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Diverting River Indus through Ghazi Ghat Road Bridge

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* DIVERTING RIVER INDUS THROUGH GHAZI GHAT ROAD BRIDGE

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I. INTRODUCTION

1.1 Pakistan is an abode of nearly 90 million people and has a gross area of 3.10 lac square miles comprising of the Punjab, Sind, Baluchistan and North West Frontier Provinces. The topography of the country ranges from high mountains in the North and North-West to flat plains in the South. All the five rivers of Pakistan namely Sutlej, Ravi, Chenab, Jhelum and Indus, rise in the Himalaya and after long tortuous course amid the snow clad hills flow in a South Westerly direction into the plains commonly known as Indus Valley. After joining with each other on way, they merge with river Indus at Mithankot and fall ultimately in the Arabian sea below the cosmpolitan city of Karachi.

1.2 The mighty river Indus, one of the largest rivers of the world, is about 1300 miles long. It rises from Lake Manserver in the Himalayas and its mountaineous stage ends at Kalabagh. Lower down in a length of about 900 miles upto Thatta it flows in the plains and then assumes the delta stage to outfall into the sea. In the plains, the river has a wide khadir width of seven to fifteen miles and the adjoining areas receive protection from floods by a series of flood embankments.

1.3 During the British rule of the Sub-continent for about a century, only five rail-cum-road bridges with steel frame structures were constructed on river Indus at the narrow gorge sites of Attock, Khushalgarh, Kalabagh, Rohri and Kotri. Then on introduction of Irrigation net work, two more crossing points became available on this river at the Headworks sites of Kalabagh and Sukkur.

1.4 After independence in the year 1947, four more bridges were introduced by the extension of Irrigation net work at Chashma, Taunsa, Guddu and Ghulam Muhammad Barrages.

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* This paper deals only with the aspect of River diversion through the bridge. Other features of the project or their planning/design strategies have not been discussed here due to space limitation.

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Subsequently three more bridges were constructed to connect Thatta with Sujawal, Kotri with Hyderabad and at Khairabad on upstream of Attock. With the rapid development of the area on the right side of the river, the need for provision of more bridges was urgently felt and the Government therefore, decided a few years back to immediately construct three more bridges on this river opposite district Daddu at Moro in Sind Province, opposite district Dera Ghazi Khan at Ghazi Ghat in Punjab and opposite district Dera Ismail Khan at Darya Khan in the North West Frontier province. The first bridge at Moro constructed on pile foundations along side the active river channel was completed in the year 1982. The second bridge at Ghazi Ghat constructed on well foundations had been located on firm high bela and was completed in the year 1984 as per details contained in this paper. The third bridge at Darya Khan also constructed on well foundations was located in the bed of an arm of the river and has attained completion in the year 1985.

II. ROAD BRIDGE

2.1 The day dawned bright, clear, full of spirits and promise. It was an eventful day in the accomplishment of an engineering feat for the progress of mankind. On February 12, 1984 mighty river Indus was tamed to pass through the newly constructed road bridge at Ghazi Ghat to connect Dera Ghazi Khan with the rest of the province by a direct route.

2.2 From times immemorial, the brave people of the plains and rugged areas of Dera Ghazi Khan/Rajanpur Districts (an abode of 15,81,000 people spread over an area of 24,239 square killo meters-census year 1981) had faced perils and hazards to cross the mighty river Indus for sharing the grandeurs and progress with their brethren living in the interior of the Province. Prior to the year 1920, communcation across the river was possible only by country boats. In the British days, steamer service was introdced in the year 1920 to reduce the fury of fast currents hampering the movement of country boats at the stage of high river flows in summer. Then the system of providing a boat bridge came into existence when light vehicular traffic (upto 5 tons load) could also cross the river in the winter season.

2.3 The first all weather road connection to the area on the right side of river Indus was developed after construction of the bridge on Taunsa Barrage in the year 1958 which entails a lengthy detour of about 57 miles for Dera Ghazi Khan. Persistent demand of the area ultimately led to a consideration by the Government in the year 1973 to construct a road bridge on river Indus at Ghazi Ghat, just opposite the city of Dera Ghazi Khan (Plate No. I). With this straight linkage, the distance between Multan and Dera Ghazi Khan was to reduce to 58 miles only against the hitherto detour of 115 miles via Taunsa Barrage.

2.4 Approximate position of the Road Bridge was determined on the basis of aerial survey of the area carried out in the year 1973. The topographical ground survey was done in the year 1974 to carry out model studies in the Irrigation Research Institute at Nandipur for establishing

the precise location of the bridge and the layout of the river training works. On the basis of extensive model studies already carried out for a similar bridge on river Indus at Derya Khan, the location of this brdige was made to coincide with the axis of river Khadir by providing symmetrical guide banks and the training works. The recommendations formulated by the Irrigation Research Institute (Technical Report No. IRR-756/Hyd/DGK – November 1979) about the layout of the works comprised of the following salient features :–

i) Location – Almost at centre of the Khadir Belt coinciding nearly with the river axis.

ii) Discharge capacity. = 10 lacs cusecs.

iii) Clear water-way at 1.2 times Lacey's width. = 3204 feet.

iv) Bridge width from abutment to abutment. = 3400 fee.

v) Guide Banks on left and right sides.

a) Distances from bridge line on downstream side. = 500 feet.

b) Distance from bridge line on upstream side. = 2500 feet.

vi) Spurs on Left Side :–
Aligned at 32 degree to the bridge axis
(J Spur L–I and J Spur L–2). = 2 Nos.

vii) Spurs on Right Side :–

Aligned at 32 degrees to the bridge axis.
(J Spur R-1 and J Spur R-2). = 2 Nos.

viii) Length of approach road on the left from Ghazi Ghat side. = 26200 feet.

ix) Length of approach road on the right from Dera Ghazi Khan side. = 21000 feet.

The layout of the bridge, guide banks, spurs and approach roads is shown on the Survey Plan of the year 1974 at Plate No. II.

2.5 The bridge 3,410 feet long has 22 spans of 155 feet width each. Two concrete columns, 4½ feet diameter each serving as piers rest on well foundation sunk 120 feet deep below the low water table. The wells are of 19 feet internal diameter, have 3 feet 4½ inches to 4 feet 6 inches thick brick masonry steining walls at top and bottom respectively and rest on 9 feet high concrete curbs. After sinking of wells, the curb portion was plugged with lean cement concrete, steining portion filled with sand and then roofed by an R.C.C. transom slab 3 feet thick upon which rest the piers. An R.C.C. girder 6 feet wide, 5 feet thick and 35 feet long joins the two pier columns at top upon which rest four prestressed R.C.C. beams (each 9 feet top and bottom widths 4'–6" and 1' – 8" respectively and web thickness 7¼") to accommodate the road-way. The bridge has 28 feet road width and 4 feet wide foot-paths on either side. The layout of the bridge span and the foundation details are shown in Plate No. III.

III. PRELIMINARIES

3.1 The river Indus at Ghazi Ghati bridge site has a khadir width of about 10 miles. It normally flows in two or three prominent channels with the main stream usually in the centre. The bridge at Ghazi Ghat has been placed almost in the middle of the khadir width on a firm high bela by closing its left arm to permit access to the working area. The entire river was thus made to flow on the right of the bridge towards Dera Ghazi Khan side, evers-since the year 1977-78 when the construction activity had been taken in hand. The bela on which the bridge has been constructed gets inundated after attaining the stage of medium flood limit, i.e. above a discharge of 3,75,000 cusecs in the river.

3.2 By January 1983, the bridge was completed to a stage that it could take the river discharge. The Highways Department Punjab, therefore, made plans to divert the river in the winter season of 1982-83. This plan envisaged excavation of a long leading channel (by re-shaping an old small river creek in a length of 38,000 feet shown in red lines on Plate No. IV) off-taking from the main river about 5 miles upstream and out falling in a left hand side creek about 2 miles down-stream of the bridge. The river flowing in a single channel immediately below the off-take point of this leading channel was then to be closed by putting a diversion bund across the flowing water. The leading channel had been proposed to be excavated in the width of 100 feet upto the sub-soil water table by providing a small cunette of 25 feet width on one side, dug about 2 feet below the sub-soil water. The plan of diversion as chalked out by the Highways Department for the year 1982-83 has been marked in red colour on the layout plan at Plate No. IV.

3.3 In a meeting held on 4.12.1982 to co-ordinate the Annual Canal Closure periods for creating low flows in river Indus at the time of undertaking the diversion operations at Ghazi Ghat, it had been desired by the Highways Department that some Officers of the Irrigation Department Punjab should visit the site to look into the diversion arrangements devised by them. The site visit on 11.12.1982 revealed that the leading channel being excavated was too narrow and shallow, as much as, its bed would remain high and dry at the time of low flows in the river while

attempting the diversion. Subsequent inspection on 6.1.1983, when a discharge of about 7,500 cusecs was flowing in the river, confirmed this observation as the bed of excavated leading channel at the mouth (R.L. 393 ±)* was found to be more than 3.5 feet higher than the water level of the river (R.L. 389±)*. The out-fall point of the leading channel (length over 7 miles) meeting the left creek of the river with bed at R.L. 386 + permitted only a mild longitudinal slope of 1 : 5500 which could not generate eroding velocities or cause retrogression to develop from the tail end. The left creek of the river into which leading channel discharge was to outfall meet the main river further about 10 miles lower down (Plate No. X) which too could not be expected to scour/develop rapidly on account of its long path.

3.4 During the year 1982-83 the river was flowing at a distance of about 2 miles on the right side of the bridge line and continued to remain in a distant position for quite a length both on the upstream and downstream sides (Plate No. IV). A small side creek on the left (with a higher bed level) however passed about 2 miles downstream of the road bridge into which the leading channel of a steep slope was not possible to join. These limitations as well as the water level of the river in the low flow stage being more than 3.5 feet below the mouth of the excavated leading channel coupled with the fact that a major portion of the working season had already gone by, the diversion of river towards the bridge in the winter season of 1982-83 did not appear to be a practical proposition in the given situation.

