PAPER No. 343

"Diverting River Indus Through Taunsa Barrage" (1957-58)

By

MOHAMMAD SAID

I. Introduction.

1. *Taunsa Barrage—A Multi-purpose Project.*

For the development of the country, situated to the west of the mighty Indus, it was necessary to have a high-way crossing over the river, so as to open this area to developments, already in operation in the areas east of the river. Many sites were proposed in the past for the projected high-ways between Ghazi Ghat and Darya Khan, the two present ferry sites connecting D. G. Khan and Dera Ismail Khan, to the Indus planes on the east. The irrigation system in the former province of the Punjab had also advanced sufficiently far, while the areas adjoining the River Indus in its three districts, *viz.*, Dera Ismail Khan, D. G. Khan and Muzaffargarh, had the old unreliable system of inundation canals. Considering all the requirements of a backward area including hydel power, a multi-purpose project was worked out to provide a high-way crossing, B. G. rail crossing and a barrage with head regulutors to feed off-taking irrigation canals of the capacity of 20,000 cusecs discharge and hydel power channel ; and was sanctioned by the Government and named after the sacred town in the area as Taunsa Project. Taunsa Barrage has been constructed 15 miles downstream of Taunsa town and 27 miles upstream of Ghazi Ghat across the River Indus (Plate No. I—General Index Plan).

2. *Location of the Barrage.*

A barrage could be constructed in the middle of the river, diverting the river during construction, through an artificial by-pass channel ; or outside the river, just adjoining, and diverting it on completion of the masonry works. As mostly done in the past in the case of head-works built in the Indus planes, and also being more economical and safe during the period of construction, the second alternative was adopted in case of Taunsa Barrage. The river at the site had three main channels, *i.e.*, the western arm called Puran Creek, the main river in the Centre and the eastern arm or Chajra Creek. Communication availability of building material, and their transport to the site of work, were the governing factors, as to the location, with respect to the two banks of the river.

The rail end and the road communication existed only on the eastern side, whereas there were no such facilities on the western side. The work was, therefore, located on the left bank adopting the eastern arm as the proposed centre line of the barrage. The site was connected by a rail link with Dera Din Panah and by a metalled road with the adjoining town of Kot Adu.

The area for the construction of the barrage, was encircled by an earthen ring bund to keep it dry throughout the construction period and the western side of the ring bund was further strengthened with five spurs to keep off the main river. (*see* Plate No. II general lay-out).

3. *Diversion Operation in the Past.*

There is no record available about the construction of weirs in the early stages across the rivers such as at Marala, Khanki etc., which could show how the engineers of the time tackled this problem with resources at their disposal. The experience of diversion of the reiver on S.V.P. and later at Trimmu may be known to many of the Irrigation engineers. The discharge in all these cases was less than 5,000 cusecs or nil during winter and the operations were successfully completed without any difficulty. The first diversion operation of a big magnitude had to be carried out on the Indus at Kalabagh with the same discharge as at Taunsa, but with different types of soil in the river bed, thus materially changing the mode of operation.

The diversion operation of the Indus at Taunsa Barrage, is an interestiug study, as never before in the history of construction of barrages and weirs in the Indo-Pakistan sub-continent, such a huge discharge was tackled in the alluvial planes. The mighty Indus with its treacherous behaviour on alluvial beds at Taunsa surrendered to the efforts of man for his benefits.

II. Investigations and Proposals for Diversion.

4. In early 1957, the progress on the construction of the Barrage indicated that the masonry works could be completed by the end of the year, and it could be possible to take up diversion operations during the winter of 1957-58. The Irrigation Research Institute arranged to carry out experiments so as to advise on correct procedure for affecting diversion operations. Proposals were also examined in the field. To sum up it was agreed that :—

(*i*) A diversion regulator may be provided to attract the supplies of the main river during its Choking up process. At Kalabagh no such regulator was provided, as the bed of river had a layer of shingle supposed to be quite safe against erosion ;

(*ii*) Leading cuts may be provided to lead supplies of the river through the barrage to a capacity of usual average winter discharge ;

(*iii*) To construct an earthen bund across the river to stop all supplies passing through the various creeks of the river ;

(*iv*) To finally choke the main river by making a stone boom across it, and extend the earthen bund across the main river to join the Right Guide Bank.

5. *Sieve analysis of soil from bed of river at Taunsa Barrage.*

No. of sieve.	Percentage retained on.
4	...
8	...
16	...
30	0·5
50	1·5
100	73
passing 100 sieve.	25

The soil on top of belas in varying depths has more percentage of clay and particles passing 100 sieve.

From the perusal of soil analysis it is evident that the structure of the soil is mostly fine sand, which is liable to be easily carried away or kept in suspension by even ordinary velocities. At Kalabagh, it was possible to tackle higher velocities without appreciably affecting the river bed, on account of gravel, but at Taunsa this could not be risked. It was necessary, therefore, to adopt means which could reduce head across to a minimum to avoid velocities that would cause erosions in the bed. A temporary regulator, therefore, was considered a necessity at Taunsa Barrage for the diversion operations, whereas, no such device was adopted at Trimmu or at Kalabagh Leading cuts to lead maximum possible discharge through the barrage were also considered essential to reduce possibilities of erosion as a result of choking.

6. The operations as suggested above were proposed to be carried out during the winter of 1957-58 which involved roughly the following major items and quantities of works in addition to the work of constructing and completing the barrage under progress :—

1.	Earthwork.	...	5,000 lacs cft.
2.	Masonry work.	...	1·5 ,, ,,
3.	Concreting.	...	2·0 ,, ,,
4.	Sheet piling.	...	181 tons.
5.	Stone dumping and pitching etc.		40 lacs cft.
7.	Pilchi work.	...	32 ,, ,,

A study of the behaviour of the river in the past indicated that only the period from November to March would be available for the collection of material and execution of all the items of the work involved.

7. Plate No. III is the hydro.graph of the 10 days minimum and maximum discharges passing Ghazi Ghat, a discharge site 27 miles downstream Taunsa Barrage. The discharges experienced during the 10 years prceding diversion operations can be summed up as :—

Month	Usual minimum discharge.	Usual maximum discharge.	Freshets or floods.
January ...	22,000	28,000	Very few freshets upto 33,000 cusecs.
February ...	20,000	25,000	Occasional freshets upto 60,000 cusecs.
March ...	23,000	26,000	Occasional freshets upto 77,000 cusecs.
April ...	35,000	50,000	Occasional freshets upto 1,15,000 cusecs.
May ...	50,000	60,000	Occasional floods upto 4,50,000 cusecs..
June ...	1,00,000	2,00,000	Occasional floods upto 4,50,000 cusecs.
July ...	2,00,000	4,00,000	Period of usual floods.
August ...	3,00,000	4,00,000	Do.
September ...	1,50,000	3,00,000	Occasional high floods.
October ...	50,000	1,00,000	Very few floods.
November ...	30,000	35,000	Very few freshets upto 2,50,000.
December ...	25,000	28,000	Freshets upto 50,000.

The months of January and February can be taken as the period having minimum supplies (20,000 cusecs) and minimum number of freshets of minimum discharge, but one must be prepared to allow occassional freshets upto 40,000 cusecs and fluctuations under normal conditions between 20,000 and 26,000 cusecs.

The months of March and December have also usually low supplies, but are liable to get freshets ranging from 50,000 to 80,000 cusecs. The months of November and April have normally low supplies, but high

discharges beyond 1,00,000 are not unexpected. The months of May, June, July, August, September and October have high discharges and are out question.

III. Construction of Leading Cuts.

8. It is evident from Plate No. III and from the discussion in Paragraph 7, that the discharge that was to be tackled at Taunsa Barrage varied between 20 to 35 thousands cusecs during the months from November to March when diversion could be attempted.

In order to divert maximum possible discharge without heading up the main river, and to affect quick development of river course towards the barrage, it was proposed to excavate leading cuts of 30,000 cusecs capacity to be able to pass about 40% discharge. An estimate showed that it would involve earthwork about 600 million cubic ft., with 70% excavation below sub-soil water level, which was beyond the means at our disposal. Consequently the leading cuts were reduced to a discharge of 12,000 cusecs on the upstream and 10,000 cusecs on the downstream, which could draw about 4 to 5 thousand cusecs or 20% of the minimum discharge. This work, too, involved 23 crores cft. of earthwork to be done in three months, *viz.*, October to December, before choking up operations of the main river could be started.

9. Efforts were made to do a part of this work during summer, within the river bunds, but no work could be done outside the river protection bund earlier than October. A good number of earthmoving machinery had been collected for the first time on this barrage, but most of the machinery had to be employed on the completion of the masonry works and the protection works during floods. Even the leading cuts within the ring bund could not be completed. The task being beyond the bounds of possibility the leading cuts were further reduced to 8,000 cusecs discharge involving 17 crores cubic feet of earth work. Excavation of Cut No. 2 was curtailed and it was connected with Cut No. 1. Similarly on the downstream side Cut No. 7 was joined with two existing creeks, instead of taking it independently upto the river. These changes were most advantageous according to the changed circumstances and means of execution. The partially silted-up eastern creek was linked with the river and helped in-adding to the capacity of the leading cuts. The leading cuts after their completion were opened on the dates :—

No. 1	...	21-2-58
No. 2	...	4-2-58
No. 3	...	24-1-58
No. 4	...	23-1-58
No. 5	...	21-2-58
No. 6	...	21-2-58
No. 7	...	24-1-58
No. 8	...	23-1-58

As advised by the Irrigation Research Institute, the cuts on No. 3 and No. 4

on the left side were to work satisfactorily, but No : 1 and No. 5 on the right side to silt up in a short time and therefore to be opened last of all. Plate No. IV—Leading Cuts—shows the proposed and actually executed leading cuts, their L and X-sections and capacity.

10. The excavation of leading cuts involved 9·12 crores cft. of dry earthwork, 7·7 crores cft. of wet and slush earthwork costing Rs. 22·96 lac.

IV. Construction of Diversion Regulator.

11. The work on the temporary regulator begun in March, 1957. After about 1½ months, trouble started at Spur No. 5. Erosion set in on the bela in front of T-head of the spur by an early freshet which cut the foreshore above Spur No. 1 and an embayment accentuated to an unsafe extent, thus endangering the diversion regulator, which was being constructed under the shade of shank of the spur in an enclosure ; formed by the shank of spur on upstream side and a ring bund on the other three sides. The situation was that if Spur No. 5 was lost, not only the work so far done on the regulator was washed away, but the ideal site selected for diversion operations was also gone.

12. The work of construction diversion regulator was kept suspended throughout the floods, machines, were withdrawn from the pit to a safe place, and the struggle to safeguard the existing works continued throughout the flood season which ended successfully. While fighting the floods, all types of machinery collected at Taunsa for diversion and other works had to be put in operation delaying the works specially in connection with diversion, such as excavation of leading cuts and completion of barrage.

13. The work on the temporary diversion regulator could be restarted on 1-10-57 and completed on 31-12-57. The work on the approach channel and the tail race was started on 15-10-57 and completed partially on 31-1-58.

Due to very little time available, the approach and tail race channels for regulator could not be completed before the opening of the regulator and their excavation on both sides, specially on downstream, continued long after the end of February, 1958.

14. The diversion regulator was originally proposed to be constructed for a discharge of 20,000 cusecs *i.e.*, considering the total discharge as 30,000 cusecs and distibuting it as 10,000 through the leading cuts and 20,000 cusecs through the temporary regulator. But as the prospects of excavating leading cuts were reduced, the capacity of the temporary regulator had to be increased. Provision for a freshet during the operations was also taken into consideration. The temporary diversion regulator, ultimately was constructed to a capacity of 30,000 cusecs as a non-modular weir and 70,000 cusecs when it worked modularly.

15. A diversion regulator would function the best, if it could be constructed with the lowest possible floor and crest so as to attract the river to it, causing the least afflux, with the minimum possible width and costs. But it would not function as desired, unless its approach channel and

tail race would also be of the same bed levels, design and capacity. With the sub-soil level ranging from 435 to 432 at the site, it was practically impossible to dig below 425 levels. The crest of the temporary regulator was, therefore, proposed at R.L. 425.0 as that of the undersluices of the barrage, with upstream and downstream approach channels of the size of 600 feet in width and about 17 feet in depth, R.L. 425 controlling the bed levels. The length of upstream channel was 450 feet and that of downstream 1,250 feet. The length of the approach channels was kept at the minimum possible so that it would create minimum head-across at the boom site and also involve minimum quantitles of earth-work to be excavated.

16. The site of the temporary regulator had been selected nearest possible to the final diversion site proposed in the main river with the shortest possible approach channel, also taking advantage of the shank of the spur to act as ring bund on the upstream of the regulator.

The diversion regulator which was designed for 30,000 cusecs, with 48 bays of 10 feet width each, was equipped with steel gates manipulated with the help of wheeled trollies, for which track was provided on the upstream end of the piers. Plate No. V and VI show site and detailed drawing of the work of temporary regulator.

17. The construction of temporary regulator with its approach channels costed Rs. 14,33,858.

V. Main Operations

18. Condition of river in November, 1957 after the flood period (Plate No. VII and VIII).

(*a*) The main river at about 8 miles upstream of the barrage, after the off-take of Puran Creek, developed a swing towards the right reducing the distance between the two creeks to about 2000′ only. Puran Creek was drawing a discharge of about 4,000 cusecs at the time.

Three other small creeks off-taking on right of the main river had practically ceased flowing.

A shoal had been formed in front of the left bank of the main river in the entire length opposite Spurs No. 1 to 5, masking entry to the leading cuts under excavation with a gap adjoining Spur No. 5 on the upstream, and keeping a deep channel between the firm edge of the river and the newly formed shoal. Part of this shoal extended beyond Spur No. 5 also, but was still drowned.

Series of shoals had also been formed splitting the main river into two channels from a distance about 3 miles upstream of Spur No. 5 and upto about a mile downstream of the Spur No. 5. The river showed further tendeney to turn to the right, making a deep channel at the foot of the right bank and adding silt to the shoals on to the left side. The action during summer on Spur No. 5 created two embayment just on upstream and down-stream of the spur.

On the downstream of the barrage, the main river shifted towards the right and a creek off-taking opposite barrage towards the left had taken the lower route of old eastern arm.

Selection of site for the Stone Boom

19. To raise a loose stone barrier or dam on alluvial foundations a definite site had to be selected, well in advance, to construct other works in relation to the site.

Spur No. 5 had stood the onslaughts of the river during 3 years in the past, and lacs of cft. of stones have been sunk to save this spur. It was, therefore, considered to be the best site for anchoring a stone boom *i.e.*, the last gap could be squeezed on to the face of this spur. The river opposite this spur had the minimum width. There was no local scour and the depths of the river was no where more than 10′. The site could be approached both by land and river.

Training the river to pass at one site

20. There was a possibility that the small creeks may develop in the 8 miles width of the river on the west when the main river was choked. It was, therefore, necessary to close the creeks off-taking on the west, upstream of the final closure site or Spur No. 5. As discussed in Paragraph 17 above, it was only the Puran Creek which was in flow at the time. The other three small creeks could easily be choked by putting earthen embankments at their head and 2nd time on the alignment of the proposed diversion bund.

Closure of Puran Creek

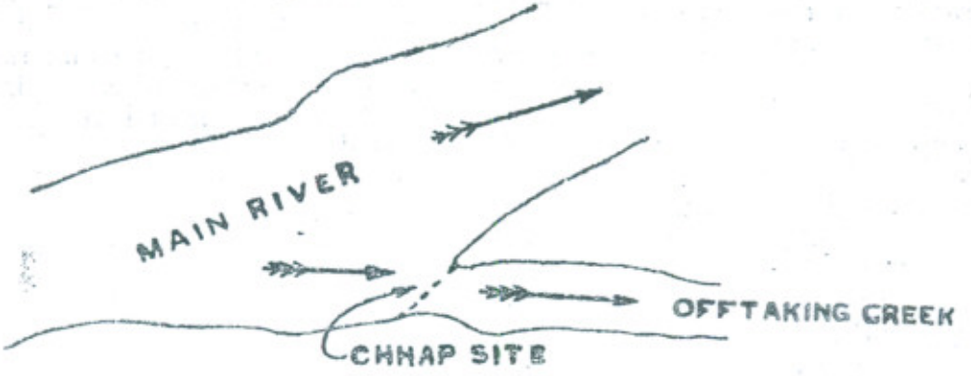
21. The swing of the main river reducing the distance between the two creeks namely the Puran Creek and the main river, about 8 miles downstream of the off-taking of Puran Creek, afforded a timely opportunity to divert this creek back on to the main river. The 2000′ wide high land in between had an old small creek also, which was converted into a creek joining the two main creeks. A pilchi chhap was put just downstream the off-take of the small creek and the entire supplies of Puran Creek of about 4,000 cusecs were diverted on to the main river. The pilchi chhap was further backed by an earthen embankment across the Puran Creek, and lower below the creek again was crossed by two banks of D.G. Khan Canal. Puran Creek was to be closed on January 22, 1958.

