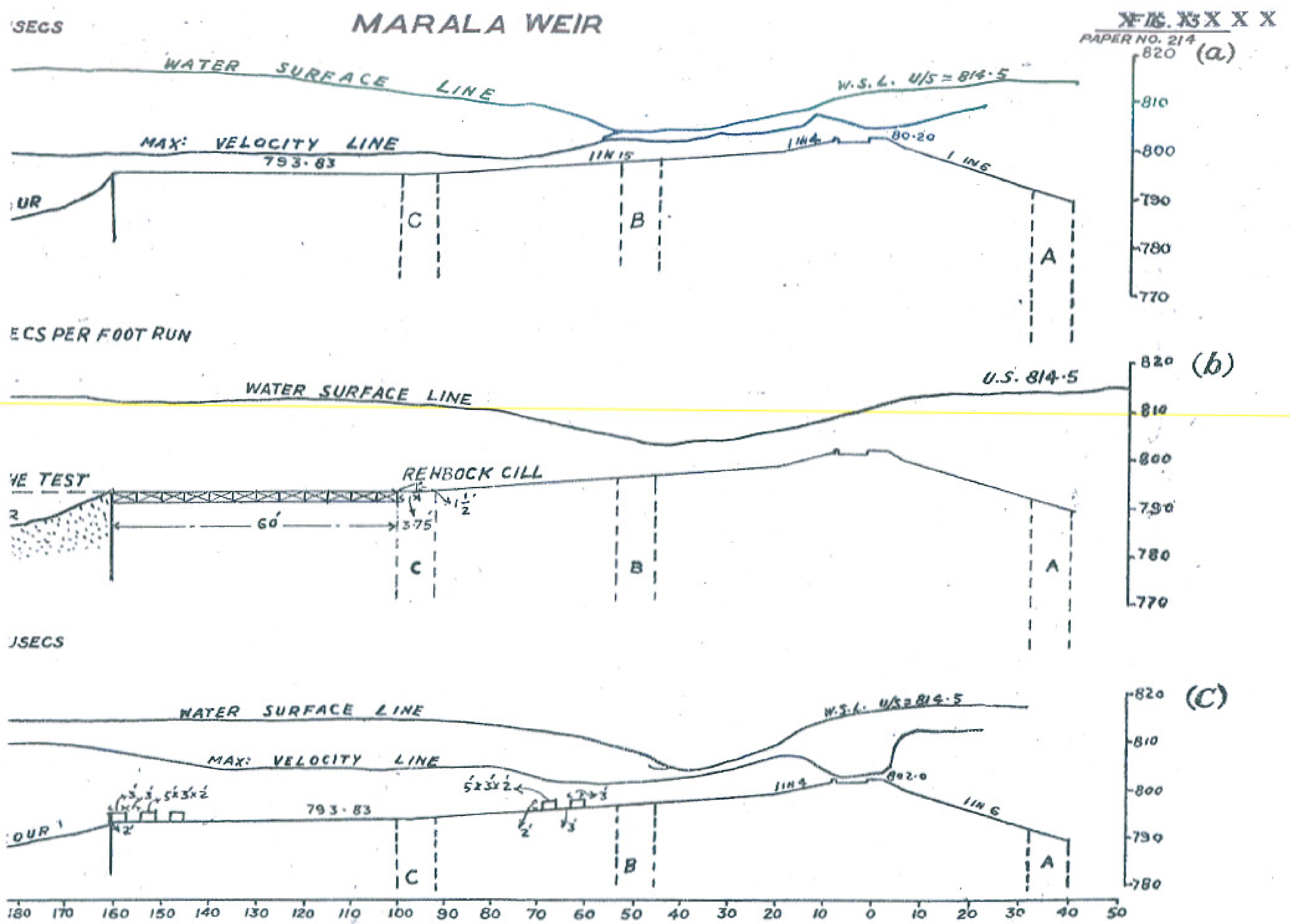

MARALA WEIR
DISCHARGE = 162·5 CUSECS
W.S.L. D/S = 810·4
WATER SURFACE LINE
MAX: VELOCITY LINE
793·83
11·75
SCOUR
C
DISCHARGE = 162.5 CUSECS PER FOOT RUN
D.S. 810·4
WATER SURFACE LINE
RIVER BED BEFORE THE TEST
REHBOCK CILL
9·9
SCOUR
60'
3·75
C
DISCHARGE = 162·4 CUSECS
W.S.L. D/S = 810·4
WATER SURFACE LINE
MAX: VELOCITY LINE
793·83
6·42
SCOUR
C
240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60