3.5 The existence of favourable river condition is a pre-requisite for any successful diversion operation. Such conditions if not existing naturally, are required to be created by proper and timely manipulation of the river well in advance of the expected diversion time. In fact the training of the river conducive for diversion has to be started two to three years ahead of the anticipated diversion time. The adverse conditions existing at site were liable to remain unfavourable unless some changes had been brought about by suitably and progressively tinkering with the river according to the site position occurring from time to time. Such operations to the extent practicable upto the beginning of flood season 1983 were accordingly planned and undertaken.

3.6 For working out a detailed plan of action to divert and tinker with the river, an accurate topographical ground survey and latest river course as well as the active and dormant creeks in a distance of about 15 miles upstream (covering at least two or three loops of the river) and 5 miles downstream of the bridge is a pre-requisite. No such survey work had been done in the past except in the year 1974 for undertaking initial model studies to determine the bridge location and the layout of the river training works. The Highways Department was therefore advised to pick up this basic data again and this became available towards end March 1983.

3.7 The existence of an active river arm on the right, namely Dhrama Creek, and possible development of any other loop on the upstream was liable to shift the river position further on the right side away from the bridge axis. This situation would have made the diversion efforts still more difficult. To forestall this development, it was considered advisable to expedite

* NOTE: Levels given in this paper are with reference to the bench mark of the Highways Department used for the construction of the bridge which is 3.30 feet higher than the Canal/G.T.S. datum.

construction of the right Spur R–1. Fortunately the spur was completed by June 1983 and this provision not only checked further development of the right arm but during the ensuing flood season also gave a push to the river to come closer to the bridge. (See Plates No. IV and X depicting river position before during and after 1983 flood season respectively).

3.8 Farness of the river on the right from the bridge axis required excavation of long leading cuts to connect the main river via the bridge spans. This operation in itself would have required a lot of excavation work in a limited period apart from being an extremely expensive proposition. The left creek flowing about 2 miles downstream of the bridge had a higher bed which prohibited excavation of deeper cuts or to achieve steep slopes, for generating the scouring velocities (as already stated in para 3.3, at best longitudinal slope of 1:5500 was available and the mouth of the leading cut at off-take point was to remain about 3.5' higher than the low water level in the river at the diversion stage).

3.9 In a situation given in para 3.8, it was considered advantageous to strive for development of the dormant left creek which had been made to join across the bridge via Bay No. 2 (numbering from left Ghazi Ghat side) by excavating the leading channel as described in paras 3.2 & 3.3. Towards this end, the plug bunds closing mouths of the old creeks, leading to the blocked left river arm, were removed at Point A–A and B–B (refer Plate No. IV). This made some water, coming from an upstream point in the left arm, to flow towards the bridge. Encouraged by this phenomena, the left arm flow channels joining the main river were blocked at points C–C and D–D by cross bunds. The obstructions that could hinder the passage of water in these creeks were also removed and tight gullets widened all along the route to attract as much flow towards the bridge as could be manipulated. To augment the discharge for possible further development of this passage, the flow of yet another side creek of the river further upstream was diverted on this side by putting initially a langar chhap (pervious wall of pilchi rolls tied together between row of wooden pegs and loaded with stone/earth filled bags) and then by putting a bund at its back at points E–E and F–F respectively. Motor launches were made to run in the creeks for generating waves to disturb/loose/pick up the fine particles of the soil by flowing water.

3.10 The tinkering efforts enunciated in para 3.9 taken up in January–March 1983, made the passage of the creek under the bridge to deepen and develop in width from original of 50' to about 200' during the low stage of the river flow in winter. The discharge passing under the bridge along this passage was then observed to be a maximum of 25% of the total river flow so long as the cross bunds at C–C, D–D and F–F remained in position.

3.11 The flow of water in the creek under the bridge can be termed analogous to that of a leading channel of an inundation canal off-take arrangements, whereby the supply is tapped from the upper surface of river sheet flow by a side channel from a long distance upstream. The side channels have usually higher bed and flatter slope, most conducive for a comparatively silt free flow of water into the inundation canal system. Exactly similar situation prevailed in this case.

The water coming towards the bridge was via side channel of old left arm and from above point E–E. The water level along this route was about 2 feet higher than river water opposite the bridge confirming the character of its flatter slope. Comparatively silt free water also helped in picking up the fine particles on way to deepen its bed. Sizable flow of water in this manner helped to enlarge the section of the left creek as well.

3.12 The first freshet of about 2 lac cusecs below Taunsa Barrage in late May 1983 partially or wholly washed away the cross bunds at point C, D & F and the old flow routes direct to the river became active again. The flow of water towards the bridge via creeks abruptly fell to about 4% of the river discharge which too completely stopped in September 1983 on siltation of their mouths during the flood season.

3.13 A maximum of about 30,000 to 40,000 cusecs is reported to have crossed the bridge in Bays 2 and 3 on development of the left creek before or during the flood season of 1983. The creek section thus got widened and deepened and could therefore now serve as an outfall channel of the leading cuts in the future diversion plans. The dis-connection of the creeks at the mouth made this channel in winter to function as a seepage drain causing the sub-soil water to fall in its close proximity. Whereas the junction of this channel with the main river remains at a distance of about 10–12 miles downstream the bridge line, the standing seepage water in it was however 4' to 5' lower than the river level at bridge line. This situation no doubt became helpful in excavating relatively deeper leading cuts by steeper longitudinal slope (may be about 1:4000 as against possible slope of 1:5500 previously) to generate somewhat scouring velocities in them.

3.14 An attempt to close the right arm of the river namely "Dhhrama Creek" was also made by the Highways Department in low stage of its flow (discharge below 1000 cusecs) in early April 1983 by putting langar – chhap at point H–H and at its back, a vague effort of putting a cross bund at point G–G. This operation therefore did not yield any fruitful result.

IV. DIVERSION PROPOSALS

4.1 In the Punjab, the rivers can be broadly divided into two categories viz the rivers flowing in incised channels forming sharp loops (River Ravi is a typical example) and those in the braided form flowing in parallel channels. In the former category, the diversions are comparatively easy, as usually favourable chord-loop ratio is available. In the later case, the diversion is more complex and problematic, as steep slopes in the diversion channel are not normally available. The usual practice in such cases have been to create artificial ponding up of the water to generate steep slopes and eroding velocities in the diversion channel. The amount of heading up required in these cases is usually difficult to attain by normal process of throwing langar chhap, stone boom and a cut-off bund across the flowing river.

4.2 Experience has shown that in the alluvial soils the closure of the final river gap is very

difficult to achieve if the head across the plug bund becomes more than about 2.0 feet or shooting velocities of over 12 to 15 feet are generated at the closure point. The usual practice in such cases has been to construct temporary regulator of one type or the other as had been done in cases of diversion of river Indus at Taunsa, Gudu, Kalabagh and Chashma Barrages construction.

4.3 The usual concept of diversion is that the diversion channel (leading cuts) should be so designed as to start taking discharge as soon as its mouth is opened and the flow goes on increasing as the diversion operations progress. The leading cuts should have adequate capacity to take discharge of the incoming river with minimum heading up at the stage of final river closure.

4.4 At Ghazi Ghat in view of the inter-provincial character of river Indus, a large quantity of water continues to flow in it in the winter season also to meet the irrigation requirements of the Sind Province canals. The hydrograph of the river from October to March after the construction of Tarbela Dam, from the year 1976-77 to 1982-83 (Plate No. V), shows that a discharge of 30,000 cusecs to 50,000 cusecs has historically been flowing in the river channel below Taunsa Barrage except for a short period of 15 to 20 days from late December to mid January i.e. at the time of Sind Canals annual closure, when it falls to about 15,000 cusecs. Under such high flow condition in the river, the sub-soil water table in the area remains very high and it therefore does not permit excavation of sufficiently deep leading cuts that would begin taking sizable discharge on opening of their mouths at the time of diversion or provide ample relief in reducing the flow of water at the site of throwing a bund across the flowing water.

4.5 Taking the advantage of available diversion capacity of water for Sind Province from the upstream via Chashma-Jhelum and Taunsa-Panjnad Links, (after accounting for the transfer requirements of the canals in the Punjab Province), it is observed that normally a discharge of about 10,000 cusecs to 20,000 cusecs would still be flowing at Ghazi Ghat at the time of diversion operations in January/February. Even if by adjusting the closures of Punjab and Sind Canals, an attempt is made to create Nil flow condition below Taunsa about 4,000 to 5,000 cusecs discharge would even then be flowing below the Barrage from leaking gates and for maintaining the differential head across the structure within safe limits. (Differential head across limit fixed at 22 feet against designed 30 feet). In addition, a regeneration of the order of 2000 to 4000 cusecs usually takes places in the river belt upto Ghazi Ghat. Under such a situation, the minimum discharge that can be expected at the time of diversion under ideal conditions of manageable flow and weather, may range from 6000 to 8000 cusecs. This statement is confirmed from the fact that a discharge of 7551 cusecs had actually been observed at Ghazi Ghat on 6–1–1983 at a stage when the effect of closure conditions below Taunsa for the last 3 to 4 days had been generated to give relief for repairing the damaged gates at Sukkur Barrage.