Closure of right arm

22. As observed in early October 1957 the discharges passing through the two arms of the river opposite spur No. 5 were 17000 cusecs in the western channel and 25000 cusecs in the eastern channel. The river at the time further showed tendency to form a deep channel along its western bank and form shoals on the eastern side.

For a final closure the eastern bank had no firm base to tie the stone boom nor quantities therefor in a length of 4,500 feet could be collected. The device of 'langar pilchi chhap' as usually adopted on the Indus for closing creeks was therefore, put into practice for closing the right channel, and to divert its supply into the left channel.

Technically, langar chhap is to be attempted if the channel to be diverted has a discharge not more than 50% of the discharge of parent channel, as in the case of higher ratios, the heading up would not permit the chhap to be laid under the conditions. The other condition that must be fulfilled is that the closure site must be as close to the main river as possible.



The time available was limited, and the work of diverting the western arm was to be completed by end of 1/53. Statement below gives material consumed on the chhaps to visualise the extent of work and labour that had to be put in.

1.	Pilchi.	32.0	lacs cft.
2.	Larmahl.	45	thousand No.
3.	Stone.	55,000	cft.
4.	Tranger.	99,00	No.
5.	E. C. bags	77,000	bags
6.	Manila rope.	12	cwt.
7.	Sall ballies.	849	Nos.
8.	Trees.	2435	Nos.
9.	Khajji trees.	2275	Nos.

Langer Chhap. (Plate No. IX).

23. In a systematic work, a few anchors with floats, made out of stone tied in trangers and wooden pieces, are launched as a first measure at a distance of about 200′ upstream of the proposed chhap, controlling the entire length of the proposed chhap in the stream line. Langers are usually made out of small trees or big branches having dense leaves as from jal trees, or berris, etc. The number of trees would be one, two, or three while branches of trees in any number can be used to make a langer of a size 20′ to 30′, in length and about 10′ dia, or of a volume that can be handled and launched by a gang of about 6 coolies from a boat.

The branches or trees are tied on the stump side by a rope locally made out of leaves of date palm trees (khajji) usually called 'larhmal' locally of about 1″ dia. The tying up must be perfect so that no branch or tree is taken away by the current of the water, but it must also be

slightly flexible so that when launching, the labour can tilt individual trees or branches to facilitate the handling of heavy loads. Where necessary the larhmal is doubled, trebled, or quadrupled according to the pressure that rope is required to stand. Usually boats with a carrying capacity of 100 to 200 maunds of weight are most suitable for the job of launching the langers. Heavier boats are not likely to be controlled in water running at a high velocity, nor workable in shallow water, nor quick in operation as compared to smaller boats. The langers (trees) and the anchors made out of about 10 cft. stone tied in munj or khajji trangers are loaded in the boat, and guided to the floats of the anchors already placed in the river. A trebled larhmal of 100 feet length is tied round the anchor at one end, and the langer of tree tied to it at other end. The anchor for the langer is launched about 80 to 100′ (according to the length of the larhmal) upstream of the proposed closure line. After launching the anchor of the langer, the boat is further rowed downstream into the channel to be closed and the trees launched on the line of closure. The lowest points on the cross-section of the line of closure are filled in, to begin with, so as to raise the langers in the same level all across. The process is repeated for many days, according to the section and discharges to be closed. The langers are placed till the branches of the trees are above water level. The premeable bar across the channel to be closed, is allowed to function for at least a fortnight to reduce the velocity of the creeping water through the chhap, choking itself, sinking, and eroding silt from its upstream and depositing the same on its downstream. Replenishment of the langers continues during the period of silting. Lastly the bundles of pilchi are tied down and added on the top of trees, that have been already launched. This compresses the trees, sinks them and reduces the water way through the permeable bar across the channel. To help squeezing, and thus stages, when the chhap is sufficiently raised above water level by about 4′, it is further weighed down by sand bags or stone. Usually discharge about 70% of the whole, may pass through the chhap when the line of trees is through. With the addition of pilchi it may be reduced down to 30 to 50% to begin with, but by weighing down and squeezing the mass nearer to imperviousness the discharge may be reduced to a negligible percentage.

The chhap cannot be relied upon for a long period nor can be perfectly water-tight. It must, therefore, be backed up by an earthen embankment. Another closure for the small discharge passing through the chhap has always to be tackled, when completing the earthen embankment at the bank. Pilchi is usually used at this stage also. In case earth-moving machinery is available, this item can be tackled eassily by such machinery as was brought in operation at Taunsa Barrage. In some cases, for the speeding up the work, the langers made out of trees are omitted and the pilchi work done from the very beginning. This is, however, only possible for original work where scoured depth is not more than 12′. In case of shallow depths pilchi chhap is also adopted directly. For repair to failures and deeper depths, the tree langers, forming the base and providing extra anchorage, are necessary.

The technique employed in pilchi chhap is described in the following paragraph.

Pilchi Chhap. (Plate No. X).

24. Normally the depths of the channels to be closed are not more tean 10′ when pilchi chhap without use of trees can be adopted. The guiding floats and anchor are placed as usual described under the langer chhap. Pilchi is usually carried to site in Rolls, 10 to 14′ in length or and 2′ to 3′ in diameter tied in Dib or Khajji larhmals. Each to gether 4 to 12 rolls as per depths and velocity to be tackled. bundle is perfectly tied with trebled khajji larhmals and before pushing it into the river it is tied to anchor of its own, which is placed about 80′ to 100′ on the upstream as in case of a tree langer. The bundle is further overlapped by two thick ropes or larhmal, and tied down to anchors, thrown in advance, in line of chhap, and two ropes from anchors of stone placed on top of completed work or at the start on N.S. at the back.

One, two or three bundles thus made are pushed, advancing the chhap from both ends of from more faces created in the middle. The gaps on upstream, downstream, in between the two main bundles, and low places on top are filled in by single rolls tied to main bundle.

This process is quicker than langer chhap, but is liable to more failures during the operation as the bundles the anchors and even some times a good length of the completed work, can be taken away by the river due to under-mining in front, or concentration of currents on one face, or underflowing as no time is allowed in this case for silting up at the back. The chhap is loaded as in case of langer on the top, with sand filled bags and stone to compress voids in between, and it may sink if there is flow under-mining it. It requires a good deal of patience to deal with this type of chhap to overcome failures, mentioned above.

Closure of right Arm Continued.

25. The work of closure by adpoting pilchi chhap process was started at Taunsa in the middle of November and carried upto point 'C' (Plate No. VII). To cut the work short, a bold attempt was made to close the right arm along XY alignment to remain in the line with C.L. Balli chhap, but it could not be accomplished. The usual alignment along the bifurcation of the two channels had to be continued.

The pilchi chhap and in deep portions langer and pilchi chhap along the entire length of 11,000′ was completed on January, 22, 1958. It created a head across at EF line of 4.5′. The next day a length of 50′ gave way, causing a deep scour in the gap, and washing off along with it the entire mass of pilchi and anchors. The gap was re-filled with three langers topped with pilchi bundles. The flow of the river which used to enter the western arm got concentrated along the bifurcation line at the toe of the pilchi chhap in a parallel line, causing failure at one or the other place. At the time pilchi from within 20 miles radious on upstream and workable distance from downstream got exhausted, no trees were available within reasonable distance whereas the demand increased on account of failures and loading to compress the chhap and to replenish it to required sections. It was time

of great anxiety and even shock the confidence of some of the officers in the use of pilchi langer chhap for diverting such big discharges, where the two bifurcating channels had the same capacity.

Ffforts to collect pilchi from far off places as Ghazi Ghat by road and boats after all succeeded and the failure in chhap fully controlled by 2-2-58 reducing the seepage through chhap to about 2500 cusecs. The process of loading and replenishing the chhap continued. A warning from Kalabagh indicated that a freshet was expected shortly. A discharge of 1,100 cusecs still flowed through the chhap, when a determined attempt was made to seal the diversion bund by earthmoving machines on February 15, 1958. The first day's efforts did not avail much. The chhap was further loaded with bags, where possible backed with earthen embankment, and the efforts at closing the gap in the diversion bund were accelerated. The hard labour on the second day was crowned with success and the right are was sealed for ever on 16-2-58. The discharge observed in the morning on that day was 835 cusecs.

The concentrated parallel flow along the chhap, specially in the upper portion, indicated that this chhap and the earthen bund at its back could be washed off at any time. A free entry of river water into the western arm from its upper reaches would create the same levels when headed up at diversion bund as of the river 4 miles upstream, which could overtop the sandy bela at the diversion bund and enter the eastern arm, thus reviving the flow of the western arm, and endangering the safety of the diversion bund. A second advanced bund at XY in line with balli chhap had been proposed, but closure at this site by chhap could not be materialised. A permeable stone boom of boulders, as available from hills along the west bank of the Indus, was continued at XY during the laying of the chhaps along EF.

As soon as the western arm was closed at the diversion bund, the gap at XY was constructed with an earthen bund and joined to balli chhap. Although the pilchi chhap never failed afterwards, the bund at XY provided a definite security against any freshet or other failures, causing the river to take its old course along the western arm. The stone used at XY was salvaged at the first opportunity, after the diversion operations were over.

Training the river from final operations.

As explained in paragraph 17, a bela had masked the entry to leading cuts. The temporary regulator as constructed on the eastern bank of the main creek could not attract supplies directly from the river, except by winding round the upstream nose of Spur No. 5 which could never occur unless the river was headed up at NP (Stone boom No. 1). A gap in the bela at GG was opened but this would not develop further, but showed tendency to silt up as the discharges in the river reduced. A balli chhap was put in at CL to effect a little heading up to induce supplies entering the gap (Plate No. XI). Leading cuts were also dug to provide more passage from west to east, but these devices alone could not guide, to the extent desired, the supplies towards the leading cuts and temporary regulator.

A langer chhap (made of trees only) starting from point S joining the point T was introduced to obstruct supplies in the main river and guide them to the leading cuts and temporary regulator. The two chhaps, balli -

chhap across the river causing a little heading up, and langer chhap guiding the flow, pushed more supplies into the creek leading to temporary regulator and reduced supplies in the main river.

The bela had its projections passing through the proposed stone boom, also closing a passage of the main river on to the temporary regulator. This projection of bela also interfered passage of boats from the eastern ghats carrying stone to stone boom.

A spur at Point HH in an alignment H. J. was laid. This spur totally changed the conditions and at latter stages the deflected river at this spur was guided to rush straight on to the leading cut No. 1 and the temporary regulator.

As pilchi and trees had become scarce, date palm trees, which were available free of cost within the point area to be drowned for ever, were used in constructing this spur which afterwards got its name as Khajji spur (Plate No. XII). A date palm tree having its cluster of leaves at the end and a stump about 30′ in length was further made into a compact mass of 10′ dia, with kahi and pilchi in about 15′ length top side. The stump end was tied with a trebled larhmal and an ancher as in case of other langers. The trees when placed in position, one on the other made a regular wall with only 10 to 20% leakage. The barrier thus made proved strong enough to take concentrated parallel flow. The deflection caused deep scour at the nose of the spur, at one time measuring 30′ in depth, but the progress on the spur, was never blocked, although slowed down sometimes to fill in the deep scours. The portion completed had the silt deposited at its back raised in some cases about the water level.

Stone boom (Alignment).

26. On February 1, 1958 the work of making a stone weir across the main river was started on schedule. The stone boom was proposed to join the diversion bund on the west and spur No. 5 on the east. For successful operation it is essential that the weir must be at right angles to the stream currents. The stone boom therefore, was aligned in a curvature as detailed in plate No. XIII.

Anchors for Boats

27. Ten anchors made out of 4 munj trangers having about 50 cft., stone, were launched at about 500′ upstream of the proposed site. To each of these anchors a float of wooden sleeper was tied. The loaded boats were first to reach these floats before being guided for dumping on the stone boom. These floats were placed out of the danger zone. Every boat was measured or checked as to its contents at these waiting harbours.

A line of anchors 50′ apart normally and 30′ apart in main stream was launched 300′ upstream of the boom. These anchors were made out of steel trangers (crates made out of G.I. wire No. 8) 6 to 8 in number tied together with steel rope (old ropes of 1″ dia), each anchor having 200 cft. stone. With the steel rope of each another were tied 2 manila ropes of 30′ length and $1\frac{1}{2}$″ dia each. The two ropes were further tied together for about 20′ and the one free end, tied to a float of full sleeper. The other end had a ($1\frac{1}{2}$″ dia. or $1\frac{1}{4}$ dia.) rope tied to it, of 300′ length. The rope was put on top of float when not in use. The boat intending to dump stone on the boom was to take up the float and with the help of this float,

and the rope, would move down slowly to the boom. In strong currents a boat would take ropes from two anchors. This would hold also in side movements. The line of floats 300′ upstream of the boom also indicated the danger line, as small boats, plying within 200′ of the boom would be sucked by strong velocities and would be destroyed.

Collection of Stone Along Ghats. (Plate No. XIV).

23. (*i*) To feed the boats 40,000 cft., of stone on average daily ;

(*ii*) To collect about 15 lacs cft., stone in advance at the loading ghats, and

(*iii*) To accommodate about 100 boats at a time for loading ;

A good length of loading ghat, where boats could have at least 2½′ depth of water, was required. This was managed by collecting about 5 lacs cft. of stone along the eastern side of the bela bifurcating the two streams of the main river in a length of about 1 mile on upstream or along right bank of diversion boom. On the left the ghat had to be extended in a length of 2 miles from Spur No. 5 to 4, across the leading Cut No. 1. Stone from Spur No. 4, 3, 2 was also salvaged and Spurs No. 4 and 3 were utilized as loading ghats. During the months of November, December and January, the boats that could be spared from work on pilchi chhap, were employed for carrying the stone from east to west, making a reserve of 5 lacs on the right bank. A team of dump trucks, lorry trucks and camels continued to carry stone from railway yards, that scattered in barrage area, Spurs No. 2 and 3 and hills on the right throughout the months of Nov.1957 to July, 1958. The boulders from hills on the right bank of the Indus, proved of no use in the construction of the stone boom, for when dumped they rolled down to unknown places downstream. Even when placed in trangers, with 10 to 20 cft. stone, or a heavy stone weighing about 200 lbs., they would not stand against high velocities. The angular stone from Sikhanwala, dumped loose or tied in trangers, proved a success.

Section of Boom (Plate No. XIII).

29. A matting 3′ to 6′ in thickness and 40′ in width was laid throughout 1,400 feet across the river and a crest with natural slopes raised on the upstream and ultimately making the width of the boom 90′ at the bottom. The matting was made by dumping Sikhanwala stone in trangers and loose stone alternately. The crest above matting level was entirely made out of stone dumped in trangers of the capacity of 10 to 20 cft. The top of the crest was made in steel trangers of 20 to 30 cft., capacity, laid in situe. A depth of water 4 to 6 feet on the matting was always maintained as discussed in the next para before starting the crest portion.

Width of the River for final closure.

30. A free fall having a depth of 4′ will create a velocity of 6′ and a discharge per foot run of 25 causecs. An anuglar stone will not be taken away by water with velocity upto 6′ but will not stand a velocity higher than 8′.

The alluvial soil in the river would not stand velocities more than 3 feet, normally 2·5 feet if no erosion was to be caused. Normally labour

can work in depths upto 6′ without special devices and aid. Below are reproduced the discharges passing through the various channels on 6-2-58.

Cut No. 4	... 1005		
Cut No. 3	... 1908		
East Creek or Cut No. 2	... 548		7915
Cut No. 1	... —	not opened	
Temporary Regulator	... 4451		
Main river or eastern arm	... 14474		16987
Western arm	... 2513		
			24902

The distribution at the time was that about 30% discharge was being passed through the regulator and the leading cuts and 70% through the main river.

Taking 30,000 causecs including small freshets, the discharge that was to be tackled at the stone boom, was estimated about 20,000 cusecs. Considering the above facts, a width for final closure or stone boom was proposed ;

(*i*) To safeguard against erosion in bed for laying

$$\text{apron} = \frac{20000 \text{ Cusecs.}}{6' \text{ depth} \times 2{\cdot}5' \text{ velocity}} = 1333'$$

Say 1400′ to account for inequalities.

(*ii*) To safeguard against washing off stone.

$$\frac{20000}{3\sqrt{4}} \text{ the velocity} \times 4' \text{ depth} = 833'$$

The eastern arm had a width of 1700′ opposite Spur No. 5 out of which a 150′ strip on the west side was closed down by advancing the earthen diversion bund. At one time it was proposed to dump it mechanically with the help of trucks. This was started from the right end and progress was made to the extent of 100′ after about a week it was found that a deep scour of 15′ had been caused at the nose of the diversion bund. The width of the river for final closure and lay-out of the stone boom, therefore, was fixed as 1400′ and maintained till completion of the matting. The rainsing of the crest was divided into two portions and that of the 800′ width adjoining Spur No. 5 treated as one gap for final closure and raised day by day all along to the same levels till completion.

Dumping stone on boom

31. On February 1, 1958 the dumping of stone on the boom was started. The area along the boom was marked by fixing 'ballies' deep in

bed along the centre line, marked 40′ downstream and 50′ upstream. Two ballies in line thereof were also fixed outside the river bed on each bank as a guide to refix the ballies in the river bed, which were liable to be dislocated. R. L. of water level on gauges upstream, centre line and downstream of the boom was noted every day and soundings observed at every 50′. This was repeated every day in the afternoon in order to facilitate planning for the next day's dumping. To begin with, dumping in the entire width of 90′ was done to fill in local cavities.