PLATE 1

PAPER NO. 214



RAPID NO. 8
SALAMPUR FEEDER

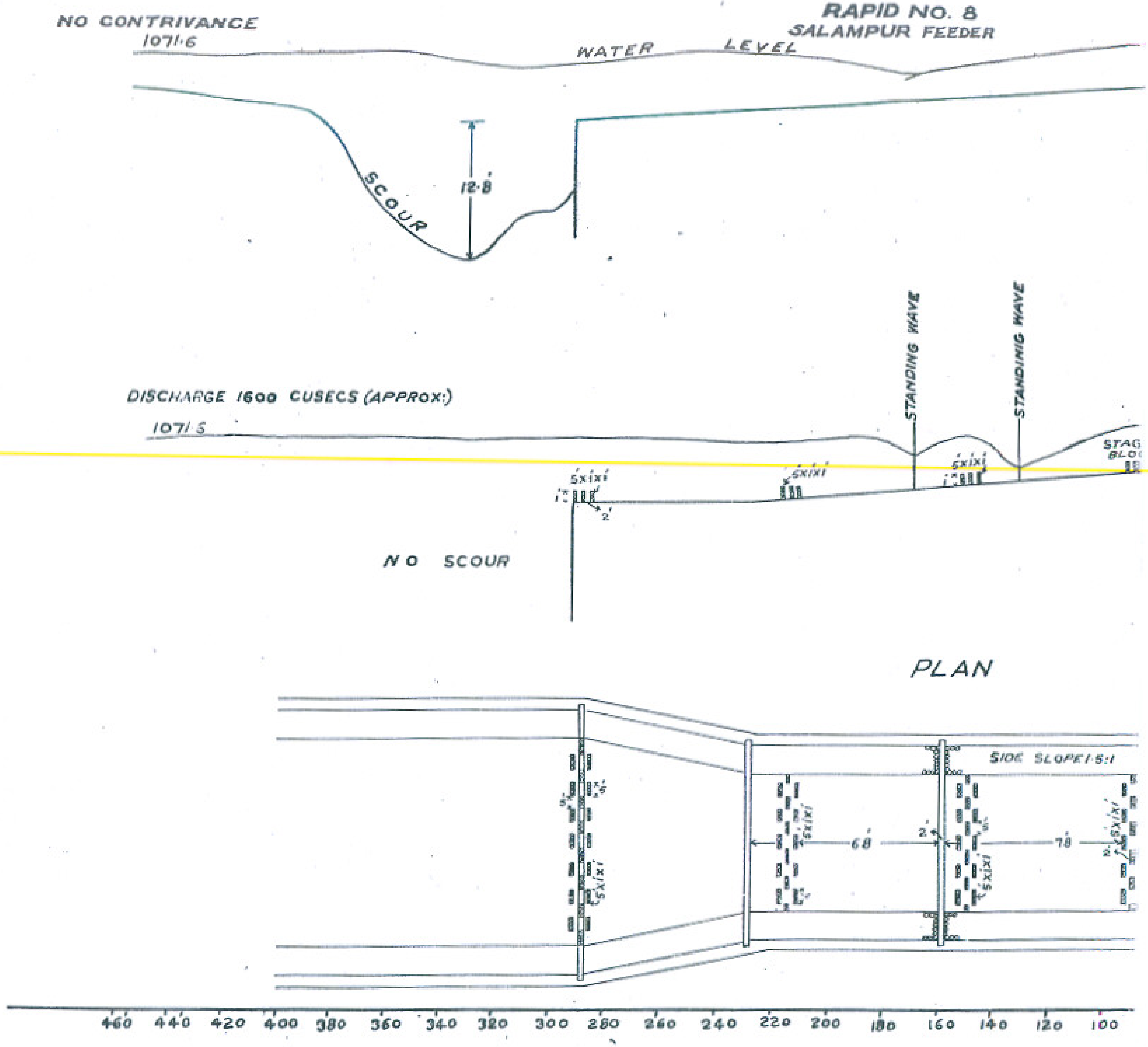
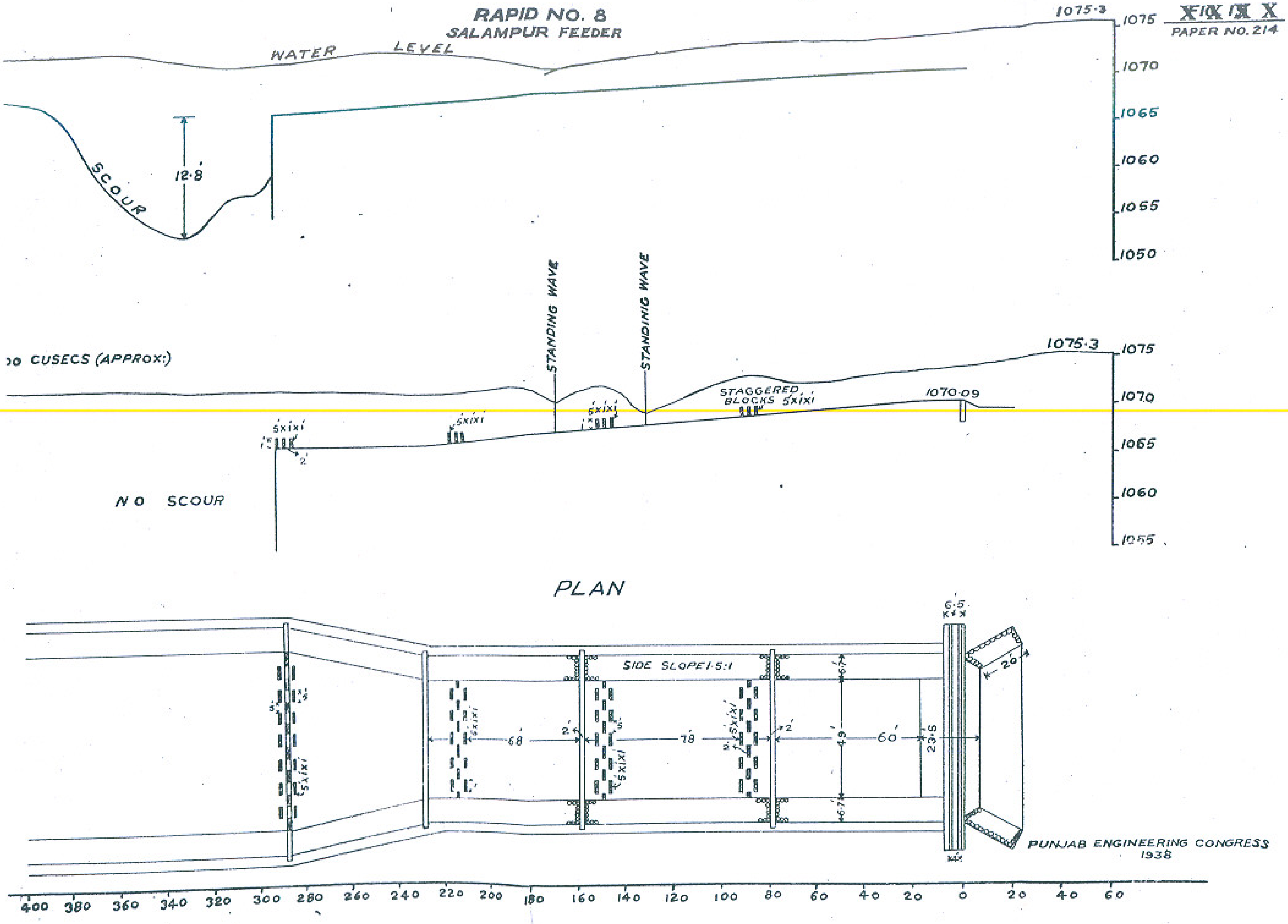