4.6 From the analysis given in para 4.5, it became evidently clear that the capacity of leading cuts cannot be kept less than 7000 cusecs. For normal diversion of the river without the provision of a temporary regulator, leading cuts should be excavated sufficiently deep to generate flow depth

of about 5 feet initially and then 6' to 7' during the diversion operations. A study of the long section of the main river and the left creek through the bridge (Plate No. XIII) revealed difference in the bed levels of over 9 feet. The scoured bed of the left creek near the bridge site is at R.L. 384 ± while the corresponding level in the straight river flow position (without a bend or constriction) had been observed to be around R.L. 375 ± (average). The water level expected at the bridge site as derived from the gauge discharge curve at Plate No. VI would be about R.L. 386 ±, corresponding to a river discharge of 6000 to 8000 cusecs. To generate a flow depth of about 5 feet at the begining of diversion operation, matching with the above discharge, the leading cuts are necessarily required to be excavated upto bed R.L. 381 ± (i.e. water R.L. 386 to 5' depth), which is 3 feet below the scoured bed of the left creek under the bridge, into which the diversion water has to outfall. This means that the left creek will also require excavation appropriately upto its junction point with the main river channel in a length of about 10 to 12 miles so as to generate a flow depth of about 5 feet in the same at the time of diversion. This would entail enormous quantity of earth-work below water in the left creek. In addition, the sub-soil water table in the area at the bridge site during the stage of construction had been observed at R.L. 390 ± which meant excavating the leading cuts about 9 feet below the sub-soil water table to generate initially a flow depth of 5 feet in them at the time of undertaking the diversion operations. Such a deep excavation in the long stretch of the leading cuts did not seem to be a feasible proposition by the machinery available within the country, unless elaborate arrangements of pumping/dewatering along the route had been resorted to. Such a venture would have itself been a big project not manageable within the available time frame, leaving apart its exorbitant cost.

4.7 The feasibility of diversion with and without the provision of a temporary regulator and whether the leading cuts are made to outfall into the left creek or the main river channel was therefore deliberated at length and by having regards to the limitations enunciated in para 4.6, the consensus had been that the diversion of the river at Ghazi Ghat would not be possible to accomplish in the given situation without a temporary regulator.

V. DIVERSION PLANS

5.1 In a joint meeting of the Ministers for Irrigation & Power and Communication & Works Departments held on 7–6–1983, under the directive of the Governor Punjab, and attended by the two Administrative Secretaries, it was decided to entrust the work of diverting River Indus through the Ghazi Ghat Road Bridge to the Irrigation & Power Department Punjab, being an intricate and highly technical hydraulic problem. As a sequel of this decision, a Project Oriented Organization comprising of two Divisions (one Civil and one Mechanical) headed by Chief Engineer (Floods) was created within the Irrigation & Power Department, Punjab with effect from 2–7–1983 on sanction of the staff by the Finance Department.

5.2 On decision of the Government as above, a team of senior officers of the Irrigation &

Power Department inspected in detail on 12–6–1983 the river position, studied survey plans prepared by the Highways Department in March 1983 and after lengthy deliberations arrived at the consensus to construct a temporary regulator for the diversion operation as concluded already in para 4.7. The site visit revealed three options for the location of the temporary regulator (shown in dotted and single/double cross lines on Plate No. VII) to suit the river position then obtaining at site, as under :–

i) Below the river creek opposite spur R–1 at a distance of about 12000 feet from the bridge line (shown in double cross dotted lines).

ii) Below the mouth of the creek at a distance of about 4000 feet from the bridge line (shown in single cross dotted lines).

iii) On the left bank of the left river creek along the bridge line-distance about one mile from the right abutment (shown in red colour dotted lines).

Tentative route of the leading cuts suitable for each option are likewise marked on Plate No. VII.

5.3 The position of the regulator opposite Spur R–1, required excavation of long leading cuts (about 4 mile each) entailing huge quantities of earth work. This site also required construction of a long protection bund connecting earthen part of Right Guide Bank with the regulator along the left bank of the river to check flow of diverted water on to the main river again on upstream of the bridge line. In addition, the access to site, being exposed from all sides, was prone to inundation and damage by sheet flow of water from above left bela during winter freshets and could thus be problematic at critical times. These factors therefore did not weigh heavily in support of this location and hence the option was ruled out.

5.4 Location of the regulator along the bridge line had a great advantage of ready accessibility on account of approach road embankment having already been constructed by the Highways Department upto that site. It was however liable to pose a serious problem of diverting the river all the way from Dhrama Creek along the right high bank, first to the main river, then main river on to another creek and finally into the regulator; a process spread over a long distance of about two miles in the active river plain. The location of temporary regulator was to be about a mile lower down the off-take points of the leading cuts calling for additional heading up capability to be incorporated in the design of the regulator to generate the desired water level there. Even if this element is ignored, the operations involved for diversion of the river in a long stretch was quite risky and hence this option had also to be dropped out.

5.5 The location of regulator below the mouth of creek about 4000 feet upstream the bridge line appeared most promising from consideration of river approach to divert the same and in the

lay-out of short leading cuts (each about two miles length) close to the right guide bank nose. The site had no ready available access to the area, but the same could easily be established quickly at a nominal cost. The consensus of opinion was, therefore, more in favour of locating the temporary regulator at this site subject to confirmation by the model studies and also in case the river conditions remained favourable here even after the flood season.

5.6 A study of the River Survey Plan (Plate No. VII) would reveal that there existed no easy way of connecting the leading cuts with the main river in a short distance below the road bridge. To connect main channel of the river on upstream and downstream sides via the road bridge (tentative alignment marked on Plates No. VII & X) meant excavation of long leading cuts of about 5 miles length each. This entailed enormous quantity of earth work excavation which did not appear feasible in the available time frame. By having regards to these factors, the general consensus was, therefore more in favour of utilizing the left arm which had incidently scoured/developed recently as discussed in paras 3.9, 3.10 and 3.13. On the upstream side, the first leading cut could follow the alignment of the existing small creek passing the road bridge almost in the middle and then join the left arm at a distance of about 1500 feet below the bridge line. The other cuts could be spaced suitably upstream by making the upper-most to join the left arm at a distance of about 1500 feet above the bridge line. The cuts were proposed to be excavated as deep as practicable and be able to take a discharge of about 8000 to 10,000 cusecs at the time of diversion.

5.7 Model tray was immediately set up at the Hydraulic Research Station Nandipur by incorporating the details of river 17 miles upstream and 3 miles downstream of the bridge line (as existing in June 1983) to determine the optimum location of the temporary regulator. The capacity of the regulator was assumed to be 15000 cusecs as it had been estimated that the discharge at diversion stage would normally be of the order of 8 to 10 thousand cusecs, but any rainfall in the lower catchment of the river may increase the incoming discharge to about 15000 cusecs. By assuming a flow depth of roughly 6 feet about the weir crest and in a non-modular working condition upto the river inflow of about 9000 cusecs, the water-way of the temporary regulator was kept at 300 feet (discussed later with more detail in para 7.4).

5.8 Model studies for the various locations of the temporary regulator (Research Report No. IRR–807/Hyd/DGK Div–2, July 1983) showed that for the alignment along the approach road (option iii para 5.2), the spill flow at this site became more and more intense as the river discharge increased beyond 4 lac cusecs. The river continued to flow in three channels even at low flow stage of 10,000 cusecs. The extreme right channel remained the dominant (Plate No. VII) part taking about 70% of the river discharge while the two left channels took about 15% discharge each. This location thus required three independent closure attempts to cross the intervening shoals for bringing the water on to the temporary regulator for a final closure. This obviously would be an extremely difficult task to accomplish in a limited time of low flow river stage. Another series of tests in the upward position of the temporary regulator at a distance ranging from 2500' to 5000' from the bridge line were then carried out. The location at about 3500'

upstream of the bridge line and at a distance of about 1200' from the river edge showed only mild velocity of spill water flow at all stages of river discharge in this zone. The working area remained at a desirable distance from the ultimate river bank position after the effect of eroding the left bank during the ensuing flood season is accounted for. Operation of the model for a hydrograph of one year upto 5 lac cusecs showed that deep channel of the river had a tendency to shift more towards the left bank opposite the temporary regulator unless any major change in the river course much upwards upsets the flow pattern. This tendency of the river appeared quite favourable for the ultimate diversion operation. The earlier concensus after site visit by the Senior Officers (paras 5.2 and 5.5) having been confirmed by the studies made on the model, the site for construction of the temporary regulator at a distance of about 3500 feet upstream of the bridge line and at a distance of roughly 1200' from the river edge was therefore finalized by end July 1983 to undertake the construction work as soon as practicable.

5.9 The location of the temporary regulator as finalized at para 5.8 was in alignment almost tangential to the right guide bank of the bridge and thus behaved more or less as its extension. The linkage of the temporary regulator via its approach road embankment planned to be tied on the back of Right Guide Bank could therefore be made to form an integral part of the permanent river training works on right side of the bridge. In this manner, the location of spur-2 (still to be constructed) could move upwards, closer to spur R-1, thus reducing the mutual distance between the training works. Introduction of third training work in the form of temporary regulator would thus be quite conducive in controlling the development of any sharp river meander close to the bridge on the right side. With the reduction of the distance between the training works, the size/dimension of Spur-2 could as well as compromised to eocnomise in the cost of its construction. The lay-out of Spur R-2 in the changed situation has tenatively been marked in green colour single cross dotted lines on the plan at Plate No. VII.

5.10 Model Studies were also carried out to precisely determine a suitable shape of the guide banks of the temporary regulator (Research Report No. IRR-810/Hyd/DGK, Div-3, August 1983). First test was made with symmetrical guide banks on upstream and downstream sides as had been proposed by the Design Directorate (Plate No. VIII). This showed a tendency of separation and starvation along right guide bank close to the structure. The right guide bank seemed to be longer in legnth and was throwing the flow towards the left guide bank obliquely, with the result, that starvation of flow along the right guide bank alignment occurred. Subsequent tests conducted were with an objective in view to eliminate the starvation and to avoid direct hit of the diverted flow on to the left guide bank alignment. Shortening and curving of the upstream right guide bank considerably helped in removing this draw-back. Further modifications in the shape and length of both upstream and downstream guide banks gave results more suitable from hydraulic stand-point and for the objective of proper river flow diversion through the temporary regulator. Progressive improvement in the hydraulic flow conditions in relation to the various shapes of the guide banks has been exhibited in Plate No. VIII. These modifications, in addition, obviated the need for the provision of any mole prong projecting from the diversion bund in the vicinity of

right guide bank as had been proposed by the Design Office.