Having levelled the bed, the dumping of stone was restricted in a width to 40′ on the downstream to form an apron of 3′ to 6′ depth. This matting all over in 1400′ X 40′ was raised equally. Plate No. XV shows cross section of the river before dumping of stone was started on 30-1-58 and on 12-2-58 when quantity of about 3 lacs cft. stone had been dumped. By February 15, 1958 about 5 lacs cft., of stone was dumped and the matting of 40 feet width and 3 feet minimum depth was in. The work of raising the crest and dumping under the crest portion in the entire length of 1,400 feet continued during the second fortnight of February 1958 and the crest was above water level in the entire length by February 28, 1958. A quantity of 12½ lacs cft., was dumped in 28 days.

32. During the dumping process on the stone boom occasionally some difficulties were faced and solved as discussed in the following paragraph :—

(*i*) On certain stormy days the boats could not work. The time available being the main factor, the loss in progress could not be afforded. The main trouble was that the boats would go astray as soon as they were put to the open river or would not move towards the direction required if the wind was against these. On such occasions ropes all along the route were stretched and the boats were led to the anchors. The progress on the day was reduced to 50%. However, it was possible to dump about 25,000 to 30,000 cft., of stone even on such a day.

(*ii*) The bela masking the entry of the leading cuts had a tendency to project right into the stone boom blocking the way from the eastern bank on to the main boom. To overcome this difficulty an artificial leading channel by *Manual Digging* had to be cut through bela and kept cleaned by pumping and dredging operations. Two double force pumping sets and an air compressor was mounted on two boats and worked continuously keeping open the passage of the boats during the last operations.

(*iii*) During the last stages when the river showed a tendency to be diverted to the regulator, the passage to the boom got blocked by sand shoals and individual loaded boats had to be led by a clearing boat working in advance.

(*iv*) When a slight heading-up was caused at the boom, the passage just on the upstream of the nose of Spur No. 5 was found chocked up as explained in the preceding para. The khajji spur, as detailed in Paragraph 17, helped on this occasion and its prolongation resulted in a quick scour of the bela, deflecting the river straight to the eastern side of Spur No. 5.

(*v*) Large boats could not carry the stone to the required place for dumping on crest in steel crates. So small boats were employed to carry stone to the required point and good swimmers were employed to lay the crest in steel crates. The manual labour had to work in water 3 to 4 feet deep and in velocities 5 to 6 feet.

(*iv*) Loaded boats when taken upstream round the bela were unmanageable. A gang of 15 to 20 labourers had to be employed to pull the boats upstream.

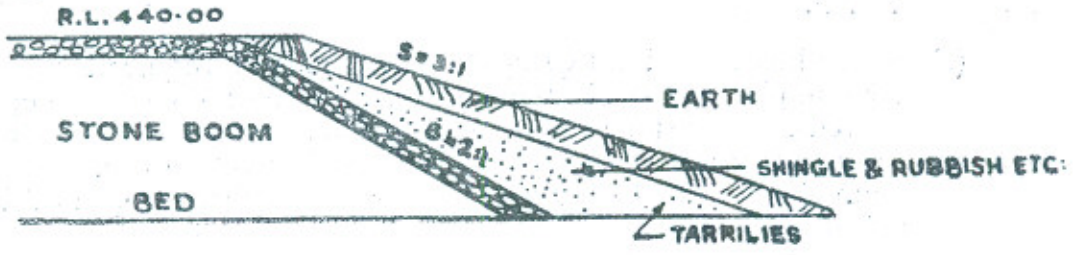
33. The work of dumping stone on the boom was mainly done with boats. Boats with a carrying capacity of 200 cft., to 600 cft., were employed. About one hundred of them were working daily. There was no wreckage but damages were frequent which were mended daily. Out of 166 boats collected for the purpose, about 100 could work at the most. Some daring boatmen would even do two trips a day. In addition to the boats, a large dragline machine was employed on the left flank to dump stone. It could control a length of about 100 feet which was also kept as a sluice valve to the last. A loud-speaker was installed on the left flank. With the help of binoculars and loud-speakers the diversion operations were controlled and directed in the entire area from a central point on the left flank. Three Sub-Divisional Officers and a dozen Overseers, with boats at their disposal, worked on the river directing and supervising the dumping of stone by each boat.

Appendix I indicates, in a nut-shell, the day to day progress and the discharges through the cuts, the regulator, the main river and the creeks from February to April.

Sealing the Stone Boom.

34. Having strengthened and raised the boom by 3′ above the existing water level on the upstream during the first week of March, 1958, the boom was further choked by dumping spawl, rubbish, ballast and

shingle in front, with the first layer of coarser material covered by a second layer of finer material.



A good use for this proposal was made of the rubbish removed from mixers and concreting areas, where unloading of shingle had been done, but could not be cleared, and of brick ballast. This reduced the leakage through the stone boom from 2685 cusecs on 1-3-58 to 1200 cusecs on 4-3-58, paulins made out of gunny bags sewn to size 20′×20′ and 20′×30′, soaked in and surface treated with bitumen were launched on the front slope. On the right earth through machinery and on the left earth through boats and donkeys was dumped in front of the paulins to further reduce the leakages. During the period the stone boom was being constructed, the earthen diversion bund was also being extended into the river at the back of the stone boom. On 1-3-58 a gap of 60′ remained. Applying the earthmoving machinery day and night, the gap was finally closed on 4-3-58 thereby completing one phase of the diversion.

Situation Reviewed.

35. At the time of the final closure of the river the heading up caused at the boom was 0·5 and the drop in downstream water level 0·8 *i.e.*, 1·3′ in all the head created across. This was a very satisfactory arrangement and did cause no extraordinary erosion during the stone dumping operations. The short lengths of the approach channel and the tail race of temporary diversion regulator and the location of the temporary regulator very close to the stone boom helped to keep within safe limits the head across at the stone boom.

In spite of the fact that the main river had been closed, the leading cuts took only 23% of the total discharge. The development of the leading cuts was very discouraging.

Closing of Temporary Regulator.

36. The temporary regulator had been provided with steel gates (originally of works on Muzaffargarh Canal to be used during diversion on this regulator) to be worked, with moving trollies installed on a B. G. track

on top of piers. The trollies could only raise the gates or do slight adjustment but could not lower them nor hold them at certain position. The road bridge on the temporary regulator had been made strong enough to pass heavy machinery over it. One small P & H machine and one Hyster way machine fixed to a D-8 tractor were employed to work as cranes. The gates were selected and arranged over P & H machine, were lifted with Hyster machine, moved to the bay and placed in. On actually starting the operation it was found that the steel gates did not work in the grooves of the bays, but had got jammed. The grooves had to be chiselled and widened. The gates were also shorter in height and would close a bay totally not allowing any regulation. The chiselling and widening of the grooves would take long time. Gates made out of wooden sleepers to proper width and tied together in 4 Nos. each or about 3½′ height were got locally made. This also provided for the closure of the bays equally and by stages. The work on closing the regulator started on 4-3-58. All the bays were closed by obstructing 3½′ water way. Meanwhile, the work of correcting the grooves continued. A second set of horizontal logs was again inserted gradually, choking the water-way by about 5′.

On March 1, 1958, out of a total discharge of 17,038 cusecs only 4,149 cusecs, were passing through cuts, *i.e.*, 23%. On 7-3-58 the discharge passing through the regulator was 15,285 cusecs out of the total of 19,885 or 77% and through the cuts 4,600 cusecs or 23%. The discharge in the river was on the increase and the regulator was being choked, but the cuts showed no sign of development but only a tendency to silt up.

The depth on the crest by now had exceeded 10′. The lowering of the steel gates gradually started, keeping an aperture in the middle or the top wherever possible between 1·5 and 2′. This controlled the intensity of the flow only to 20 cusecs per foot run on the upstream, with downstream floors having a depth of 15′ as minimum. In some cases the wooden logs placed under-neath would not allow the lowering of the steel gates at all. Horizontal karries made out of B. G. rail were introduced to control such conditions.

From March 8, 1958, onward the choking of the regulator had its effect noticed. The levels on upstream gradually started rising and those downstream started lowering. Appendix I indicates the effects of choking the Regulator.

37. On the morning of March 15, 1958 all the gates had been choked with the exception of the aperture left for final closing and the final closure started. About 2/3rd of the gates had been finally closed when in the afternoon the temporary regulator collapsed.

There had been no indication of the mishap until it actually took place. Just before the happening, the work was going on as usual, and a good number of dump trucks and other earthmoving machinery passed over the bridges of the regulator. Then three bays in the centre started sinking all of a sudden and in about 15 minutes there was a gap. Adjoining piers could be noticed falling in, one by one. It appeared that the gap in the middle had deepened itself lower than the foundation R. L. of

the temporary regulator and was being further deepened and widened to pass all the water collected on the upstream of headed up water. The discharge passing through the gullet would be about 1 lac cusecs at the time. The deepest R. L. as could be ascertained on 16-3-58 opposite bay 25 was 396, against the lowest foundation R. L. of 403·0 of the downstream of the temporary regulator (Plate No. XVI Section of Temporary Regulator on 16-3-58).

38. All labour done so far had been lost as the mighty Indus found and broke the weakest link in the chain to bind it. The river was rising and the warning from Kalabagh indicated that a discharge of 50,000 or so was expected. The season of low supplies in the river had passed. The task looked hopeless.

The mishap at the last hour was no doubt a shock beyond description, but help from God was soon to come and it came in abundance. The morale of the staff and the labour after their recovery from the first effect of the shock, was even higher than before.

The tomporary regulator was designed to withstand a head across of 7·0′ and further strengthened to 9·0′. The intensity of the flow never exceeded 80 cusecs per foot run and at the time of the failure it was only 20′ and the head across slightly above 6′. Sinking of the remaining pier was again noticed, when the breach in the regulator was restored and the conditions of March 15, 1958 recreated.

Out of 48 bays 13 bays were totally washed away and the four adjoining ones rendered useless having partially fallen in. The capacity of the regulator had been rendered to about 50%.

39. All out efforts were made to fight the river. Some of the boats had been disbanded as there was no work for these to do. The remaining were put to work day and night, and also those which could be recalled. The staff of all the earthmoving machines and the dump trucks that had worked on the diversion so far, felt the loss as their own and were determined to repair it. With a definite and a detailed plan, the work was re-started on the morning of March 16, 1958. To begin with, the boats were to close up the breach in the regulator in a ring bund on the upstream. The remaining choked bays were cleared to reduce the pressure in the middle. The manual labour also helped in dumping stone on the breach and making the sides of the ring. The workers had to pass over shattered bridge and sinking piers of the regulator.

On March 20, 1958, the ring bund could be noticed in the entire length of the breach. The heading-up effects could be noticed by March 24, 1959. A weak ring bund was above the water level in the breach in about 10 days, but would sink now and again to fill in the deep scour on the downstream. As soon as the ring bund was above water level, the gradual choking of the other bays was also taken up. The safeguard against uplift pressure, the downstream floor of the remaining bays was further weighed down. Rafts on the downstream were made to stand, to communicate with the banks, and stone in trangers and loose dumped.

Some stone was also dumped from the bridge. The gates were reinserted and the bays on the downstream and the piers alround coverd with stone. (Plate No. XVII shows stages of stone dumping on temporary regulator on different dates.)

The process continued upto March 30, 1958. The discharges and gauges on that date were :—

Gauges.		Discharges.	
Regulator Upstream	439·56	Discharge passing through regulator.	6,677
Regulator Downstream	433·10	Through cuts.	19,524
Head across	6·46	Total	26,201 cusecs.

The situation so far had been controlled by the gradual raising of the crest all over, but the deep cavity in the middle would adjust its slopes now and again, and pull down the stone ring bund sometimes endangering its very existence. The machinery at this stage, specially the dump trucks came to the rescue. The work of dumping by dump trucks from the left and first end later from both the ends was started in day and night shifts. By working day and night, a solid stone bund right from one end to the other was put in the dump trucks. The discharge passing through the regulator was reduced to 562 cusecs against 48333 cusecs in all on April 7, 1958 which further reduced to 331 cusecs on the next day. By April 9, 1958 the earthen bund on the downstream of the regulator was also complete. The discharge passing througd the barrage on the day 49,086 cusecs and the head across at the Regulator $\frac{442 \cdot 10}{430 \cdot 8}$: 11·3′. It was a closure of about 50,000 cusecs.

40. The leading cuts did not develop at all to the end and it was only the heading-up which pushed the works through them. The floor of the regulator, further weighed by loose stone, could stand the head across of 11·3′ and proved a help at this stage. No alluvial soil could stand the unexpected head across.

Below are compared the quantities of stone and spawl etc., consumed on the two closures (*i*) of main river and (*ii*) of temporary regulator and the time involved in both.

	Stone and Spawl consumed	Period involved	Discharge at closure
Main river ...	16, 16, 617 cft.	1/2 to 28/2=28 days	17,279
Temporary Regulators	20, 68, 619 cft.	16·3 — 9·4=25 days	49,086

41. A copy of the estimate as Appendix II is enclosed indicating the work executed at different stages and the costs.

42. The closing of the regulator did not end the diversion operations. The day and night work had still to be continued. The snow melting season was on. The development of leading cuts was not proportional to the increase in discharge of the river. The diversion bund could not be raised beyond R. L. 448 in all its length. The levels were safe for low supplies upto one lac of discharge, but for higher discharges more earthwork had to be put in. The struggle continued right upto the end of August, 1958. On July 21, 1958, the peak discharge of 7,60,784 cusecs passed the newly opened Barrage. The bunds could be raised upto 454 levels by that time but with only 25′ top width. The changed course of the river caused parallel flow in reaches along the newly made diversion bund. Round the clock dumping of stone at vulnerable points continued. The ponded up supplies formed a ten miles by 12 miles lake on the upstream. A heavy storm on this night of July 8 and the following morning proved more dangerous than the higher discharges and the banks were washed away, reducing the standing width to nil in some portions. The damage had to be repaired without any loss of time and the bunds protected against waves even as a temporary measure at very high costs. There was, however, no further damage or trouble until the end of the flood season 1958. The mighty river was harnessed to the benefit of mankind.

With faith in God, our hard and sustained labour did bear fruit.

APPENDIX I

Gauges, discharges and progress on dumping of stone on

Date	Gauges Stone Boom		Gauges Temporary Regulator		Discharge passing through Barrage				
	U/S	D/S	U/S	D/S	Cut No. 4	Cut No. 3	Cut No. 2	Cut No. 1	Total
1	2	3	4	5	6	7	8	9	10
1-2-58		435·5	435·5	435·42	1152	1952	267		3371
2-2-58		35·5	35·5	35·42	1146	1967	316		3429
3-2-58		35·6	35·62	35·53	1187	2102	350		3639
4-2-58		35·6	35·55	35·42	1153	1951	702		3806
5-2-58		35·4	35·4	35·27	1019	1928	645		3591
6-2-58	435·3	35·2	35·31	35·13	1005	1988	548		3461
7-2-58	35·3	35·2	35·32	35·30	987	1927	529		3443
8-2-58	35·29	35·20	35·28	35·25	934	2921	458		3318
9-2-58	35·31	35·21	35·30	35·28	1067	1980	425		3412
10-2-58	35·32	35·20	35·31	35·29	976	1057	466		3499
11-2-58	35·42	35·30	35·32	35.30	1046	2100	516		3662
12-2-58	35·38	35·26	35·38	35·36	1127	1925	442		3494
13-2-58	35·33	35·20	35·31	35·29	1083	1902	412		3397
14-2-58	35·33	35·20	35.30	35·28	1066	1955	403		3424
15-2-58	35·24	35·10	35·17	35·14	1174	1766	411		3351
16-2-58	35·23	35·08	35·14	35·11	1095	1710	401		3206
17-2-58	34·98	34·80	35·0	34·97	1052	1657	396		3105
18-2-58	35·0	34·80	34·98	34·95	952	1625	388		2965
19-2-58	34·98	34·72	34·90	34·87	1037	1777	397		3211
20-2-58	35·0	34·65	34·81	34·78	961	1889	454		3295
21-2-58	35·24	35·10	35·17	35·14	226	1805	443	648	3174
22-2-58	35·09	34·63	34·80	34·74	902	1696	399	925	3922
23-2-58	35·15	34·63	34·74	34·69	913	1676	375	994	3958
24-2-58	35·16	34·55	34·67	34·63	1001	1721	388	1128	11223
25-2-58	35·14	34·40	34·64	34·60	1057	1869	358	1184	4436
26-2-58	35·15	34·39	34·68	34·63	not observed				
27-2-58	35·20	34·22	34·69	34·64	1056	1827	366	1132	4381
28-2-58	35·26	34·02	34·66	34·60	918	1962	342	1094	4310

Stone Boom and failed Temporary Regulator.