PLATE II

XIX XX X X

PAPER NO. 214



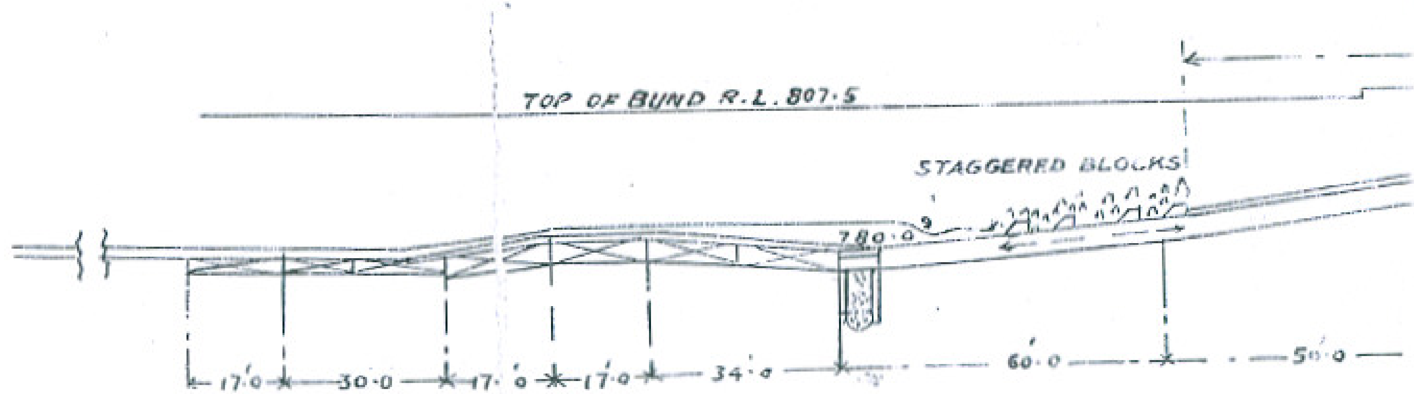
PUNJAB ENGINEERING CONGRESS
1938

UPPER JHELUM CANAL
JHELUM DIVISION

CROSS SECTION OF WE
JABA ESCAPE
SHOWING POSITION OF STANDING

SCALE 1/400

DATE OF FLOOD	15·7·37
MAX: GAUGE UP STREAM	806·05
MAX: DISCHARGE.	1620·9
MAX: GAUGE DOWN STREAM	796·0
DIST: OF S. WAVE (FROM U/S FACE OF GATE)	189



UPPER JHELUM CANAL

JHELUM DIVISION

CROSS SECTION OF WE
JABA ESCAPE

SHOWING POSITION OF STANDING W

SCALE 1/400

DATE OF FLOOD	15·7·37
MAX: GAUGE UP STREAM	806·05
MAX: DISCHARGE.	1620·9
MAX: GAUGE DOWN STREAM	796·0
DIST: OF S. WAVE (FROM U/S FACE OF GATE)	189