5.11 The diversion plan as finalized therefore comprised of the following major components (lay-out of works marked in single cross dotted lines on Plate No. VII).

i) Construction of TEMPORARY REGULATOR for a capacity of 9000 cusecs and 15000 cusecs in the non modular/semi modular working flow conditions respectively at a distance of about 3500' up stream of the bridge line in a direction almost tangential to the right guide bank. The structure will be placed at a distance of about 1200' from the existing river edge so as to retain a minimum distance of about 800' from the left bank after its erosion in the flood season of 1983. The shape of the guide banks of the temporary regulator will be in accordance with the modifications suggested by the Irrigation Research Institute as discussed in para 5.10 and shown in Plate No. VIII.

ii) Construction of an ACCESS ROAD upto the temporary regulator to maintain approach during high flows or winter freshets. With the higher river flows in summer, the ground of the bela had become boggy and standing water in an intervening creek prohibited normal access to the area. Construction of a short embankment from the back of right guide bank upto the regulator site could serve the desired purpose.

iii) Extension of 11 k.V. TRANSMISSION LINE from Ghazi Ghat upto the site of temporary regulator to dewater the area for construction of the structure below the sub-soil water-table. To cater for break-down of power from the national grid, provision for stand-by generation will also have to be catered for at site.

iv) Construction of DIVERSION BUND linking shank of Spur R-1 upto the right edge of the river facing the temporary regulator. This bund should be sufficiently strong to withstand the pressure of about 50,000 cusecs river discharge (expected upto March 1984 by which time the right approach road embankment will have to be completed).

v) Excavation of LEADING CUTS to connect the river with the left creek crossing the road bridge in bays 2 and 3 (numbering from left Ghazi Ghat side). The size of leading cuts should be sufficient to pass a discharge of 8000 cusecs to 10,000 cusecs at the time of river diversion.

vi) PLUGGING/DIVERSION OF RIVER CHANNELS/CREEKS of the right side to confine the river in one channel for ease of constructing the diversion bund in its maximum length. A continuous watch on the river behaviour will also have to be

kept for progressive tinkering/training of the river to generate flow pattern that will be more conducive for the diversion operation.

vii) Construction of DIVERSION CHANNEL to link the river on upstream and down-stream side via the temporary regulator so as to permit smooth passage of water through it as soon as blocking of the main river channel is taken in hand.

viii) CLOSURE OF MAIN RIVER CHANNEL by diverting the river flow through the temporary regulator. This operation will be udnertaken as soon as the discharge in the river is reduced by manipulating the programme of annual canal closures in the Provinces of Punjab and Sind. The closure bund will in fact be an extension of the diversion bund in the portion of the main river channel.

ix) Lowering the gates of temporary regulator to stop the waer flowing across the structure and then putting a PLUG BUND at its back. The lowering of gates shall make the water to rise on upstream and create ponding effect above the temporary regulator and thus force the water to flow through the leading cuts towards the road bridge. This operation will be a concluding activity in the chain of works to accomplish the diversion of river through the bridge.

5.12 The steps enunciated in para 5.11 above do not take into account the on-time completion of other ancilliary works, which though not related to the aspect of river diversion are the essential components of the road bridge before commissioning to public traffic and to face any flood situation or higher flows in the river. These works are :—

i) SPUR R-2. This spur had not been constructed so far perhaps due to non-favourable flow conditions of the river in relation to the alignment of the spur. The construction of Spur R-1 in June 1983 and consequently the shift of the river on its downstream towards the left bank in the flood season of 1983 had formed a sandy bela where the nose and shank portion of spur R-2 could now be constructed. The blocking of the river course at the time of diversion creates a pondage effect and the belas on upstream side of the structures invariably get submerged. This phenomena is expected to be more pronounced at Ghazi Ghat, because no prominent natural old well defined wide river channel crosses the bridge structure. The development of the river passage through the bridge will therefore take quite some time and till that stage, ponding effect in the area will persist. In such a situation, the construction of Spur R-2 in a solid form after the creation of pond (i.e. on completion of diversion operations) will be extremely difficult (perhaps impractable) and un-economical. The stone aprons and pitching in this situation will also not be possible to lay at the desired low level. The borrowing of earth to construct the emabnkment of shank would not be possible

from the adjoining areas and thus entail exorbitant cost of construction at a later stage. The construction of Spur R-2 simultaneously with the completion of diversion works should therefore be endeavoured as its non-provision may allow the river to develop non-favourable river meander at the right guide bank nose or near the right approach road and thus pose problem of safety for the permanent works. The layout of this spur closer to Spur R-1 (due to introduction of the third training work on the right side in the form of temporary Regulator as discussed in para 5.9) and with reduced length of its shank on account of combination with the Diversion Bund (Plate No. VII), the spur in the prevailing set of river conditions could amostly entirely be constructed on the dry bela with ease.

ii) RIGHT SIDE APPROACH ROAD – The construction of Dera Ghazi Khan approach road on the right side is closely linked with the progressive advancement of diversion bund from the high bank on the west. To economise in construction cost, the diversion bund was planned to serve the purpose for low flow discharge in the river to meet the Rabi Crop water requirements of Sind Province Canals i.e. upto a maximum river discharge of 50,000 cusecs till March 1984. With the opening of non-perennial canals from April, the water requirements of Sind Province increase and it would therefore be obligatory to complete the right side approach road emabankment by end March 1984.

iii) MOLE PRONGS OF SPURS R–1 and L–1 – Model Studies (Research Report No. IRR-805/Hyd/DGK, Div-1, June 1983) have indicated that the newly constructed Spur R-1 experienced a parallel velocity of the order of 6.0 feet per second along the upstream face of its shank at various stages of the river flow. Similar would be the condition on Spur L-1 when the river swings to that side in future. These velocities are inimical to the safety of the spurs. The upper most spurs R-1 and L-1 play a dominant role in receiving the initial thrust of the meandering river and then guiding its flow lower down towards the bridge. Any damage to these spurs or their malfunctioning can have repercussions of far-reaching consequences. Model Studies indicated that provision of mole prong stone spurs 875' long on upstream tied to the shanks about 2250' from the tip of the J-heads (Plates No. VII & X) would eliminate development of any dangerous parallel velocities along their shanks. The construction of the two mole prongs prior to the creation of a water reservoir (pond) is essential on account of reasons similar to those enunciated in sub para (i) regarding the provision of Spur R-2.

VI. REVISION OF DIVERSION PLAN

6.1 The work plan detailed in paras 5.11 and 5.12 required execution of enormous quantity

of stone and earth work in addition to the construction of an intricate hydraulic structure namely, the temporary regulator. The pattern of river flow below Taunsa Barrage in summer, after the creation of Chashma Barrage and Tarbela Dam reservoirs from the year 1976, as shown in Plate No. IX, indicated that the construction activity in the field could commence from beginning of September 1983, as the flood stage of river Indus in the past has generally been ending by August. Again the stage of minimum river flow below Taunsa during winter has been occurring in end December to early January (Plate No. V) coinciding with the annual closure of Sukkur Barrage Canals in the Sind Province, and in this period it would be desirable to accomplish the diversion operations. The working time for the construction of various works therefore comprised of only four months from September to December 1983 which made the task extremely difficult for completion in a very tight time schedule.

6.2 With the limitation of time in view, steps were therefore taken on emergency basis, to proceed with maximum speed to quickly complete the preliminaries, like, extension of electric transmission line, construction of access road, selection/transportation of earth-moving machinery and other construction equipment, conducting model studies, working out design details as well as steps for tendering/award of works to mobilize the contractors. The preliminaries had been completed by the end August 1983 and mustering of necessary resources (men, material and machinery) were organised simultaneously on a CRITICAL PATH METHOD to ensure meeting of the end results on time.

6.3 The extension of 11 k.V. electric transmission line over a distance of 7 miles from Ghazi Ghat was got stretched, transformer and distribution panels placed in the control room and also about a mile long approach road from right guide bank to the site of temporary regulator had been completed by 10th September 1983. The sinking of tubewells for dewatering and excavation of working pit to construct the temporary regulator was also taken up in early September.

6.4 River Indus below Taunsa Barrage has been in a state of flood for much longer duration in the year 1983 as compared to the previous years (Plate No. IX). The time for which the river remained in floods stages in the past few years is given here under :–

Time (Hours)

Year	Low flood stage	Medium flood stage	High Flood stage
1983	541	404	16
1982	252	5	-
1981	460	54	-
1980	534	34	-
1979	425	255	-
*1978	548	847	38
1977	390	85	-
*1976	467	364	41
1975	204	96	42
1974	360	-	-

Low flood stage = Discharge above 2.5 lac cusecs

Medium flood stage = Discharge above 3.75 lac cusecs.

High flood stage = Discharge above 5.0 lac cusecs.

* Exceptionally wet years.