Discharge passing through River			Temporary Regulator	Total 10+13+14	Stone dumped by boats and labour	Stone dumped by machinery or Dump Trucks
Western creek	Eastern creek or main river	Total				
11	12	13	14	15	16	17
			Stone boom main river			
3064	17328	23763	3571	27364	6000	
3059	17353	23841	3667	27508	12000	
2955	18895	25489	4036	29575	20000	
3376	17612	24794	4154	28678	20000	
1943	16833	23368	3907	27375	25000	
2513	14474	16987	4454	24902	35000	6500
2479	13533	16002	7441	21196	20000	8500
2206	13932	16138	4592	24043	37000	5400
1648	14740	16388	5066	24860	42000	5500
1624	15283	16907	5618	26024	48000	10000
1563	16242	17805	6028	27495	50000	10000
1338	15333	16671	5813	25978	50000	
1226	14778	16004	5630	35031	42000	
1167	13777	14944	5701	24069	35000	
1113	12905	14018	5873	23242	45000	
835	12608	13443	6063	22662	50000	2500
closed.	12133	12133	5802	21040	50000	4700
	11325	11325	5927	20217	50000	1000
	10485	10485	6381	20077	50000	
	11722	11722	6113	21130	47000	
	11444	11444	6623	21886	50000	
	9911	9911	6129	19962	60000	
	9712	9712	6397	20067	64000	9000
	8339	8339	6985	19562	65000	11000
	6135	6135	8338	18959	67000	13000
			8779		heavy	12000
					wind storm.	
	5094	5094	8450	17925	50000	8000
	2924	2924	10039	17279	87000	13000

APPENDIX I

Gauges, discharges and progress on dumping on stone on

Date	Gauges Stone boom		Gauges Temporary Regulator		Discharge passing through				
	U/s	D/s	U/s	D/s	Cut No. 4	Cut No. 3	Cut No. 2	Cut No. 1	Total
1	2	3	4	5	6	7	8	9	10
1-3-58	435·10	434·10	434·56	434·50	933	1842	364	1010	4149
2-3-58	35·01	34·25	34·42	34·36	919	2117	378	1284	4698
3-3-58	35·08	34·25	34·34	34·28	983	2130	401	1061	4575
4-3-58	35·05	34 20	34·28	34·23	1044	1844	408	914	4210
5-3-58	35·12	35·12	34·35	35·27	1000	2036	374	1000	...
6-3-58	35·65	35·14	34·38	34·30	not observed				
7-3-58	35·14	35·14	34·38	34·30	987	2053	375	1185	4600
8-3-58	35·65	34·60	35·0	34·70	1166	2058	471	1161	4856
9-3-58	35·92	34·60	35·25	35·8	1244	2269	505	1261	5280
10-3-58	36·30	35·05	35·75	34·75	1296	2400	783	1427	5996
11-3-58	36·50	34·55	36·0	34-60	1803	2744	909	1685	7141
12-3-58	36·90	34·09	36·35	34 20	1875	2906	1109	1940	7830
13-3-58	38·16	33·01	38·02	33 10	2182	3675	1737	3128	10722
14-3-58	38·6	32 9	31·5	33·0	3628	4576	3123	4768	16095
15-3-58	38·1	32 9	39 0	33 0	3671	4420	4220	6013	18314
16-3-58	36·5	35·5	36·0	35 5	1736	2827	1041	2214	7818
17-3-58	36 70	35·70	36·20	35 70	2149	3532	1272	2752	9705
18-3-58	37·05	37·0	35·65	36·10	2208	3538	1685	2962	10393
19-3-58	37·08	36·05	36·65	36 05	2506	3669	1629	1756	10560
20-3-58	37·05	36·0	36 60	36 0	2009	3160	1499	2396	9064
21-3-58	37·0	35·8	36·60	35·85	2027	2618	1687	2343	8675
22-3-58	36·80	35·75	36·58	35 8	1984	3391	1713	2391	9479
23-3-58	36·82	35·5	36 56	36·25	1912	3293	1677	2683	9562
24-3-58	37·1	35·52	36 82	35 20	1810	3095	1582	2587	9074
25.3-58	37·20	36·95	37·08	35·0	1840	3080	1585	3206	9712
26-3-58	37 65	35·15	37·52	34·90	1852	3100	1631	3681	10264
27-3-58	38·02	34 95	37·9	34 8	1900	3150	1755	4189	10992
28-3-58	38·65	34·72	38·1	34·5	2445	3532	2010	4307	12294
29-3-58	38·05	34·30	38·48	34·10	2593	3628	2366	4914	13501
30-3-58	38·96	33·92	39·0	33·8	3094	3894	3086	6095	16169
31-3-58	39·6	33·05	39·56	33·10	3893	4682	3629	7220	19524

Stone boom and failed Temporary Regulator.

Discharge passing through river.			Temporary Regulator.	Total 10+13+14	Stone dumped by boats and labour.	Stone dumped by machinery or Dump trucks
Eastern creek	Western creek or main river	Total				
11	12	13	14	15	16	17
	2685	2685	10204	17038	105000	11000
	2628	2628	10592	17918	35000	
	2285	2285	11103	17963	55000	
			14340	18550	90000	
			15227	19637	40000	
					Stone boom No. 1 complete	
			11285	19885		
			17100	21956		
			19110	24390		
			17374	23370		
			14242	21384		
			11932	19762		
			11156	21878		
			9257	25352	Ty. Regulator	
			6380	24694		
			22204	30082	15000	
			34317	44027	40000	
			37154	47447	54600	
			37732	48292	60000	
			33111	42175	91000	
			29515	38190	83000	
			24273	33752	81500	
			21484	31046		
			20335	29409	94000	
			19040	28752	106000	
			18151	28715	86000	
			17404	28396	91000	
			14270	26560	78000	8000
			12911	26412	87000	8000
			10193	26362	91000	21000
			6677	26201	138000	12000

APPENDIX I

Gauges, discharges and progress on dumping on stone on

Date	Gauges Stone boom		Gauges Temporary Regulator		Discharge passing through Barrage				
	U/s	D/s	U/s	D/s	Cut No. 4	Cut No. 3	Cut No. 2	Cnt No. 1	Total
1	2	3	4	5	6	7	8	9	10
1-4-58	440·5	432·60	440·5	432·40	4291	5815	4070	8460	22636
2-4-58	40·97	33·08	41·51	32·0	4442	6020	5010	9635	25107
3-4-58	42·65	32·0	42 55	32·04	8865	12981	13286	15605	50707
4-4-58	42·6	32·0	42·60	31·90	9960	13071	13645	15960	51636
5-4-58	42·23	31·54	42·15	31·52	8250	12200	12330	14760	47540
6-4-58			42·11	30·70	6875	16593	11054	13263	42785
7-4-58			42·40	30 82	7760	12530	12724	17890	47771
8-4-58			42·83	31·10	not observed.				
9-4-58			42·10	30·8	7670	12213	12223	16667	48783
10-4-58			40·0	30·65	6913	11410	11394	17387	44807
11-4-58			41·80	31·31	6205	10580	10531	13571	40787
12-4-58			41·91	32·74	not observed				
13-4-58					8895	13052	15997	17270	55314
14-4-58			42·65	35 05	9214	13143	17137	10772	60266
15-4-58			42·12	35·85	not observed.				
16-4-58			41·65	36·28	7525	11890	11665	17442	48522
17-4-58			41·4	36·56	7014	10511	12479	15715	45710
18-4-58			41·5	36·85	7375	10818	12472	16169	46834
19-4-58			41·44	37·11	7525	10988	12137	15333	46983
20-4-58			41·60	37 32	8200	11820	12630	17702	50352
21-4-58			41·70	37·70	not observed.				
22-4-58			42·15	38·3	9720	12954	14320	19365	56359
23-4:58			42·15	38 81	9980	13160	14740	19696	57576
24-4-58			42·08	39 20	9760	2980	14370	19470	56520
25-4-58			43 20	39·90	not observed.				
26-4-58			43·55	41·01	14725	15153	22669	29658	82205
27-4-58			43·18	40 10	14121	14655	21897	27832	78505
28-4-58			42·90	40·20	12504	13415	21222	25093	72734
29-4-58			43·50	40·25	12165	13508	23729	34597	83799
30-4-58			44·20	40·43					103152

contd.

Stone boom and failed Temporary Regulator.

Discharge passing through river.			Temporary Regulator	Total 10+13+14	Stone dumped by boats and labour	Stone dumped by machinery or Dump trucks
Eastern creek	Western creek or main river	Total				
11	12	13	14	15	16	17
			4390	27026	86000	48000
			3208	28315	88000	35000
			4794	55501	113000	33000
			7013	56649	69000	
			3754	51294	19500	
			1644	44329	13500	2000
			652	48333		
			331			
			303	49086		
			closed	44807		
				40787		
				55314		
				60266		
				48522		
				45719		
				46834		
				46983		
				50352		
				56359		
				57576		
				56520		
				82205		
				78505		
				72734		
				83799		
				103153		

APPENDIX II

ESTIMATE FOR MAKING LEADING-CUTS FOR DIVERSION OF RIVER INDUS

THROUGH TAUNSA BARRAGE

General Abstract of Cost

Earthwork

			Rs.
1.	60015683 cft. earthwork done by donkeys and manual labour	...	8,74,476
	(*a*) 90909946 Cft. earthwork done by machines	...	8,37,279
2.	Jungle clearance and making boundary road	...	2,458
3.	Pumping on leading Cut No 2	...	3,517
4.	Petty items of material issued	...	944
5.	1718674/- add contingency at 3% item 1-4 above	...	51,560
6.	Workcharge establishment as per actual	...	13,992
7.	Bonus, as per detail attached	...	1,04,141
	Total	...	18,88,267

DETAIL OF WORKS

1. Work done by donkey labour.

				Rs.
10630370	Cft.	Cut No. 1 U/S	..	1,27,397
3187065	Cft.	Cut No. 2 U/S	...	41,410
3114801	Cft.	Cut No. 3 U/S	...	40,280
4203037	Cft.	Cut No. 4 U/S	...	60,350
3591044	Cft.	Cut No. 5 D/S	...	55,692
1782576	Cft.	Cut No. 6 D/S	...	26,945
12856692	Cft.	Cut No. 7 D/S	...	1,81,230
2323222	Cft.	Cut No. 8 D/S	...	36,305
259922 plus 521948 =781870	Cft.	Small Cuts in bela opposite spur No. 4 downstream Small Cuts joining tail and Nos. 5 and 8 to main river.	...	14,954
17545006	Cft.	Eastern arm creek (Cut Nos. 2-A and 2-B)	...	2,85,289

Muster Roll	Running drain in bela and washes out choking in mouth of cuts	...	1,362
1-2-58 to 28-2-58 as per muster rolls	-do-	...	228
	Total	...	8,74,476

1-A. Work done by Machines.

		Rs.
(*a*) 6095	Working hours of Osgood @ 18/5/8 per hour ...	1,11,869
(*b*) 5012	Working hours of 7-W @ 30/15/3 per hour ...	2,55,377
(*c*) 10973	Working hours of P & H @ 23/4/6 per hour	2,55,465
(*d*) 922	Working hours of P & H Small @ 7/3/3 per hour ...	6,641
(*e*) 16795	Working hours dozers and scrapers @ 12/3/0 per hour ...	2,04,689
(*f*)	Rs. 2935 Running Dredger ...	2,935
(*g*)	Rs. 616 carriage of consumable store ...	616
	Total ...	8,37,279

2.	Thick jungle clearance and boundary road	...	2,458
3.	Constructing Sub-Station for pumping in leading cuts	...	3,517
4.	Petty items of material issued	...	944
5.	Workcharge establishment	...	13,892
6.	Bonus paid as per details attached	...	1,04,141

DETAILED CALCULATIONS OF BONUS

		Rs.
1.	46,09,111 cft. earthwork amounting to Rs. 95,978 Bonus @ 12·26% ...	11,767
2.	74,60,799 cft earth work amounting to Rs. 88,223 bonus @ 9·426% ...	8,316
3.	1,16,12,216 cft. earthwork amounting to Rs. 1,70,408 bonus @ 15% ...	25,561
4.	2,67,89,210 cft. earthwork amounting to Rs. 3,97,493 @ 15 (bonus) ...	57,782
5.	3,04,730 cft. earthwork amounting to Rs. 4,767 bonus @ 15% ...	715
	Total ...	1,04,141

ESTIMATE OF CONSTRUCTING TERMPORARY REGULATOR FOR DIVERSION OF RIVER INDUS AT TAUNSA BARRAGE

General Abstract of Cost

			Rs.
1.	Constructing Temporary Diversion Regulator	...	5,20,968
2.	Constructing 10 Nos. Sump Wells	...	7,994
3.	Constructing Decking of Temporary Diversion Regulator	...	16,859
4.	Cost of laying and linking of B G. Track for trolly	...	5,101
5.	Cost of subsidiary works of Temporary Regulator for Diversion.	...	8,82,936
	Total	...	14,33,858

DETAILS OF WORK

			Rs.
1.	Constructing Temporary Regulator for Diversion of River Indus.	...	
	(*i*) Labour	...	60,787
	(*ii*) Material.	...	4,06,213
	(*iii*) Carriage	...	28,171
	Rs. 4,95,171 Site clearance 2% on above	...	990
		...	
	Total	...	4,96,161
	(*iv*) 4,96,161 W. C. Establishment @ 2%	...	9,923
	(*v*) 4,96,161 Contingencies 3%	...	14,884
	General Total	...	5,20,968
2.	Constructing 10 Nos. Sump Wells.	...	7,994
3.	Decking of Temporary Diversion Regulator.	...	16,859
4.	Laying and linking of B. G. Track for Trolly	...	5,101
5.	Cost of subsidiary works of Temporary Regulator of Taunsa Barrage :—	...	
	(*i*) Excavating pit for Temporary Diversion Regulator at Taunsa Barrage	...	1,11,359
	(*ii*) Supplementary Estimates of Excavating Foundtion of Temporary Diversion Regulator at Taunsa Barrage	...	40,648
	(*iii*) Constructing upstream and Downstream Guide Banks of Diversion Regulator	...	23,178
	(*iv*) Fixing sheet piles in Temporary Regulator at Taunsa Barrage	...	46,231

(*v*)	Maintaining sumps and drains in Temporary Regulator at Taunsa Barrage	...	11,409
(*vi*)	Constructing installing and running power houses at Right Guide bank of Taunsa Barrage...		62,888
(*vii*)	Providing Temporary H. T. transmission line over Taunsa Barrage for diversion	...	2,974
(*viii*)	Excavating Road and tail race channels of Diversion Regulator	...	5,84,249
	Total	...	8,82,936

ESTIMATE FOR CLOSING OF THE RIVER INDUS FOR DIVERSION THROUGH TAUNSA BARRAGE

General Abstract of Cost

			Rs.
1.	Laying Chhaps	...	7,48,388
2.	Making Stone Boom No. 1	...	7,88,456
3.	Closure of Temporary Diversion Regulator with stone (Boom No. 2)	...	12,18,699
4.	Making stone Boom at X-Y	...	1,83,811
5.	Compensation for 2 Nos. boats damaged and drowned during the closures of Temporary Diversion Regulator (2500+1200)	...	3,700
6.	Constructing Bund (M & P)	...	9,90,452
	Total	...	39,33,506

ESTIMATE FOR CLOSING OF THE RIVER INDUS FOR DIVERSION THROUGH TAUNSA BARRAGE

Detail of Works

1. Laying chhaps and constructing defence bund behind chhaps :—

(*a*)	Cost of laying langer chhaps (Z-Z) at the head of main creek	...	25,037
(*b*)	Cost of laping Khaji spur for diversion (G-G)	...	62,720
(*c*)	Cost of laying chhaps at C-D, X-Y and E-F	...	4,09,271

(*d*) Cost of laying chhaps at A. G.		...	1,56,982
(*e*) Cost of replenishing work of chhap AC & CD		...	31,589
(*f*) Cost of constructing bund across phooti creek near Taunsa Barrage		...	8,936
(*g*) Cost of making earthen bunds behind chhaps for transportation of labour through boats, dressing and levelling bund through daily labour		...	44,727
(*h*) Cost of laying balli chhap and making way for transportation of boats through sand shoals to chhap site		...	9,126
	Total	...	7,48,388

2. Making stone boom in main creek (No. 1) :—

(*a*) Labour		...	5,03,190
(*b*) Material		...	8,24,197
(*c*) Carriage		...	2,30,505
1557892 Add contingency at 3% on above		...	46,737
Work charge establishment as per actual		...	18,972
	Total	...	16,23,601
D/d credit		...	8,37,145
	Total	...	786,456
Add for electric charges		...	2,000
	G. Total	...	7,88,456

3. Closures of temporary Diversion Regulator with stone boom (No. 2) :—

(*a*) Labour charges		...	4,37,713
(*b*) Carriage charges		...	2,31,426
(*c*) Cost of Material		...	16,28,995
	Total	...	22,98,134

Rs. 1,128 for workcharge establishment as per actual ...		1,128
Rs. 22,98,227. Add Contingency at 3%	...	68,945
Total	...	2,368,207