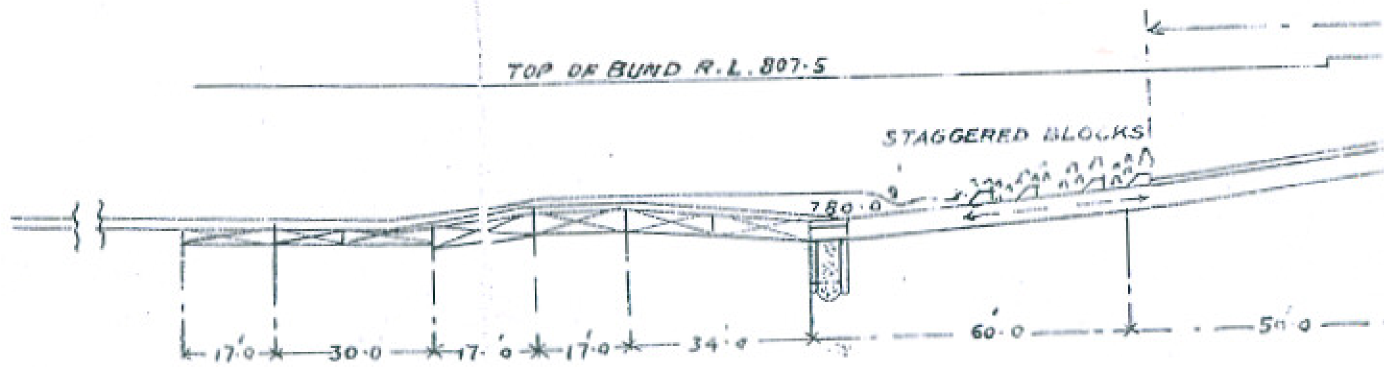


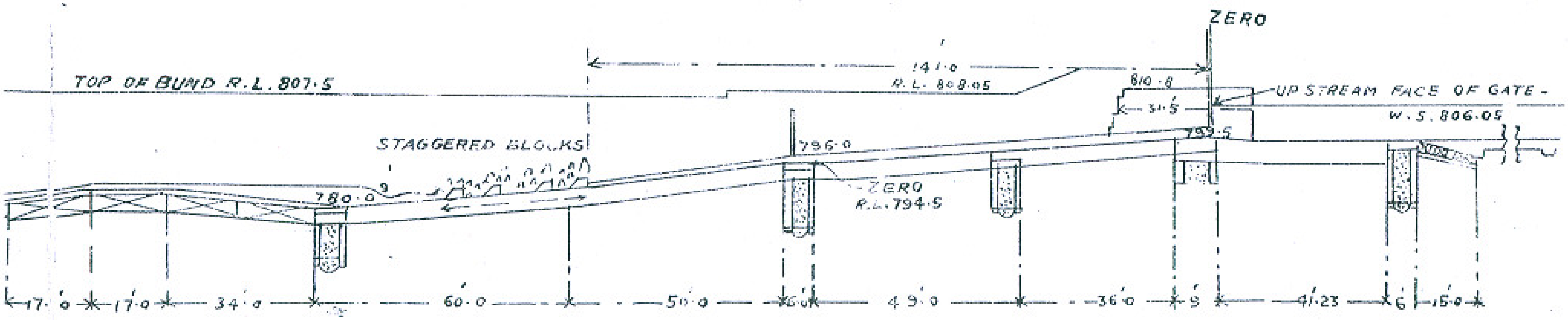
Fig. XXX X X
PAPER NO.214

UPPER JHELUM CANAL
JHELUM DIVISION

CROSS SECTION OF WEIR
JABA ESCAPE

SHOWING POSITION OF STANDING WAVE
SCALE 1/400

DATE OF FLOOD	15·7·37
MAX: GAUGE UP STREAM	806·05
MAX: DISCHARGE.	1620·9
MAX: GAUGE DOWN STREAM	796·0
DIST: OF S. WAVE (FROM U/S FACE OF GATE)	189



PUNJAB ENGINEERING CONGRESS
1939

DISCUSSION.

The Authors, in introducing the Paper, said that the cause of erosion was the tractive force or the drag. The tractive force was a function of the depth of flowing water and the slope of the water surface. However, where the flow was parallel the slope in the water surface was the same as the bed slope, that is to say $F_t = 62 \cdot 3\, d \times s$, where :—

F_t was the tractive force in lb. per square foot,

d was the depth of flow in feet,

s was the slope of water surface.