6.5 Spur R-1 on the right was captured by the active river flow by early floods and kept hugging along it upto August 1983. This resulted in the development of the main river course along the left high bank (on the upstream and downstream sides. of the proposed site of temporary regulator) and the right channel assumed the role of side creeks (Plate No. VII). This pattern of flow became very favourable to the scheme of river diversion works as had been devised so far (shown in red colour on Plate No. VII). At the fag end of the flood season, the river unexpectedly rose again and remained in a state of flood (with discharge above 2.50 lac cusecs) for over three weeks from 22nd August to 13th September 1983. In this period a maximum discharge of 4,48,272 cusecs passed below Taunsa Barrage on 31.8.1983. The last flood wave considerably changed the flow pattern on the upstream and also left its hugging action along Spur R-1. This phenomena brought about a major change of the river course in the vicinity of road bridge (Plate No. X). The change became visible in mid September when the discharge in the river reduced to about 2.0 lac cusecs.

6.6 A study of the newly developed river course (Plate No. X) would show that the original scheme of constructing the river diversion works (shown in red colour Plate No.VII) was no longer feasible because of extensive shoaling/silting tendency opposite the off-take points of the proposed leading cuts as well as the temporary regulator site. Senior Officers of the Department again inspected the area on 22.9.1983, held detailed discussions at site and recommended to modify the work plan suitably, as shown in Plate No. X as under :–

i) The site of the temporary regulator may be shifted downwards in line with and close to the road embankment on its upstream side (now as per option iii para 5.2).

ii) The approach road embankment from Dera Ghazi Khan side may be used as diversion bund.

iii) Spur R-2 should be constructed at its original location (as the temporary regulator at the new site will no longer serve any additional role of river training work on the right side), by constructing the spur head and earthen shank on either side of the river on the newly developed sandy belas. The part of the shank in the river portion could be constructed at an appropriate time after the diversion operations have been accomplished.

iv) The lay-out of the leading cuts should be shifted downwards, closer to the right guide bank nose by keeping the off-take points preferably in contact with the flowing river or in the deeper portion of the channel in between the firm old and new sandy belas which had now become dormant but maintained its linkage with the active river.

6.7 The recommendations listed in para 6.6 above were suitable so long as the right handed river meander close to the diverson works did not advance lower down the bridge line, as in that

case, the sandy bela opposite the off-take points of the leading cuts will grow in size and travel lower down to block the diversion cahnnel of the temporary regulator. This development (of which the chance could not be ruled out) would pose great difficulty to activate the diversion channel of the temporary regulator and may perhaps even frustrate the effect of putting the diversion bund across the main river channel and thus jeopardize the entire diversion plan. A careful watch on the behaviour of the river was therefore essential to avoid creation of any such adverse situation.

6.8 The rvevised scheme of works had its own limitations and merits as briefly listed here under. (Earlier proposal. Plate No. VII - single cross dotted line, modifed plan No. X-red colour).

i) The layout of leading cuts in the earlier proposal was more favourable for the development of a desirable river course on the eastern side of Spur R-2 towards the road bridge.

ii) In the original set up, Spur R-2 could be constructed as a single whole without any intermediate gap. The legth of earthen shank could also be curtailed by making it to join with diversion bund in a short distance, without encountering any deep river channel on-way. The construction cost of this spur would have been thus far less as compared to the manner of its execution in the revised plan.

iii) A portion of the leading cut No. 1 near the off-take point could serve the dual purpose of diversion channel on the upstream side of the temporary regulator and thus economise in the construction costs.

iv) Further development of the left handed river meander close to the diversion works, in the earlier proposal, would have been still more favourable in acquiring a desirable approach of the river towards the bridge. Constant vigil on the river behaviour would have perhaps not been called for to the extent demanded by the later proposal.

v) The temporary regulator in the original lay out had been placed just below the off-take point of the leading cuts which was more appropriate from the operational view-point. In the modified proposal, the temporary regulator had been placed roughly 3000 feet to 4000 feet lower down the leading cuts which in turn required building up of some additional head of water there to generate equivalent flow condition in the leading cuts about a mile upstream. The setting of the crest of temporary regulator in the revised position had also to be kept at a lower level to compensate for the proportionate drop of river slope in the length so as to generate equivalent depth of water flow above the crest. This also meant that the height of gates on the temporary regulator had to be increased to cater for the additional heading up of water as well as to allow for the fall of water by river

slope on account of distant location of the two iner-related works.

vi) The only advantage in the revised plan was that the need to construct a separate diversion bund on the right side had been obviated, because now the road embankment from Dera Ghazi Khan side could serve the dual purpose and thus give a cost saving to that extent. In this situation road embankment was also to become ready simultaneously with the completion of the other diversion works.

6.9 With the revision of the work plan, the original site for the construction of the temporary regulator was abandoned. The electric transmission line was quickly got re-routed, new sub-station established for housing the transformer and the distribution control panels and line re-energized on October 13, 1983. The material of the already sunk tubewells was also salvaged and sinking of the tubewells at the new site taken in hand again. Excavation of the new working pit was also started without any loss of time by resorting to open pumping initially and by dewatering with tubewells subsequently.

6.10 Fresh river survey of the area was carried out quickly and fed to the Irrigation Research Institute for conducting model studies about the lay-out of revised diversion works and the manner of constructing Spur R-2 with a view to incorporate further improvements. Apprehending that the river channel might have widened and deependd by the prolonged high river flows in the recent flood season, the determination of an appropriate crest level of the temporary regulator was given a particular significance in the model studies. The shape of the guide banks of the temporary regulator and the lay-out of its diversion channel was again tested on the model to modify them in relation to the changed set of river course.

6.11 The prolonged flood wave of the summer season, coupled with drastic change of the river course in the vicinity of road bridge gave a serious set back to the construction work for a period of at least one month. The construction activity of about two weeks on the original site of the temporary regulator had virtually gone waste. The work remained completely suspended for about 10 days, waiting for the outcome of the revised layout plan. On the final decision to shift the site of temporary regulator lower down, arrangements for re-routing of the 11 k.V. electric transmission line and shifting of the work force took its own time which also accounted for the overall set back. The entire ground of belas had become boggy due to submergence/inundation by late floods and this laid restriction for the shifting of heavy earth moving and other machinery to the works areas. The original planning of completing the diversion works in a very tight schedule by end December, 1983 no more appeared practicable. Efforts were, therefore, made to muster more resources of men, material and machinery, both in public and private sectors to bridge the back-log to the maximum possible extent. By having regards to the quantum of work and the extent of resources that could possibly be mustered, programme for the completion of temporary regulator and other diversion works was carefully chalked out afresh as shown on Plate No. XI and Plate No. XII respectively.

VII. TEMPORARY REGULATOR

7.1 The capacity of Temporary Regulator as discussed in para 5.7 had tentatively been fixed at 9000 Cs. in a non-modular working condition and for a discharge of 15,000 Cs. on semi modular functioning. While the river was flowing with a discharge of 7551 Cs. at Ghazi Ghat on 6th January 1983 (at the time of site inspection of Highways Department works by the Irrigation Officers), water elevation opposite the bridge line was observed to be R.L. 386).

7.2 The river remained in high flow stage for a very longer duration in the flood season of the year 1983 and this could have developed the main river channel to an extent greater than last year. In that situation, at low stages of the river flow, slight drop in the water elevations could have been expected in the 1983-84 winter season. Assuming that there may be a general drop of about 0.5 feet in the water levels, for design purposes, corresponding water level for a discharge of 7551 Cs. was, therefore, assumed at R.L. 385.5. The constriction of water-way to be done at the site of river closure and then erection of Langer Chhap across the flow was expected to cause water heading up by about 1 foot. Therefore elevation of water at R.L. 386.5 was assumed in the river corresponding to a discharge of 7551 Cs. Likewise water elevations at R.L. 387.0, R.L. 388.5 & R.L. 390.0 were expected to prevail in the river for the discharge of 9000 Cs., 15000 Cs and 20000 Cusecs respectively (see stage rise of water in the gauge discharge curve on the basis of data observed in the winter season of 1982-83 & 1983-84 at Plate No. VI).

7.3 Non-silting velocity of water in any channel with normal longitudinal slope requires a minimum water depth of 5 to 6 feet for any discharge about 1000 Cs. The minimum depth of flow over the crest of the temporary regulator was therefore, desired to be kept in no case less than this limit at the time of starting diversion of water through it. Assuming that a minimum flow depth of 5.5 feet must prevail over the crest of Temporary Regulator even at a low discharge of 7500 cusecs in the river, the level of crest worked out to be R.L. 386.5 - 5.5 feet = R.L. 381.0. Other parameters of the Temporary Regulator were designed on this basis.

7.4 Having fixed the crest of the temporary regulator at R.L. 381.0 as at para 7.3 above, the requirement of water-way for a discharge of 7500 cusecs and 9000 cusecs in a non-modular condition works out as under :–

i) Discharge 7500 Cs. at water elevation R.L. 386.5
Head above the crest = 5.5 feet

$$Q = C \times B \times H^{3/2} \quad \text{.....Non modular working}$$

$$\text{or } 7500 = 2 \times B \times (5.5)^{3/2}$$

$$\text{or } 7500 = 2 \times B \times 12.9$$

$$B = \frac{7500}{2 \times 12.9} = 291 \text{ feet.}$$

ii) Discharge 9000 Cs. at water elevation R.L. 387.0
Head above the crest = 6.0 feet

$$Q = C \times B \times H^{3/2} \text{ .....Non modular working}$$
$$\text{or } 9000 = 2 \times B \times (6)^{3/2}$$
$$\text{or } 9000 = 2 \times B \times 14.7$$

$$B = \frac{9000}{2 \times 14.7} = 306 \text{ feet.}$$

Like-wise water-way for a discharge of 15000 Cs. and 20,000 Cs. in semi-modular working conditions respectively works out as under :–

iii) Discharge 15000 Cs. at water elevation R.L. 388.5
Head above the crest = 7.5 feet.

$$Q = C \times B \times H^{3/2} \text{ .....Semi modular working}$$
$$\text{or } 15000 = 2.5 \times B \times (7.5)^{3/2}$$
$$\text{or } 15000 = 2.5 \times B \times 20.5$$
$$B = \frac{15000}{2.5 \times 20.5} = 292 \text{ feet}$$

iv) Discharge 2000 Cs. at water elevation R.L. 390.0

$$Q = C \times B \times H^{3/2} \text{.....Semi Modular working}$$
$$\text{or } 20000 = 2.5 \times B \times (9)^{3/2}$$
$$\text{or } 20000 = 2.5 \times B \times 2.7$$

$$B = \frac{20000}{2.5 \times 27.0} = 296 \text{ feet}$$

By having regards to the calculations made above, the general consensus was to adopt 300 feet clear water-way for the temporary regulator.