Credit

(*a*) 12,06,078 cft. S. K. W. stone recovered @ 73-14-0 + 12-4-0 for carriage 4 miles 86-2-0% cft.		10,55,016
(*b*) 1,29,912 cft. D. G. Khan stone recovered at the rate of 57-8-0 + 17-9-0 for carriage 8 miles 75-1-0% cft.	...	97,512
Total	...	11,52,528
Net amount 23,68,207 — 11,52,528 = 12,15,679	...	12,15,679
Add for Electric charges	...	3,020
Net amount	...	12,18,699

4. Making stone Boom X-Y—

(*a*) Labour charges	...	54,296
(*b*) Material	...	1,95,463
(*c*) Carriage charges	...	35,335
Rs. 2,85,094 contingency at 3% on above	...	8,853
Total	...	2,93,647
Cost of stone recovering	...	13,968
Total	...	3,07,615

Credit

(*a*) 52,187 cft, Sikhanwala stone @ 74-14-0 + 12-3-0 =	44,914	123,804
(*b*) 1,05,180 cft. stone @ 74-14-0% cft.	878,890	
Net amount 307,615 — 123,804	1,83,811	

5. Compensation for 2 Nos. boats damaged during the closures of Temporary Regulator = 3,700

6. Constructing Bund M. N. P. and u/s & d/s bunds of the Temporary Regulator to nose of Right Guide bank.

(*a*) 121,88,000 cft. earthwork done by machines @ 42-I3-9% cft.	...	522,370
(*b*) 4,096,000 cft. earthwork done by machines @ 42-13-9 % cft.	...	1,75,552
(*c*) 290,000 cft. earthwork undressed by donkeys @ 8-1-6% cft.+175%	...	6,475
(*d*) 38,56,000 cft. earthwork done by machine (for pushtas lead 4,000) @ 42-13-9%	...	1,65,266
(*e*) 165,74,000 cft. earthwork dressing item A to C @ 0-6-0+175% cft.	...	17,192
Add protection of diversion bund (stone pitching R. D. 18,500 to 23,000	...	57,505
Total	...	9,43,294
943,294 add contingencies @ 3%	...	28,294
943,294 add workcharge establishment @ 2%	...	18,864
G. Total	...	990,452

PAPER NO. 343

PLATE No. I

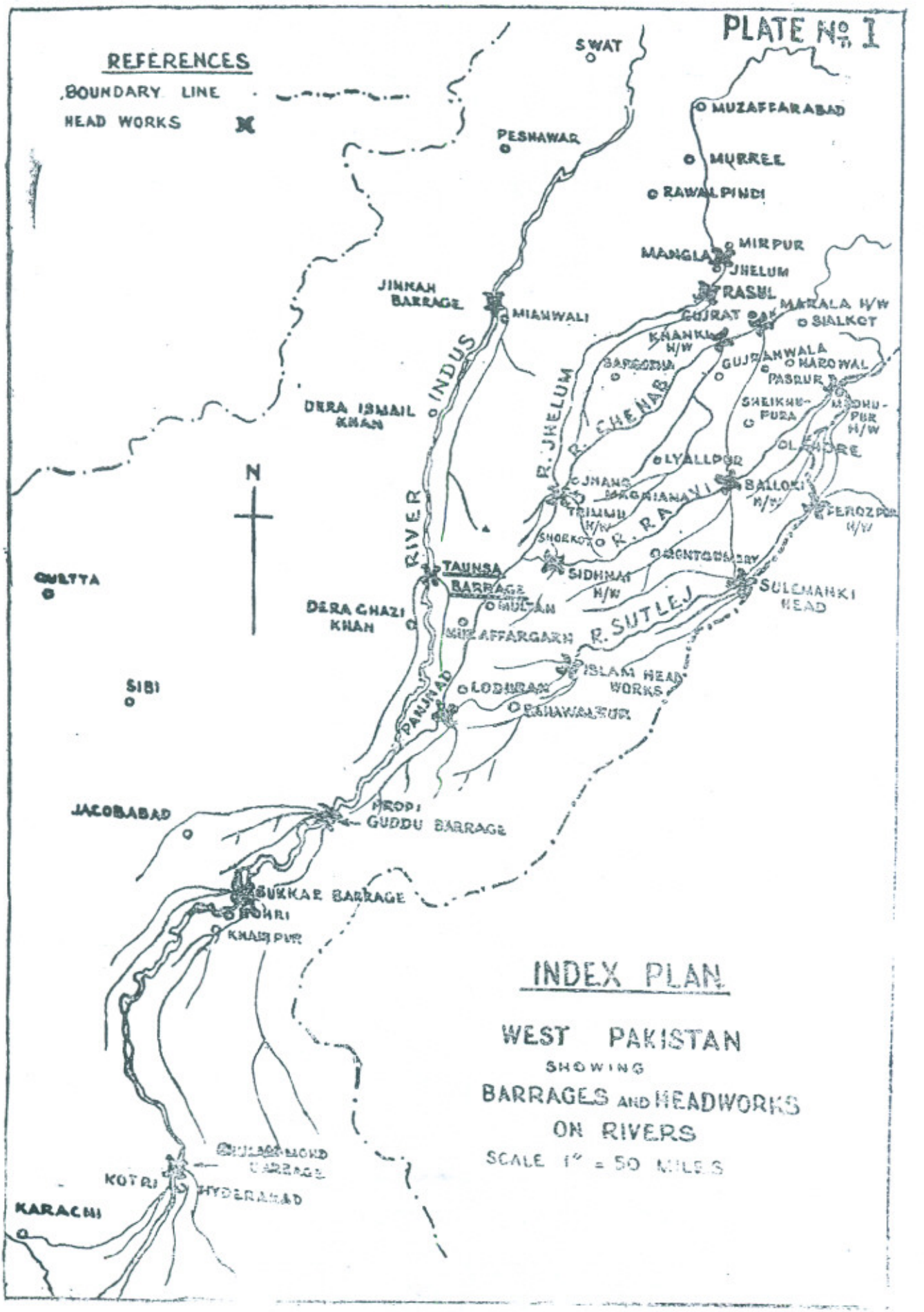
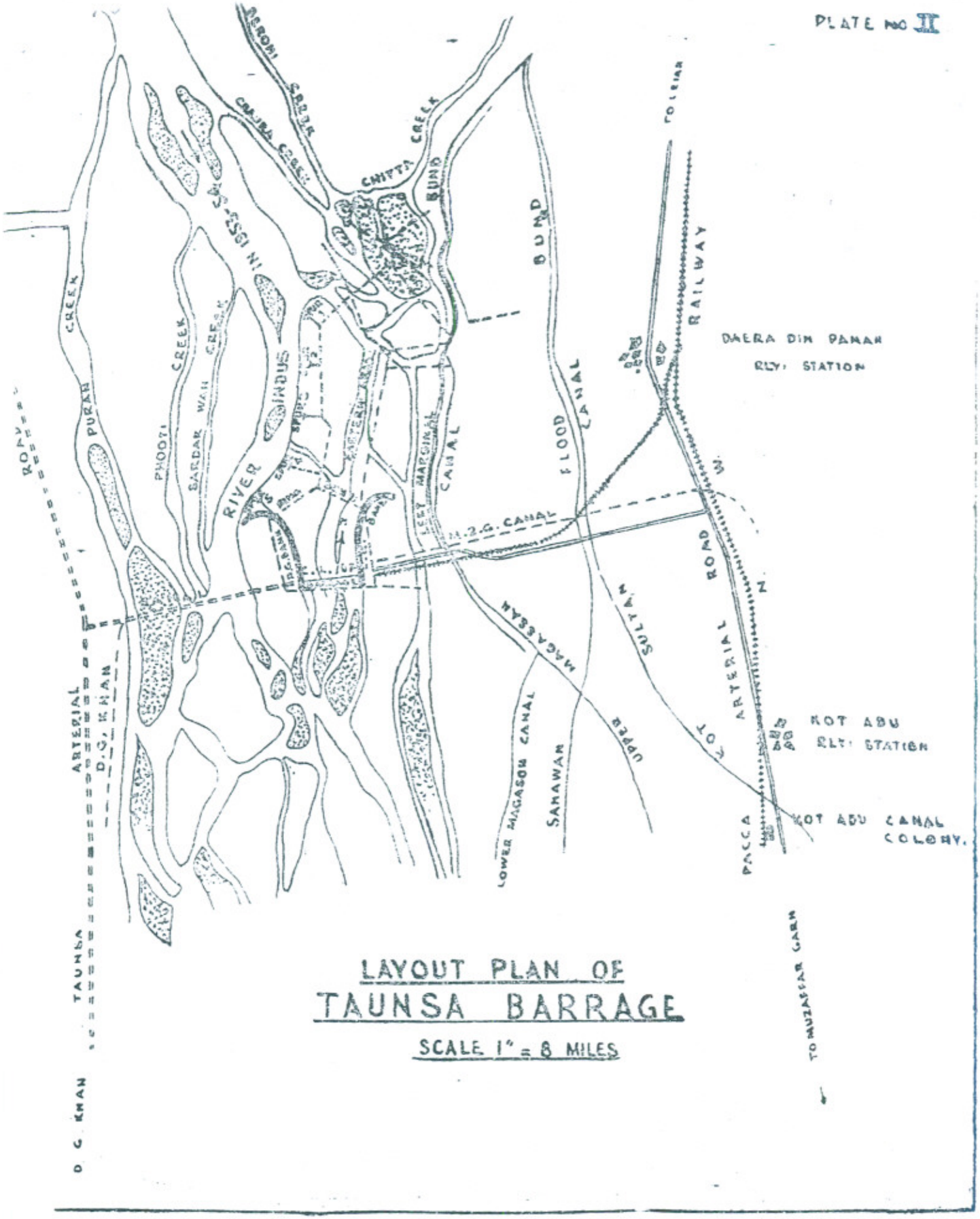


PLATE NO II

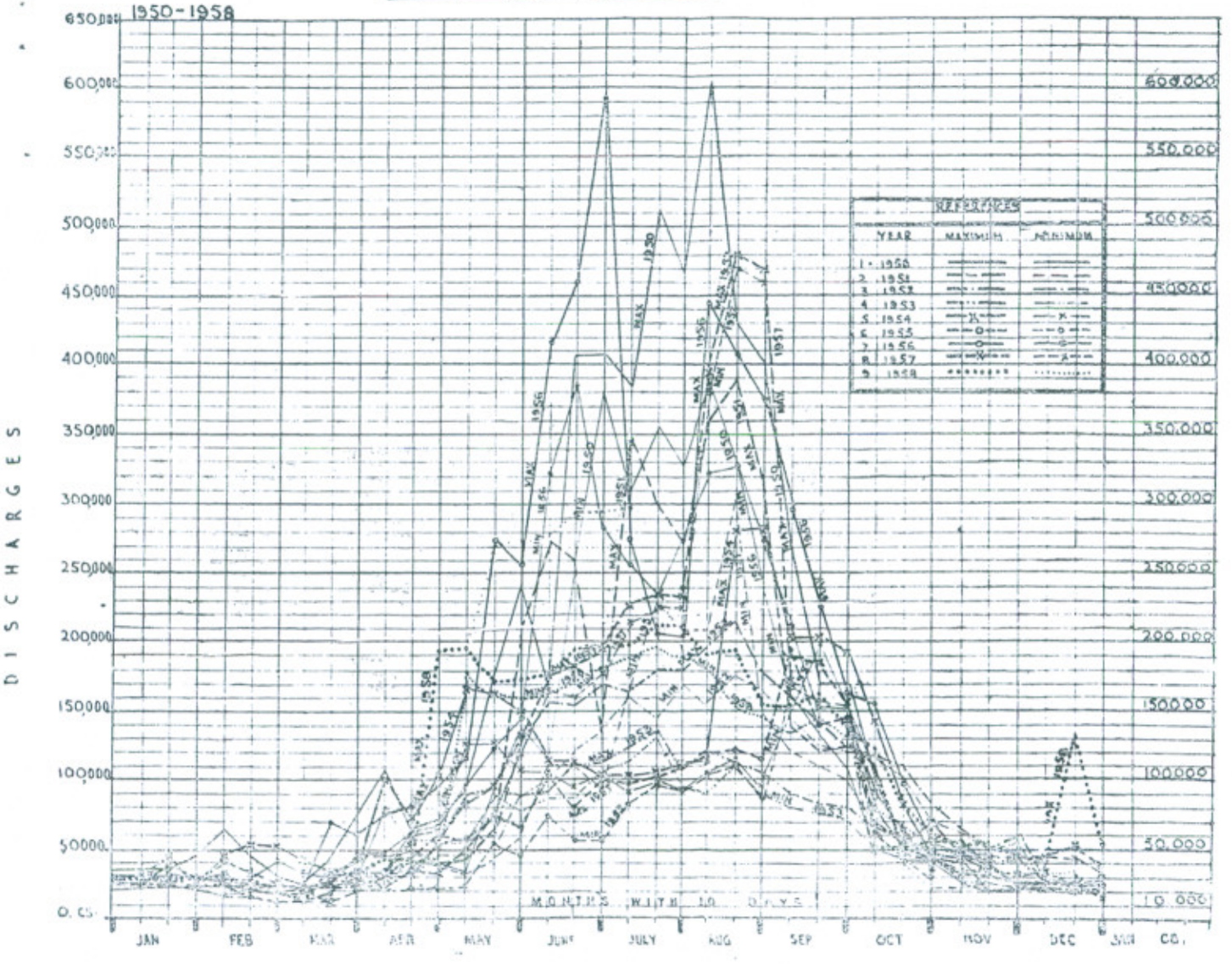


LAYOUT PLAN OF
TAUNSA BARRAGE

SCALE 1" = 8 MILES

PAPER NO 343 HYDROGRAPH OF 10 DAYS MAXIMUM & MINIMUM DISCHARGES PASSING TAUNSA BARRAGE SITE OR GHAZI GHAT (27-MILES D/S OF TAUNSA BARRAGE SITE) FOR THE YEAR 1950 - 1958

PLATE NO: III



PAPER NO. 343

PLATE NO IV

PLAN SHOWING LEADING CUTS AND ITS TYPE X-SECTION AT TAUNSA BARRAGE

SCALE 1½" = 1 MILE

REFERENCES

1 LEADING CUT AS EXCAVATED

2 LEADING CUT PARTLY EXCAVATED

3 LEADING CUT NOT EXCAVATED

1	E/WORK CUT NO: 1	14055353 CFT.
2	E/WORK CUT NO 2	4888595 CFT
3	E/WORK CUT NO 3	18289797 CFT
4	E/WORK CUT NO: 4	18811761 CFT.
5	E/WORK CUT NO 5	23342532 CFT
6	E/WORK CUT NO 6	6542716 CFT
7	E/WORK CUT NO 7	14214642 CFT
8	E/WORK CUT NO:8	24600505 CFT.
9	SMALL CUTS	2444200 CFT.
10	EASTERN ARM	22179353 CFT
11	RACE CHANNELS	1,81,30,000 CFT
G	TOTAL ACTUALLY DONE:	16,74,99,476 CFT
	ESTIMATED QUANTITY:	22,92,96,575 CFT

MAIN CENTRAL CREEK

EASTERN ARM OF RIVER

1957 IN RIVER EDGE

SPUR 1

SPUR 2

CLOSED

SPUR 3

SPUR 4

SPUR 5

L CUT NO 1

L CUT NO 2

L CUT NO 3

L CUT NO 4

L CUT

TEMPORARY REGULATOR

FIRST DEF. BUND

SECOND DEFENCE BUND

D G KHAN CANAL

D. G. KHAN CANAL

RING BUND

R.G. BANK

L.G. BANK

RING BUND

C.L. OF BARRAGE

N

LONG-SECTION OF L. CUT NO: 1 U/S

SCALE { HOR: 4" = 1 MILE / VERT 1/100

DATA

Q = 3000 CS

B = 125'

D = 8.0'

S. SLOPE = 2:1

BED LEVEL 420.0

R.L 425.85

L CUT NO:5

L CUT NO:6

L CUT NO:7

L CUT NO: 8

TYPICAL X-SECTION OF L. CUT NO 1

Scale 1/500

BED LEVEL 420.0

B = 125

5 1/2

PAPER NO. 343

PLATE NO. V

LAYOUT PLAN SHOWING LEADING CUTS, TEMPORARY REGULATOR AND STONE BOOM AT TAUNSA BARRAGE.

SCALE 2" = 1 MILE.