There were two limiting values of this tractive force, the Author said. When the upper limit was attained the bed material was set in motion. This was called the "erosive tractive force". With the lower limit of the tractive force, the bed began to silt up and this tractive force was known as the "sedimentative tractive force." There was a third value in between the two which was known as the "limiting tractive force" (F_{to}) at which the bed neither scoured nor silted. It was with the former, the erosive tractive force, that we were concerned to-day.

If the erosion of the bed and banks were to be prevented, the resistance to scour of the slopes and bottom must be larger than the erosive tractive force. If the resistance were less, the erosive tractive force moved the particles forming the sides and the bottom of a stream. Different kinds of particles had different values. For safe design, the magnitude of the erosive tractive force must be taken into consideration. The tractive force could also be expressed in terms of velocity. A limiting velocity for various types of beds could be obtained in a similar way as could the limiting tractive force. Acccording to Schoklitsch,

$$F_t = 62 \cdot 3\, d \times s.$$

Using a value for the roughness coefficient of 48·9, in Forchheiner's equation we had

$$V = 48 \cdot 9 d^{0 \cdot 7} S^{0 \cdot 7}$$

where V was the limiting velocity in feet per second. Engels gave the following limiting velocities for different types of bed soils :—

For light sandy soil,	V	$=2 \cdot 3$ ft./sec.
For average sandy soil,	V	$=2 \cdot 5$ ft./sec.
For loam,	V	$=3 \cdot 9$ ft./sec.

As the mean velocity was greater than the bed velocity it would be more correct to take bed velocities instead of average velocities.

If the bed velocity were higher than the limiting velocity, the bed of the work would scour. In the existing, as well as the new work, the bed velocities should be reduced to a value of the limiting velocity. Several devices had been tried to achieve that end and, of all these, blocks had served most efficiently in reducing the bed velocities.

Since the submission of this Paper in October last, several further investigations had been carried out which confirmed the results put forward in this Paper. In connection with the proposed designs of Trimmu weir as many as eight models were tested. For the reduction of scour downstream of the *pacca* protection, it was found that staggered blocks were the best of all the devices. At present there were four such types of devices, viz :

(*i*) Rehbock Sill, used in Germany and other European countries,

(*ii*) Baffle piers, used in America,

(*iii*) Inglis' Baffle, used in Southern India, and

(*iv*) Staggered blocks, used in the Punjab.

Out of all these it had been proved that the construction of staggered blocks gave the maximum advantage whatever be the type of work—whether it be a weir, or a fall in the main line of a canal or in a small distributary. Regarding the position of the blocks, 55 subsequent experiments had shown that the position suggested in the Paper was the best. All other positions were inferior. This was illustrated in Plate V. The blocks constructed just upstream of the toe of the glacis gave a scour of about 10 feet. If the position of these blocks was shifted on the horizontal floor just downstream of the toe of the glacis the blocks became much less effective. Constructed in the latter position they gave a scour $1\frac{1}{2}$ times as deep, i.e. about 15 feet. Similarly from several tests* on falls made by Uppal and Nazir Ahmad it had been shown that the best position for the first row of blocks was just upstream of the toe of the glacis. For the downstream or the second row of blocks the most effective position was the end of the *pacca* floor. In one case (which was a fall designed by Mr. Inglis) both the staggered blocks as well as Inglis' baffle and deflector were tried. It was found from these tests that if the baffle was substituted for staggered blocks in the same position, a definite standing wave was formed with the result that the downstream water surface was much smoother and the scour was also much less. The effectiveness of the first row of blocks in deflecting the high velocity jet towards the water surface was illustrated in Diagram C of Plate V.

Upstream of the baffle the high velocity jet was deflected towards the top but downstream, it was again kicked down to the level of the floor. The baffle also caused a lot of hurdling and turbulence. Diagram D of Plate V illustrated this clearly.

* Experiment unpublished.