7.5 On the analogy of the temporary regulator constructed at Taunsa Barrage for river diverson, piers thickness was kept at 2.70 feet and clear spans of 10 feet width each. In this way the overall width of the temporary regulator between the abutments worked out to 378.3 feet.

7.6 The temporary regulator at Taunsa Barrage designed for a differential head of 10 feet did not stand the test (mishap on that structure due to floor damage and collapse of piers occurred at the time of diversion). It was, therefore, considered advisable to make the structure somewhat

stronger at Ghazi Ghat and cater for 12.0 feet differential head.

7.7 Perusal of the river channel long section (Plate No. XIII) will show normal bed of the river to be ranging from R.L. 372.0 to R.L. 378.0 (ignoring local deep scours at bends) in the vicinity of the bridge on the downstream side. Average river bed thus being at R.L. 375.0, the downstream floor level of the regulator being a temporary structure, was kept 1 foot higher i.e. at R.L. 376.0 from consideration of economy and to reduce pumpage for dewatering. The upstream floor being subjected to lesser pressure was, however, kept at R.L. 378.0 i.e. 2 feet higher than the downstream floor.

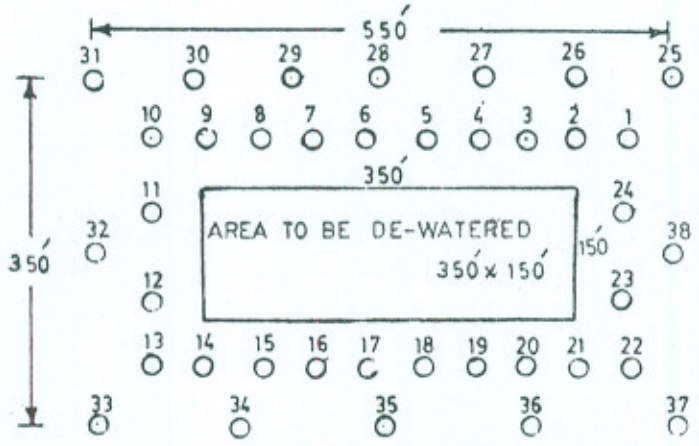
7.8 For safety of the structure against scour, exit gradient and uplift pressures, provision of steel sheet-pile line cut-off on all sides was necessary. Availability of this material from the market was explored, but to no avail. *WAPDA authorities were contacted to supply the sheet-piles from Tarbela, Guddu or any other on-going Projects but they also expressed their inability to help in the matter. Since this material could not be imported from abroad in a limited time schedule, sheet-piles kept for emergency use in the Department at Sambrial, Balloki and Panjnad Headworks was agreed to be utilized on replacement basis. The available quantity was incidently just sufficient to meet the need of the temporary regulator. The available sheet-piles (standard Larsen – Section Type 2, flange to flange width 40 cm, weight 48.8 kg. per linear meter) were in lengths of 32 feet, 16 feet and 8 feet at various sites. The depth of the sheet-pile line cut-off was accordingly manipulated in the design to avoid wastage of the scarce material. The depth of pile line at the end of the downstream floor was kept 10' – 8" while on the upstream end 8 feet. Matching provision of pile line cut-off was made on the sides to form a box of foundation and also below the upstream and downstream wing wells on either sides. The length and thickness of concrete floor was accordingly designed to be safe against the anticipated exit gradient and uplift pressures corresponding to differential head of 12 feet. The provision of stone aprons was made to withstand the scours likely to be achieved by the flow of 20000 cs. across the structure in a semi modular working condition. The lay-out of the sheet-piles, concrete floor and stone aprons etc. is given in Plate No. XIV.

7.9 The design for gates and gearing of the temporary regulator was entrustted to Mechanical Circle, Moghalpura, Lahore to cater for lifting travel height of 8 feet i.e. the bottom of the gates in up-position to be at R.L. 389.0 thus allowing free flow of 8 feet depth over the crest R.L. 381.0 for safe passage of about 20000 cs. in a semi modular condition (para 7.4 iv). This flexibility was kept to cater for any unexpected/uncontrolled increased river flow due to rainfall in the local area. The height of the gates was kept 14 feet i.e. terminating at R.L. 395.0 in completely lowered position. This level corresponded to water elevation which was likely to be generated by heading up on upstream of the temporary regulator with closed gates position corresponding to river inflow of about 15000 cs. as exhibited by model studies (Research letter No. 422-C/3130 dated 28.12.1983 - Table II) carried out in the Irrigation Research Institute Nandipur (Annexure-B).

* Water and Power Development Authority, Pakistan.

7.10 In winter the sub-soil water table during the period of bridge construction had been observed to be ranging from R.L. 390.0 to R.L. 392.0. The situation was likely to persist or even aggravate near the river edge where the temporary regulator had to be located. Experience has shown that if the structure is located at a distance of less than 500 feet from the river edge, circulation of water from the close-by liver river source would frustrate dewatering efforts beyond 15 feet to 20 feet. For driving sheet piles and laying concrete floors of the temporary regulator, dewatering of the area upto a depth of 25 feet below sub-soil water table was required. The nearest end of the regulator was, therefore, kept at a distance of 800 feet from the river edge for an assured dewatering upto the desired depth.

7.11 The problem for dewatering of the working areas was referred to Physics Wing of the Irrigation Research Institute, Lahore for advice. By having regards to the soil texture and on the basis of mathematical model it recommended (Research Report No. IRRI-1725/SM/GWD – July 1983) installation of 38 tubewells in double rectangular boundaries (24 No. in the inner rectangular spaced about 50 feet apart and 14 wells on the outer rectangular boundary) each to pump out 1 Cs. with arrangements as under :–



To cater for intereference of the draw-down effect by the adjoining tubewells, pumping sets of 1.5 cs. capacity each were advised to be installed so as to pump atleast 1 Cs. from each well under the influence of interference. The length of blind pipe in each well was recommended to be kept not less than 55 feet. From practical consideration of difficult boring deep down and on account of ready availability of generally used one cusecs capacity centrifugal pumping sets in the market, the arrangement at site was modified by providing 50% more tubewells and correspondingly reducing their capacity to one cusec. The tubewells (centrifugal type) actually insalled were however 59 in numbers (45 No. electric and 14 No. diesel) of 1 Cs. capacity each as per lay out and arrangement for disposal of pumping water shown in Plate No.XV. Barring a few bore-holes where obstructin of some previously burried stone had been encountered (south-western corner), average depth of well was kept 75 feet with 40 feet length of coire-rope strainer at the bottom (sketch) at Plate No. XV). The Blind Pipe initially kept 32 feet long was reduced in length at stages of 4 feet height as the need for lowering the pumping sets arose by gradual depression of the water

table in the working area.

7.12 A fool-proof arrangement of dewatering is pre-requisite for the construction of hydraulic structures below sub-soil water table. The diesel pumping is usually cumbersome to operate and cannot be relied upon for continuous working over a long period. Availability of electric power was, therefore, essential for day and night pumping the huge quantity of water to keep the sub-soil water table depressed at designated level. A special 11 K.V. line about 7 miles in length was got stretched by taping the existing feeder serving Ghazi Ghat village. A transformer house was specially constructed close to the regulator to step down the power for service without voltage drop to the nearby working area. Tripping devices, control panels, meters and switches were also placed in this room for regulating the supply from WAPDA Grid as well as from the stand-by generator. The requirement of power was of the order of 300 to 350 K.V.A. while 500 K.V.A. transformer had been installed as available with WAPDA. The lay-out of the over head copper conductor lines, underground cables and other service connections are shown in Plate No. XV.

7.13 Power supply from WAPDA Grid (Gujrat Grid Station along Kot Adu Road) over a long distance of about 20 miles serving doemstic/agricultural points on way could cause interruptions of varying duration. In such periods, alternative source of power supply was arranged by providing a number of stand-by generating sets as under :–

i) Two generators of 75 K.V.A. each at the initial stage when the pumping load was relatively small (boring of tubewells being in progress) and the main generating set (as per ii below) had not yet been provided for.

ii) A heavy duty caterpillar generating set 250 K.W. capacity (equivalent to about 310 K.V.A.) installed on concrete foundation in a room adjoining the WAPDA transformer – control room.

With the stand-by generating arrangements indicated above, a reliable flow of power supply to the pumping sets had been assured. As a further caution, 14 No. diesel pumping sets were also installed to overcome the effect of break of water column on the suction side of the pump in the time interval between stoppage of power from WAPDA Grid and switching over to the supply from generating sets.

7.14 The lay out of the temporary regulator was referred to the Irrigation Research Institute again for conducting experiments to precisely determine the shape of the guide banks as relevant to its present location along the upstream side of the road embankment at a distance of about 800 feet from the river edge. After a series of tests, the shape and length of the guide banks was recommended (Research letter No. 422-C/2652-53, dated 1.11.1983 and after discussions modified slightly to suit the site conditions as below (Plate No. XIV).