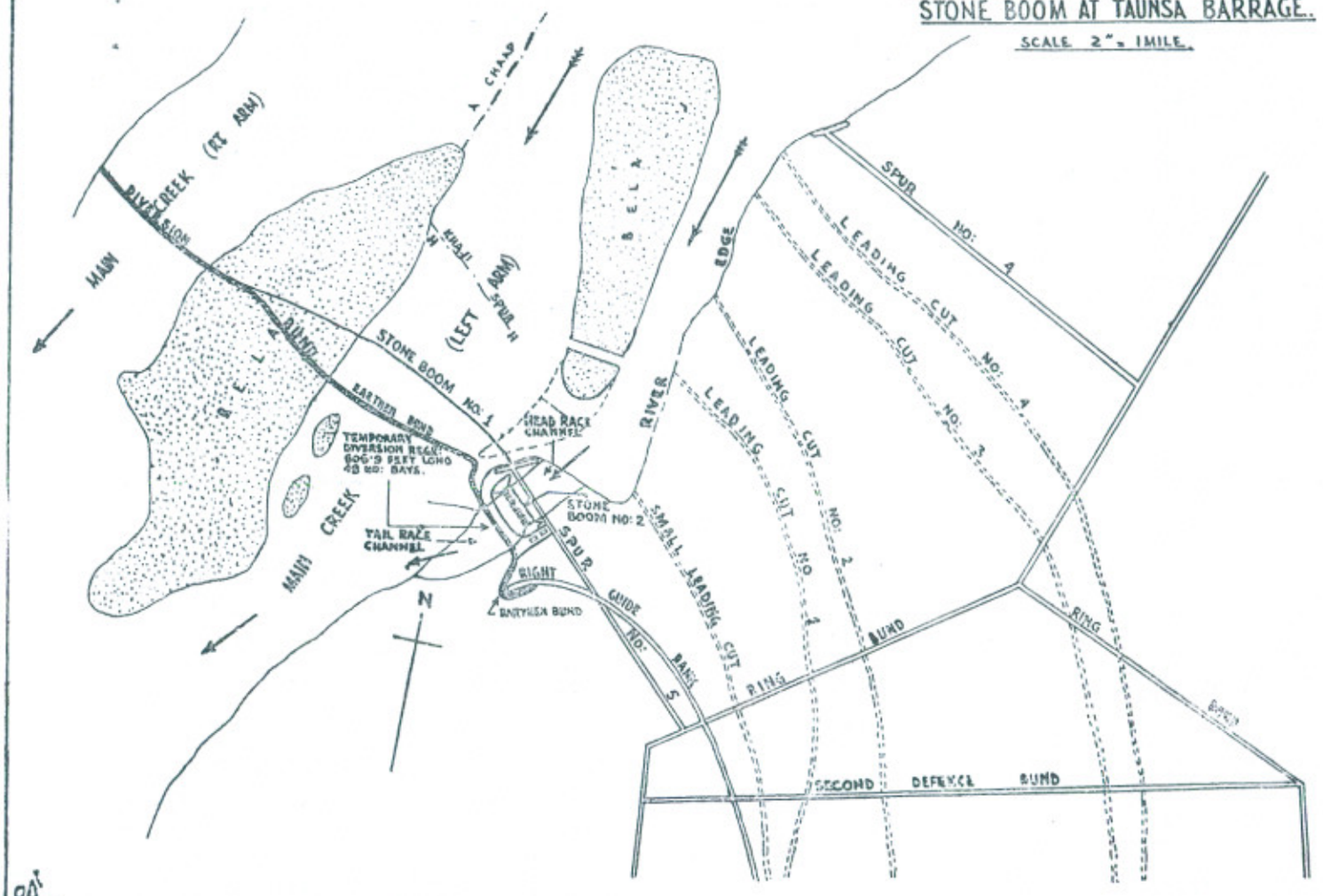
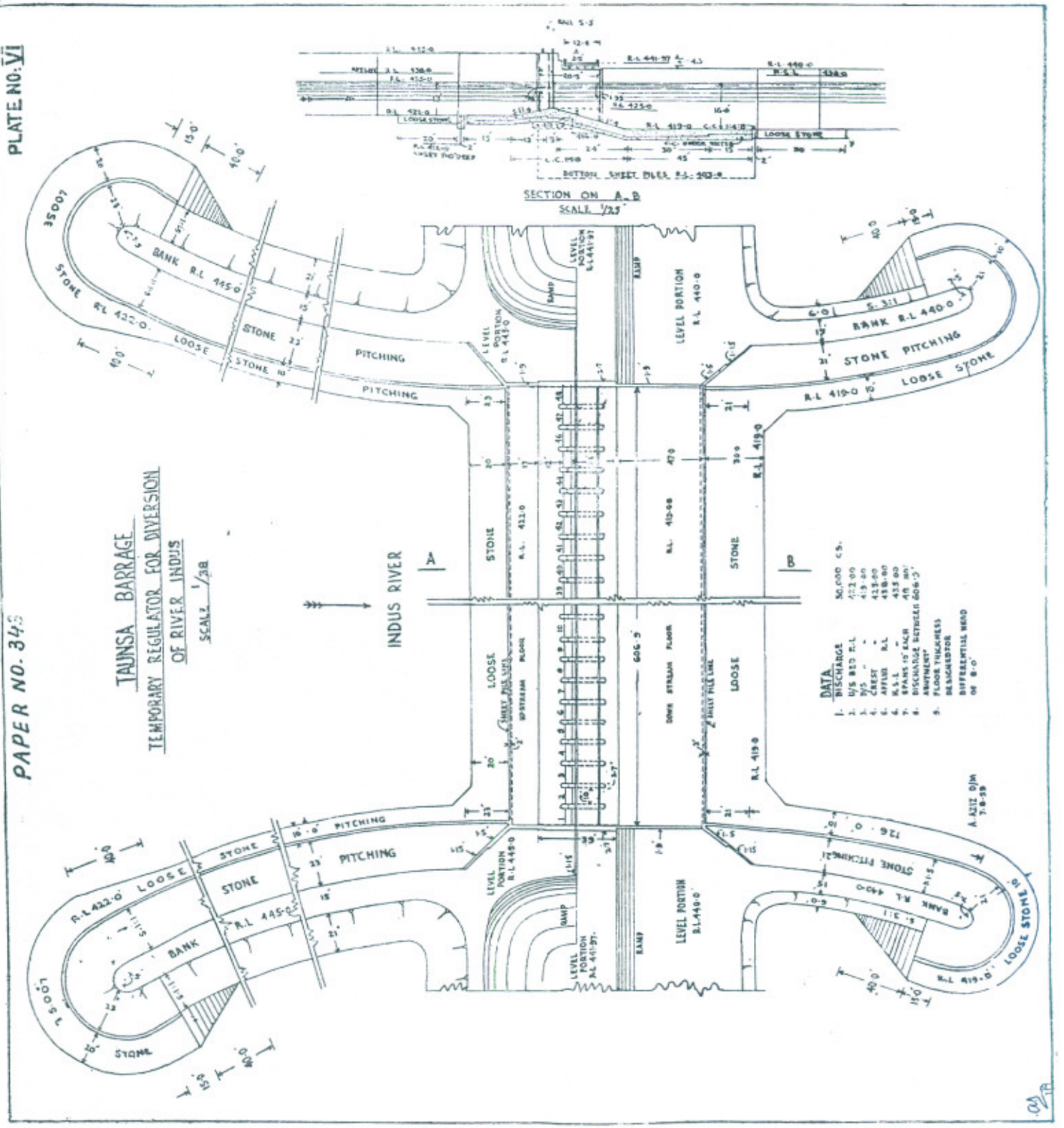