Description	Length from end of stone apron (Feet)	Radius of Curvature (Feet)
i. Left Guide Bank		
a) Upstream	700	1000
b) Downstream	250	800
ii. Right Guide Bank		
a) Upstream	300	250
b) Downstream	150	320

7.15 On arriving at a consensus at site on 22.9.1983, to shift the location of temporary regulator along the road embankment (as per para 6.6), the excavation of the pit for the working area was started on 23.9..1983. At that time, the ground was still wet and even boggy due to the effect of the late flood. Boring work for installation of the tubewells along the outer-rectangle (Plate No. XV) was taken up simultaneously and earth-work excvation continued by dewatering with open pumping of diesel pumps.

7.16 Tubewells pumpage was initially done with diesel pumps and then for some time with power generation from the two stand-by generators of 75 K.V.A. each. Transmission line from WAPDA Grid was energised on 13.10.83 and the heavy duty stand-by generator commissioned on 20th October, 1983. With the provision of later arrangements, the dewatering operations came almost under total control. The majority of tubewells, in the outer and inner rectangle of the working pit had been installed by end October, 1983. The process of installing additional tube-wells at odd locations particularly on the south-western sides (where obstructions of an old stone dumping had been encountered) had however to be continued intermitantly to keep the water-table under control. The sub-soil water-table showed a rising trend in the zone of concrete floor due to interception of seepage lines by the provision of sheet-piles cut-off. This situation was controlled by introducing another row of tubewells within the box of sheet-piles as per arrange-ments shown on Plate No. XV. The distribution of tubewells had to be kept dense on the western side of the regulator where more seepage coming from the river side had to be traped. In all 45 electric and 14 diesel tubewells were installed to achieve full control on the water-table. In the majority of the period about 50 tubewells had to be kept in operation continuously to pump out 40 to 45 cusecs for maintaining the sub-soil water depressed upto the desired level. The sub-soil water-table at the time of commencement of de-watering was only about 3 to 4 feet below the ground R.L. 400 $\pm$. In stable conditions the sub soil water in the vicinity remained at 392.0 $\pm$ and kept depressed by dewatering to the desired R.L. 368 $\pm$. The lowering of the sub-soil water-table was thus managed in the range of 25 feet to 30 feet for about three months period to construct the temporary regulator.

7.17 Construction in a very tight time schedule of the massive structure having foundations 25 feet to 30 feet below the sub-soil water-table and entailing intricate provisions of steel gates/ hositing machinery etc., demanded quick control of pumping/dewatering and driving of sheet-piles before any structural work could proceed. Immediately on achieving control (by end October 1983) of water-table upto the levels necessary for the upstream side of the structure (higher by about 6 feet as compared to the levels required on the downstream side) driving of sheet-piles was taken in hand from the north-eastern corner side. Three double stroke pilling hammers (one from Taunsa Barrage having 5000 feet pound capacity and two from M.C.P.L. each of 7500 feet pound capacity) were got repaired in advance from *M.C.P.L. Workshop Faisalabad and transported to site. An old piling machine from Taunsa was also got repaired and assembled at site. Three compressors of 600 cubic feet per minute capacity each were obtained on rental basis from the Mechanical Circle to operate the piling machines as well as the piling hammers at an air pressure of 100 - 150 pounds per sq: inch. Since more piling machines could not be made available from any other source, piling work by the other two hammers was done with the help of draglines, held in vertical position manually by fixing ropes at the four corners. The piling work was continued round the clock by engaging 2 to 3 hammers at a time. The entire sheet-piling of 11,000 sft was completed in a record period of only 20 days from 1st to 20th November, 1983 (Plate No. XI).

7.18 The concreting of the floor closely followed the provision of sheet piling at about 100 feet in the rear i.e. away from the zone of hammering effect of the piles. Concrete work was also continued round the clock in segments of manageable sizes by providing construction and expansion joints as shown on Plate No. XIV. On an average about 10,000 cft concreting was done daily to complete about 1,90,000 cft concrete work in a record period of only one month. The aggregate material was arranged mostly from the querries in D.G.Khan district supplemented by crushed shingle from the northern part of the Province. Medium to coarse sand was abundantly available from the excavation of the working area and the same had been utilised for the concrete work. Cement was procured in paper bags from Daudkhel Cement Factory for all the structural work. The size of aggregate material in the range of 3/4" to 1½" and less than 3/4" was kept in equal proportion which had already been tried by the Author in repairing the damaged Head Regulator of Punjnad Headworks in the year 1973-74 (Congress Paper No. 413). This gave adequate strength to the concrete i.e. about 1800 lbs/square inch in 7 days and about 2800 lbs per square inch after 28 days. The shuttering/form-work comprised of iron sheet units joined together by bolts and struts partly embeded in the ground on the back.

7.19 The brick work closely followed the concrete work. Recesses in the form of steps were provided in the concrete floor to grip the piers tightly for safety against slipping by the hydraulic pressure. About 1,00,000 cft. brick masonry of the piers, abutments, flanks and wing walls was completed by end December in less than 1½ months time.

7.20 The stone work of the regulator was purposely deferred till completion of the conc

*Mechanised Construction of Pakistan Limited.

floor so as to maintain uninterrupted flow of aggregate material into the working pit. The stone aprons were therefore, laid immediately after completion of the concrete work. The stone work of the guide banks had, however been carried out at leisure being independent of the main structure.

7.21 The design of gates and hoisting machinery was done by the Mechanical Circle, Lahore and their manufacture/fabrication arranged from the Irrigation Workshops Bhalwal and Moghalpura. For the provision of sliding plates to operate the gates gentle, vertical grooves of size 18"x9" were left on either side of the piers masonry. Similarly 9" wide and 6" deep grooves were left in the concrete of each bay at the crest to house the sill girders. The provision of sill-girder and the sliding plates followed the completion of the piers construction. On fixing of the sill girders truely horizontal and sliding plates truely vertical, these fittings were concrete grouted at designated locations. The gates were then lowered in the groove of final size 9" x 10" to rest on the sill girders. Immediately thereafter the fabricated channels of the hoisting plat-forms were placed in position and hoisting machines bolted with the base plates after fixing the lifting rod with their gates in true verticality. The anchor bolts of the hoisting platform were then grouted with concrete in the recessess of the piers already kept for the purpose. The arrangement of the sill girders, sliding plates, grooves, winching machines, hoisting plate form and the anchor bolts etc. is shown in Plate No. XVI.

7.22 To maintain un-interrupted flow of men, material and machinery from the left bank to the works in the river bed and vice-a-versa, it was essential to provide a road decking on the regulator. This was arranged by a provision of temporary road decking of wooden sleepers placed on B.G. rails forming the girders (Plate No. XVII). The rails (size 75 lbs per foot run) were arranged on loan basis from Mailsi Syphon because this material as available at Taunsa Barrage had worn out flanges and thus weaker in strength. The girder strength of the rails had been improved by provision of 3 pair of 6 rails at each location. Rails placed one over the other were joined together by welding their flanges at places. The openings of the rails were filled with concrete while the space on the sides and between the rails girders by raising brick-masonry of the piers to avoid lateral displacement of the girder sections. To avoid crushing of the masonry by piercing effect of point loading, a concrete cap 9" thick was provided on the top of the piers. For uniform distribution of loading 1/8" thick iron sheets were placed over the concrete to serve as base plates. The length of the sleeper was kept 14 feet to obtain a clear road way of 12 feet. Road curb 5" wide on each side was provided by placing the wooden sleepers in vertical position. The placing of the B.G. Rails girders was arranged in such a manner that under any set of load movement, the two girders on either side always remained under each track of the dozer, scraper, crane or the low-bed trailors etc. crossing the bridge. The heaviest loading had been expected from the movement of D-8 Caterpillar dozer, weighing about 35 tons while the decking from design consideration was sufficient to take a rolling load of 40 tons. This provision proved extremely beneficial and catered for all type of loading requirements of the machinery deployed on the diversion works.

7.23 As stated earlier, the gates manufactured in the workshops were 14 feet in height. The

top of the gates while resting on the crest (R.L. 381.0) in the lowered position was, therefore, to be at R.L. 395.0. Irrigation Research Institute was requested to determine time interval on the model for attaining water R.L. 395.0 on blocking of the river flow at the regulator site corresponding to different river inflows. The studies revealed that it will take about 11.4 hours (Annexure A – Geometry of leading cuts as conceived originally – Para 8.10) or about 27.42 hours (Annexure B – ultimate size of leading cuts – Para 8.11) to attain this level with the river inflow of 15,000 Cs. Since a discharge of this order could have been expected at the time of diversion, the estimated time interval would therefore be too short to permit provision of a strong plug bund in a length of about 400 feet at the back of the Temporary Regulator. To gain more time for constructing the plug bund till water begins to overshoot the Temporary Regulator gates, additional height of the gates by 2 feet was arranged at site as per arrangement shown at Plate No. XVI so as to avoid overtopping of the gates upto water R.L. 397.0. The extension piece was kept on the back of the gate, welded with additional angle iron supports for securing the clearance necessary at the hoisting platform in the up-position of the gates (Plate No. XVI).