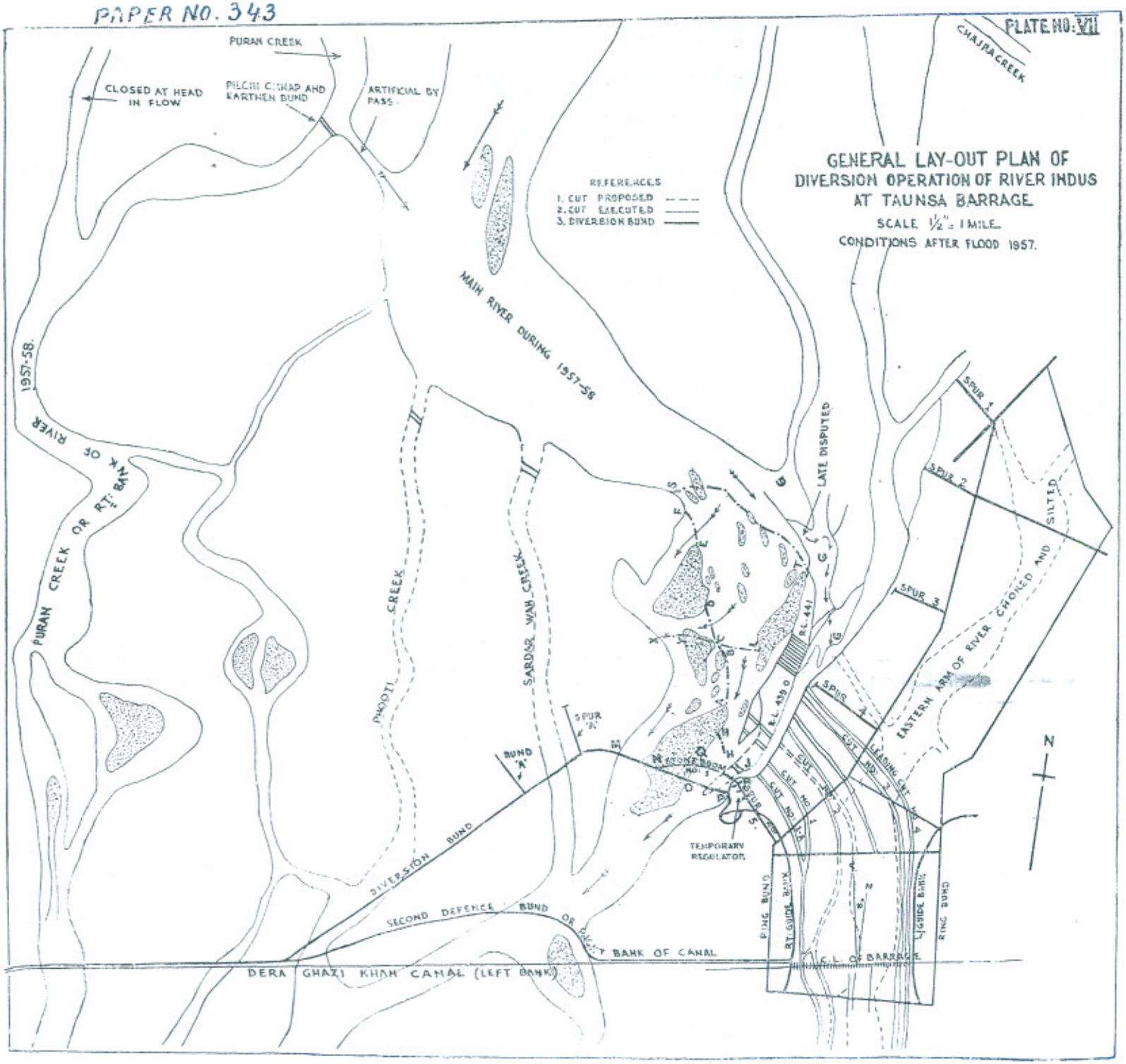
PLATE NO: VI

PAPER NO. 348



PAPER NO. 343

PLATE NO: VII



PAPER NO. 343

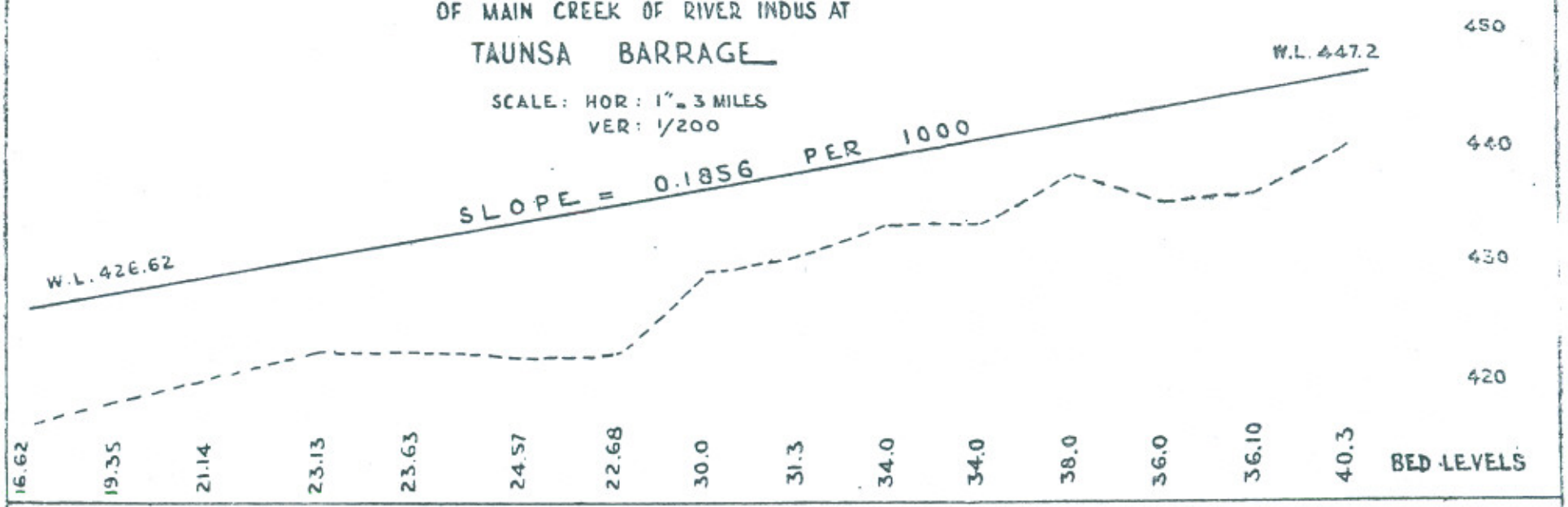
PLATE NO: VIII

L. SECTION

OF MAIN CREEK OF RIVER INDUS AT

TAUNSA BARRAGE

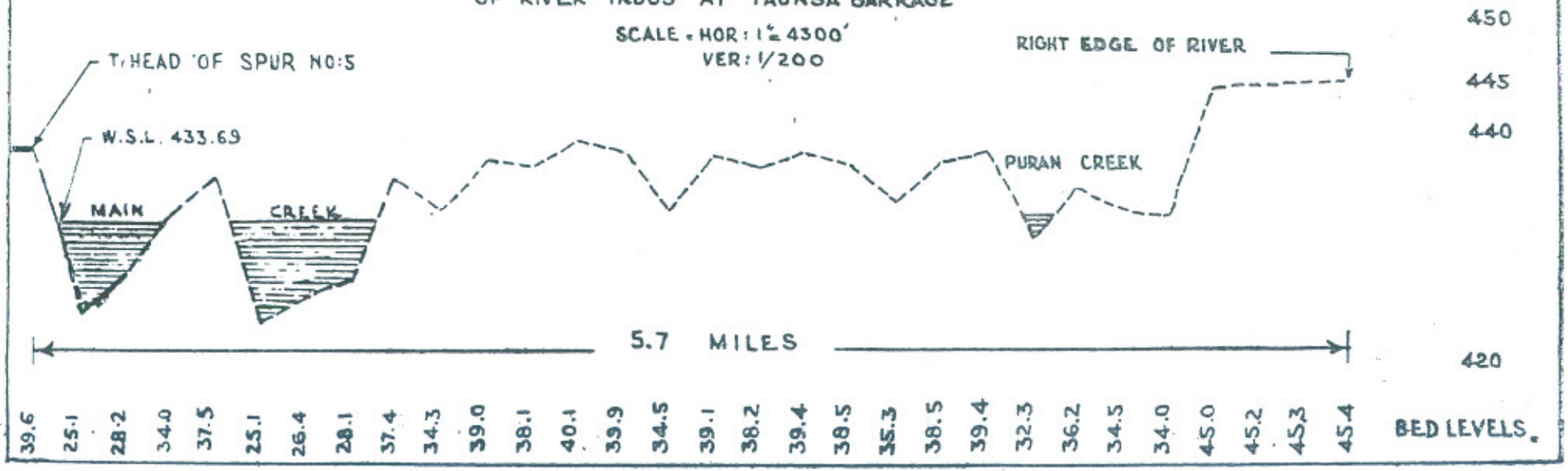
SCALE: HOR: 1" = 3 MILES
VER: 1/200



X- SECTION

OF RIVER INDUS AT TAUNSA BARRAGE

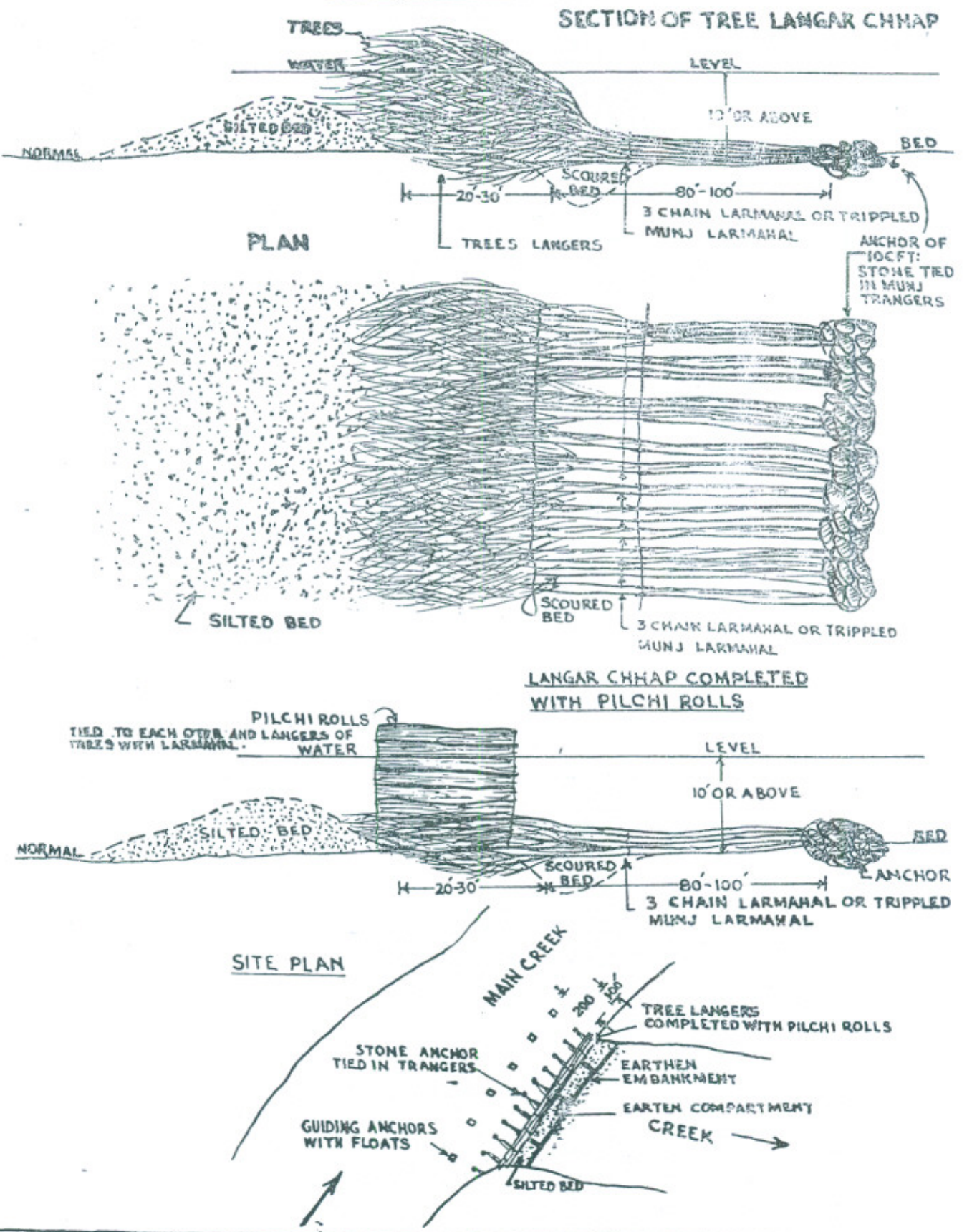
SCALE - HOR: 1" = 4300'
VER: 1/200



PAPER NO. 343

PLATE. NO IX

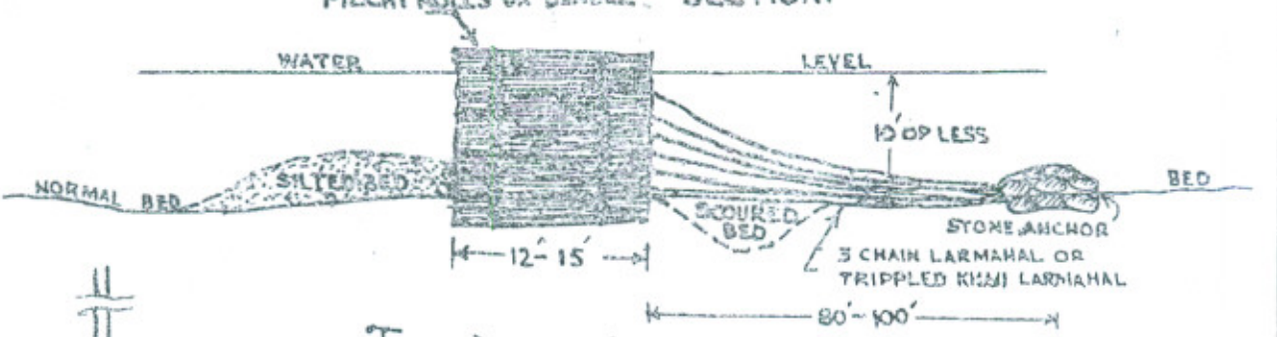
LANGAR CHHAP OF TREES

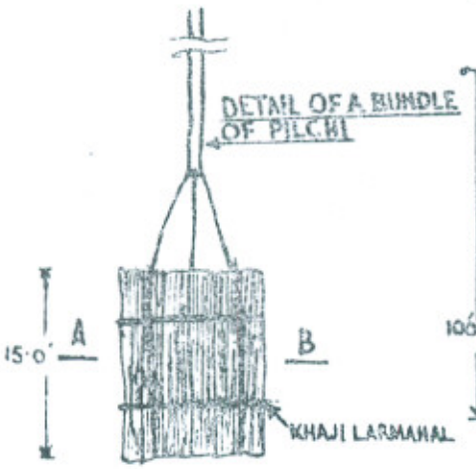


PAPER NO. 343

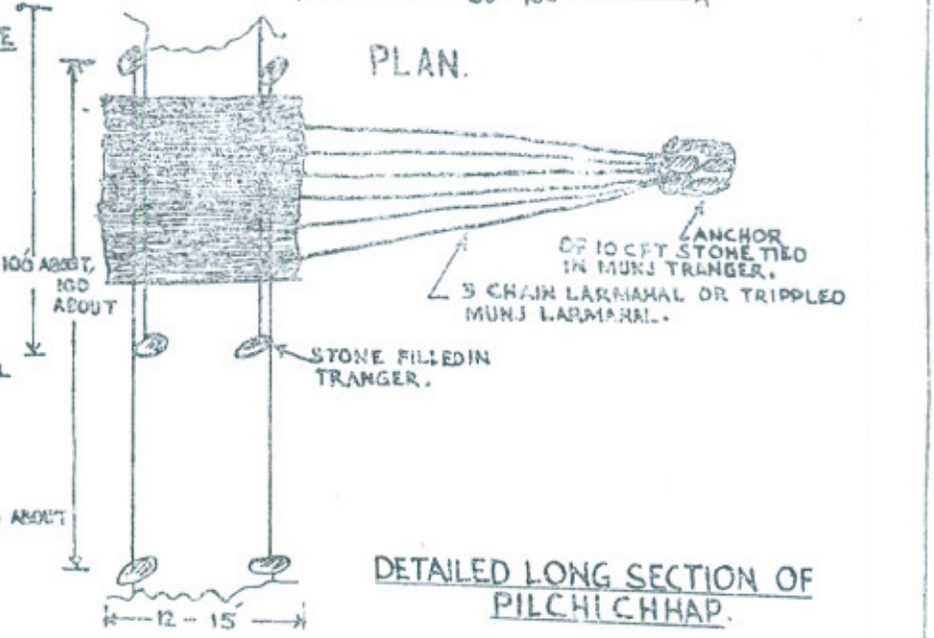
PLATE NO: X

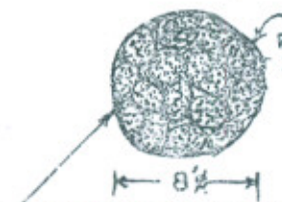
PILCHI CHHAP.



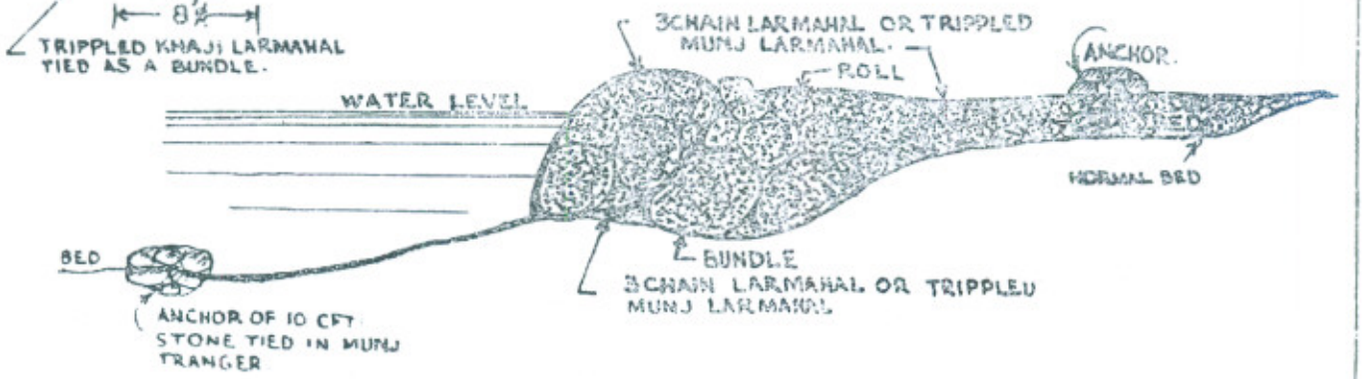


SECTION ON A-B.





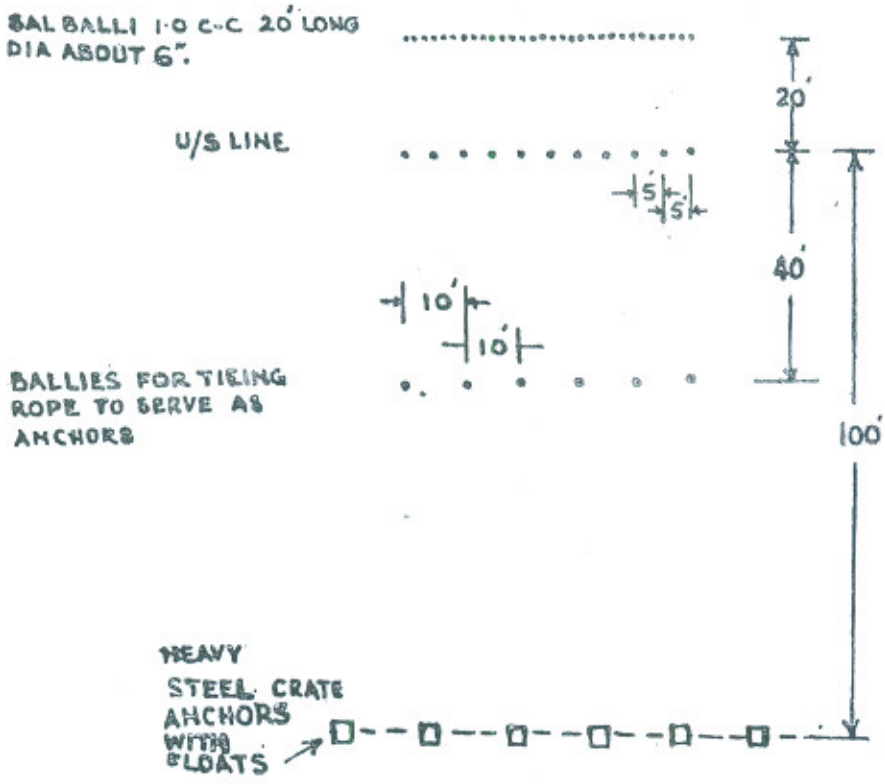
DETAILED LONG SECTION OF PILCHI CHHAP.



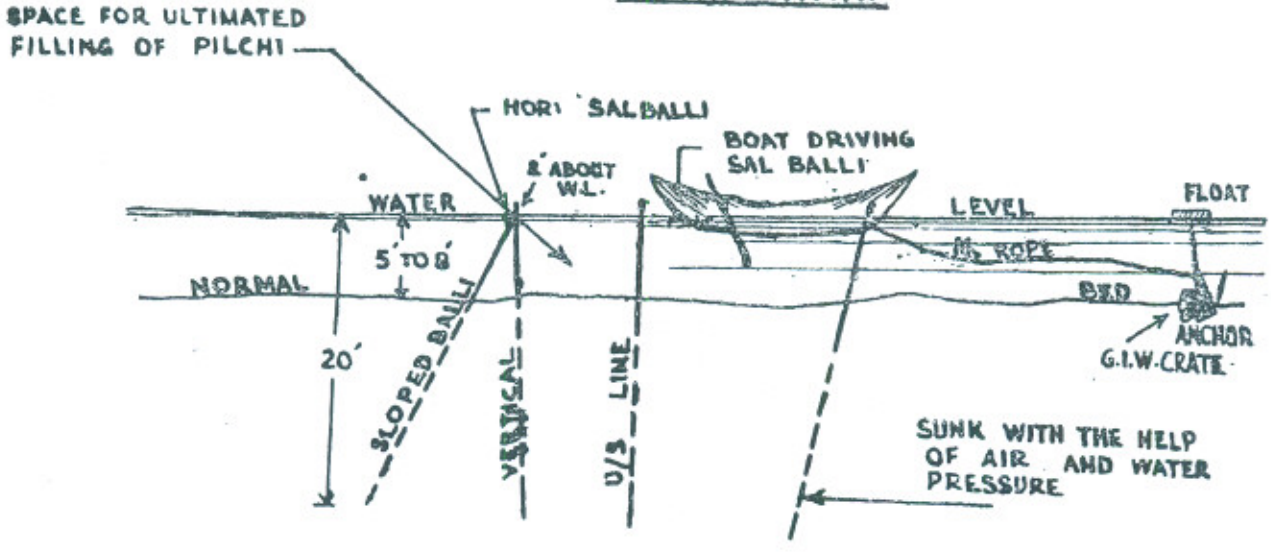
PAPER NO. 343

PLATE No. XI

PLAN OF BALLI CHHAP



CROSS SECTION SHOWING BALLI CHHAP

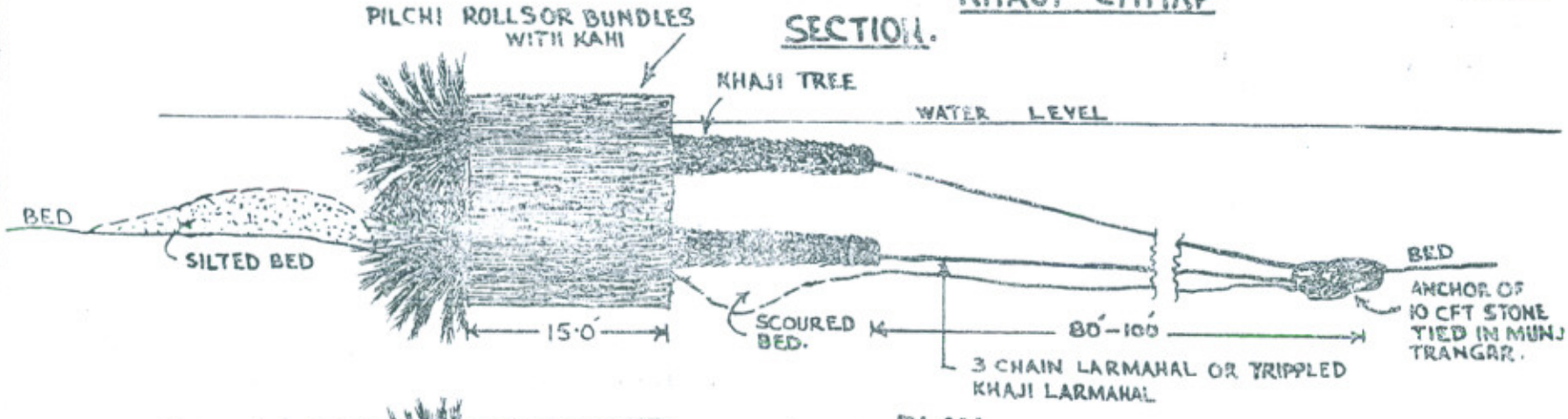


PAPER NO. 343

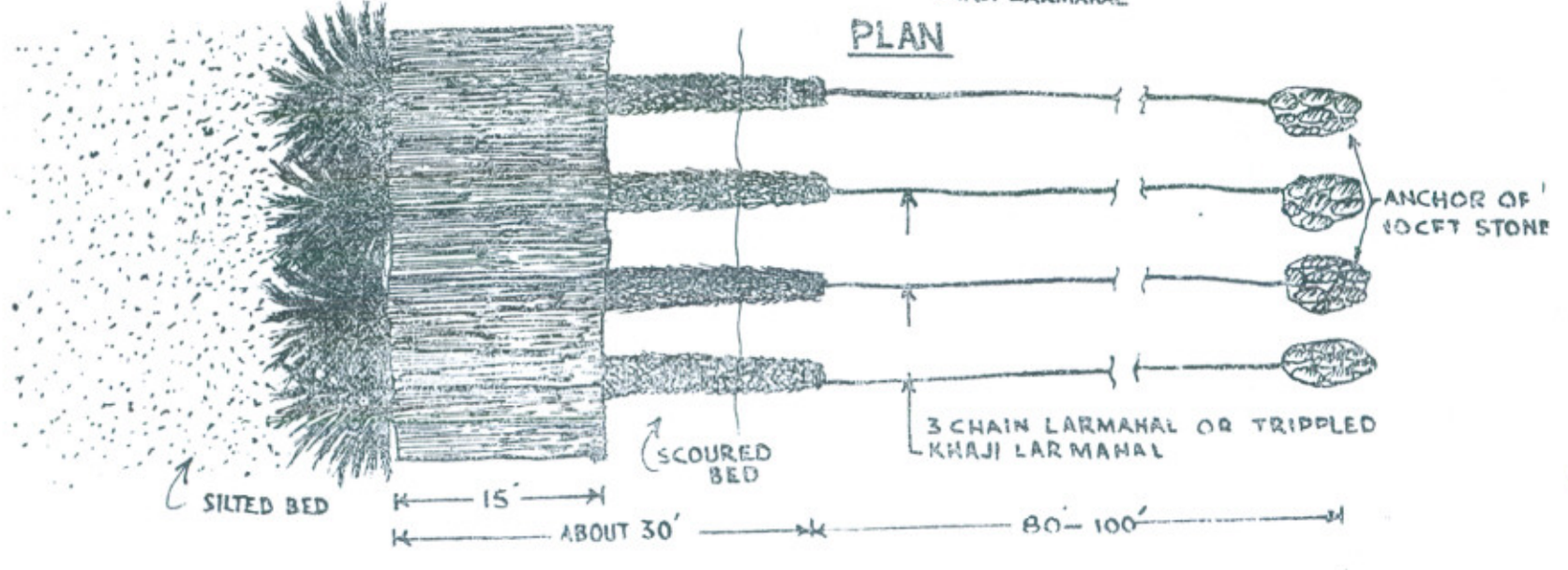
PLATE No. XII

KHAJI CHHAP

SECTION.

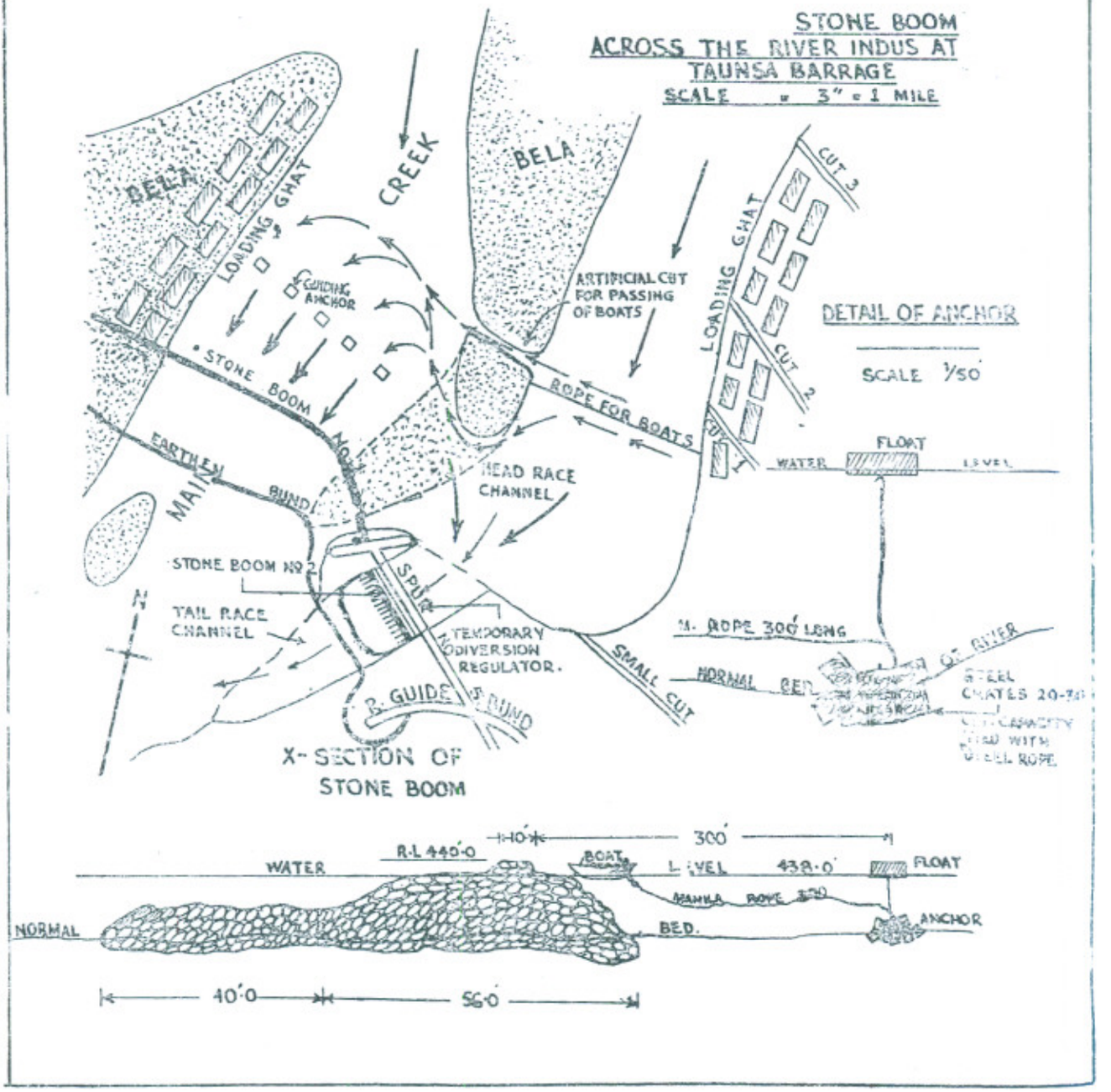


PLAN



PAPER NO. 343

PLATE NO XIII

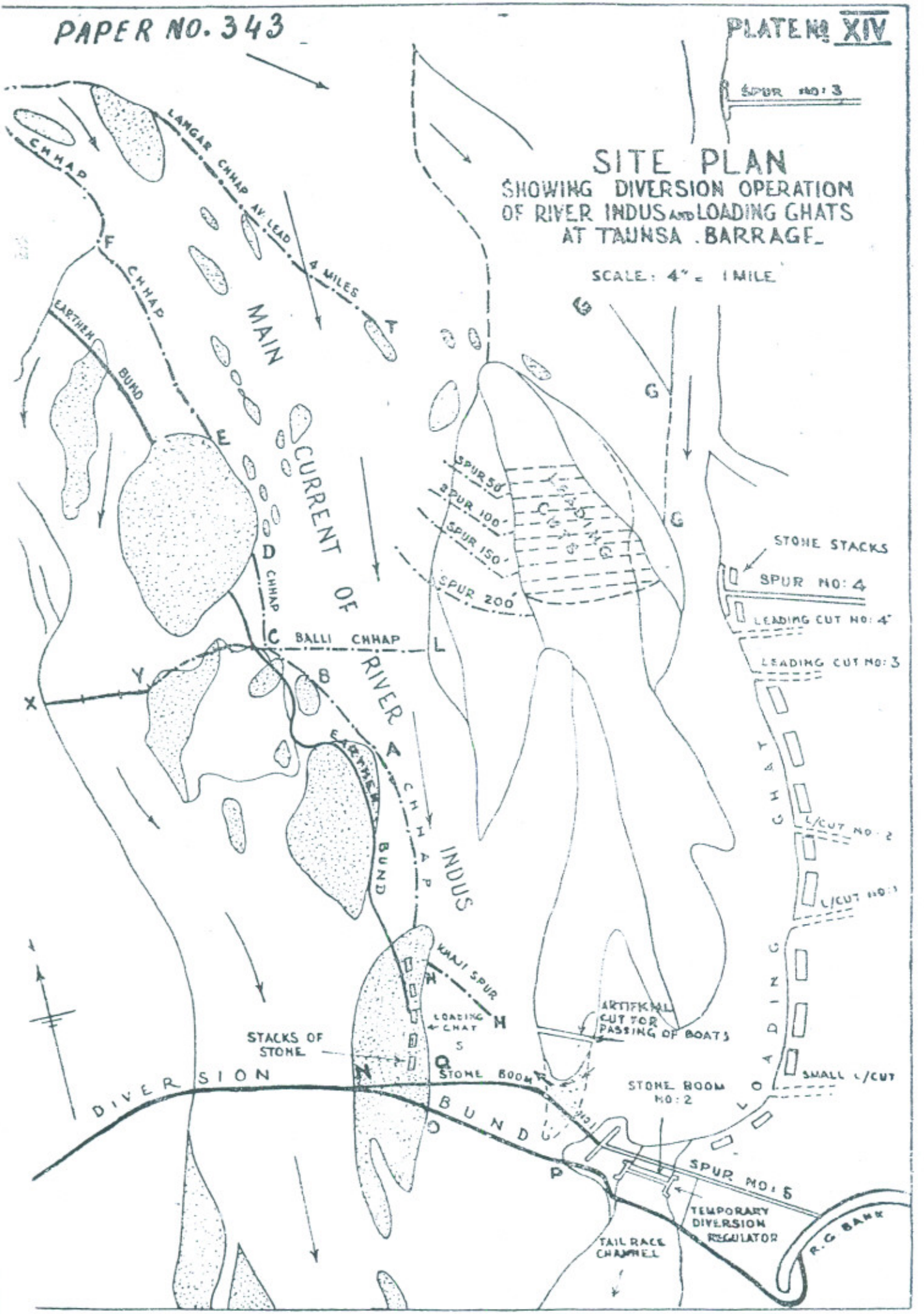


PAPER NO. 343

PLATE No. XIV

SITE PLAN
SHOWING DIVERSION OPERATION OF RIVER INDUS AND LOADING GHATS AT TAUNSA BARRAGE

SCALE: 4" = 1 MILE



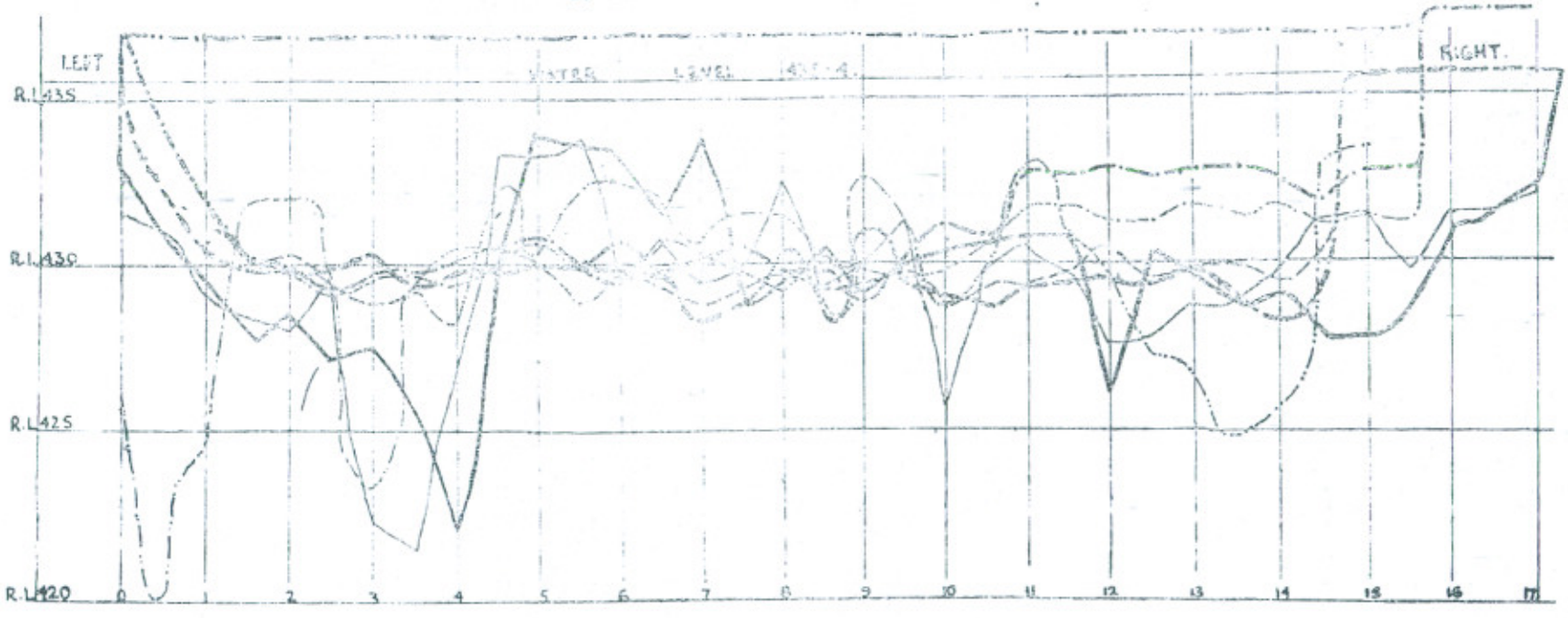
PAPER NO. 343

PLATE No. XV

X-SECTION OF RIVER INDUS DURING CLOSURE

O.N.,

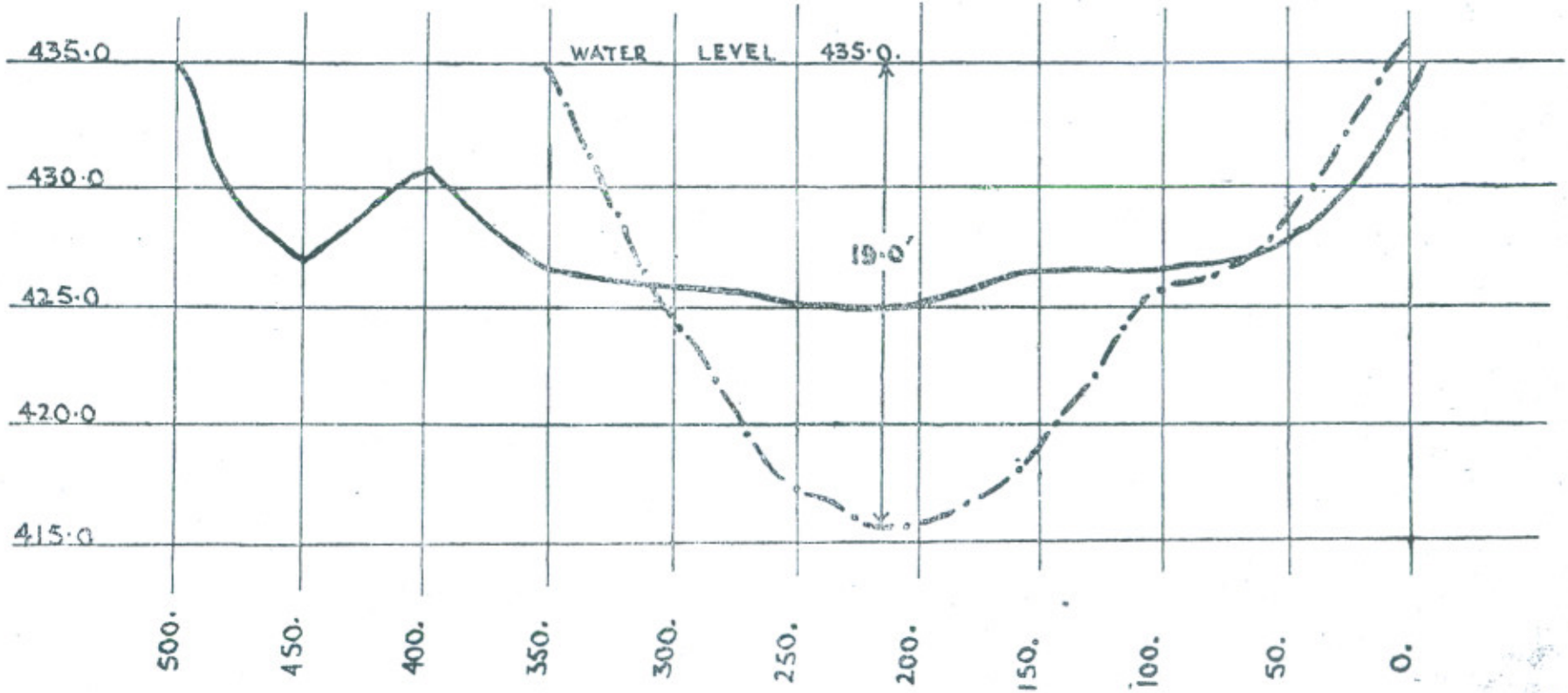
30.1.58.	A. CENTRE LINE B. POINT	———	BEFORE LAYING STONE
12.2.58.	A. C/L B. POINT	— — — — — —	METING IN PROGRESS
13.2.58.	A. C/L B. POINT	— · — · — — · — · —	METING MOSTLY COMPLETED
20.2.58.	A. C/L B. POINT	— · · — · · — · · — · ·	CREST RAISED.



X-SECTION 300' D/S OF TEMPORARY REGULATOR ON:-

9·3·58. _____ PREVIOUS TO DAMAGE.

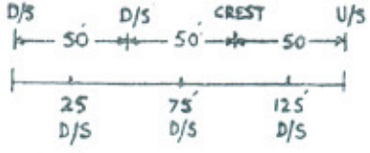
16.3.58. _._._._



PAPER NO. 343

PLATE No XVII

X-SECTION U/S & D/S OF REGULATOR ALONG THE RING BUND BOOM OR CREST ON



16.3.58 W.L 435·5.
- 16' FROM CREST U/S
- 66' FROM CREST D/S

22.3.58 W.L 435·0.
- 35' FROM CREST D/S
- 19' FROM CREST U/S

2.4.58 W.L 432·0
- 125' FROM CREST D/S
- 75' FROM CREST D/S