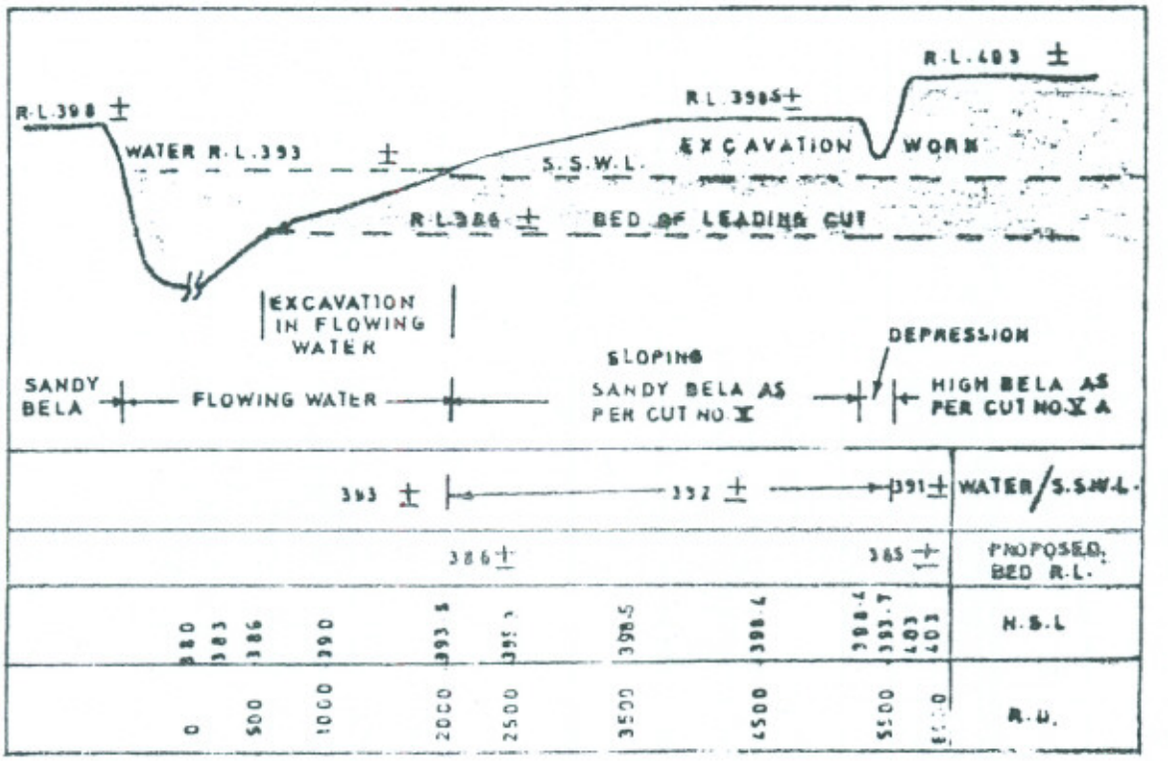
7.24 The construction of the Temporary Regulator with all the intricate provisions was completed by 10th January 1984 in a record period of 3½ months by working round the clock, which no doubt can be termed as a marvellous achievement of the human effort/determination. Salient features of the work, approximate quantities and the period taken to complete each component in relation to the chalked out schedule is given in Plate No. XI.

VIII. LEADING CUTS

8.1 The bridge has been constructed on a high firm bela and no active or a defined river creek passes underneath it. Provision of an artificial channel across the bridge (in the form of leading cuts) is therefore essential to connect the river on upstream with the downstream side. This channel as already discussed (para 5.6) should atlest be of a size to take a discharge of about 8000 to 10,000 Cs. expected at the time of diversion. Towards the fag end of the 1983 flood season, the left bank of the main river channel came closer to the bridge line (about 1 mile against hitherto distance of over two miles) while on the upstream and downstream sides it retained its distant posture. A study of the river position as depicted in Plate No. X, would show the following options for the layout of the leading cuts :–

i) a) Connect main channel of the river on upstream (above spur R–2) and downstream sides by excavating long leading cuts of about 6 miles length each (marked in zig zag line on Plate No. X). This required excavation of over 150 million cft. of earth for a channel section of 8000 Cs. Such a huge excavation in a limited time span of only 3 months (particularly the portion below sub-soil water table) would have been an impracticable proposition with the resources available particularly when colossal earthwork was to be done on other phases of the diversion plan in this period.

b) The river has a tendency of bela formation at the off-take point of the leading cuts at this location. The depth of water in the flowing river channel was only knee deep at the eastern bank (being on the inside of the river curvature) and gradually increased to over 15 feet in the centre and towards the outer western bank. This necessitated excavation of leading cuts at the off-take point in running water with depth ranging upto about 7 feet (average winter water R.L. 393 ± minus leading cut bed R.L. 386 ± = 7 feet ±) in a length of over 1500 feet to achieve the desired bed level as would be seen from the part, L-Section here under :–



c) The excavation work in the flowing river channel portion could only be done by dredgers or by building up earthen pads in the flowing river to position the hydraulic excavators. Firstly the excavation of this length in such conditions was not feasible as availability of an appropriate dredger was doubtful leaving apart its exorbitant cost of procurement, transportation, assembly, working and the constraint of time. Even if somehow this excavation could have been accomplished, it was not feasible to maintain the identity of the excavated section in the flowing water portion more so in the zone prone to progressive siltation being on the inside of the river curvature.

d) The distant location of the off-take point of the leading cuts from the temporary regulator required building up an additional afflux of water at the regulator site to

generate flow into the cuts. This necessitated increased height of the steel gates of the regulator and also increase in the construction cost of the structure to cater for a higher differential head. The onstruction of the temporary regulator was already quite cumbersome, expensive and time consuming. Such additionalities were bound to create more complications and uncertainities in the safe performance of the structure for the purpose envisaged.

e) In view of what has been stated in sub-paras a, b & c above, any idea or consideration to place the off-take point of the leading cuts on the upstream side of spur R–2 was mere a fantasy, non-feasible and devoid of technical basis.

ii) a) Connect river channel on upstream side (below spur R–2) and on the downstream side also by excavating lengthy leading cuts of about 4 miles length each. This required excavation of over 100 million cft. of earth for a channel section of 8000 cusecs. The excavation of this magnitude in a tight period of 3 months, (particularly the portion of huge work below the subsoil water-table) appeared impracticable by the available resource leaving apart the compulsion of rolling in the same period the enormous quantity of earthwork for other phases of the diversion operation.

b) Outfalling the leading cuts back into the right main channel of the river on the downstream side of the bridge also meant re-activation of the course along the right high bank which had faced large scale devastation in the past and has also been posing danger to the safety of Link No. 1 of D.G. Khan Canal ever since its operation on construction of Taunsa Barrage. Link No. 1 has time and again been shifted back more than 17 times since the year 1967 in a short stretch of about 10 miles near the road bridge. During the flood season of the year 1983, the Link was saved from erosive action of the river with great difficulty in a reach of about two miles below Haiderwala Regulator (Link R.D. 138–148). Re-activation of the erstwhile river course along Link No. 1 even after diversion of the river through the bridge would have caused an unrest and upheavel in the affected area.

iii) The dormant creek crossing the bridge in bay No. 2 (along the left guide bank) had been developed before and during 1983 flood season as already discussed in paras 3.9 to 3.11. As an alternative, the leading cuts could be made to outfall into this creek as per alignments marked in red on the plan at Plate No. X. The length of each leading cut in this case would be about 1.75 mile entailing on earth-work of roughly 50 million cft for a discharge of 8000 Cs. This limit of excavation appeared somewhat feasible in the available time frame.

8.2 By having regards to the factors enunciated in para 8.1 above, the obvious choice (rather

the only choice) was to adopt a shorter alignment of the leading cuts i.e. with off-take point in the deeper portion of the river channel in the shadow of the firm old and new sandy bela as shown in red colour on the plan at Plate No. X. This alignment being the only feasible choice entailed minimum excavation of earth and also caused least pressure on the temporary regulator because of the close proximity of the off-take points – a desirable feature to generate flow in the leading cuts quickly on creation of an afflux by closing the regulator gates.

8.3 A perusal of the L-sections of the deep main river channel and the left creek into which the leading cuts had to outfall (Plate No. XIII) would show that :

i. the bed of the left creek (average R.L. 384) is generally about 9 feet higher than the river bed (average R.L. 375.0).

ii. the bed of the left creek is just about 2 feet to 3 feet lower than the low water-level (R.L. 387 ±) expected at the take-off point of the river at the time of diversion.

iii. the left creek has a flat bed slope of 1 in 6000 (average) as against the river slope of 1 in 4700 (average).

8.4 In a position explained in para 8.3 above, it is amply clear that the leading cuts will not begin to accept the discharge of river inflow by a customary manner of attempting a closure i.e. with the help of tree/pilchi & langer chhap followed by stone boom. With this technique, a differential head of about 2 to 3 feet can possibly be generated across the langer chhap/stone boom as is being experienced on incised rivers for such works. The afflux of this order will generate an additional depth of only 1 or 2 feet at the mouth of the leading cuts about one mile upstream. This would cause a negligible flow of water in the leading cuts particularly on account of limitation of mild/flat slope of the left creek and its long route (about 12 miles) below the bridge to join the main river course. In this situation perhaps 5 to 10% of the incoming discharge may find its way into the leading cuts while the major component (over 90%) will still be flowing in the main river channel across the langer chhap/stone boom. The minimum flow in the river at the time of diversion as already stated in the preceding chapters is not expected to fall below 7000 to 8000 Cs. even though full efforts are made to block the flow on an upstream point i.e. by closing the Barrage gates at Taunsa. With 90% of this discharge flowing across the langer chhap and stone boom, it will be impossible to plug the river course at their back with earth. Very high velocity of a great volume of gushing water in the tight gap will wash away any quantity of earth advanced from the two ends in a bid to close it. This mode of operation is only possible if the majority of the incoming discharge finds its way to flow along the alternate route with ease so as to reduce the pressure of water on the gap at the back of langer chhap/stone boom, a condition not possible to manipulate at Ghazi Ghat in the given situation.

8.5 In the peculiar situation narrated in paras 8.3 and 8.4 above, coupled with the compul-

sion of non-excavation of deep leading cuts as explained in para 4.6, non-availability of steep slope in the lengthy left creek and the bridge having been located on a very high firm bela at a distance from the flowing river edge, it is well neigh impossible to divert the river through the bridge by the usual technique of langer chhap/stone boom as being practised on other smaller rivers of incised character with low flow of water in the winter season. Under the conditions prevailing at Ghazi Ghat, the only choice was to resort to the construction of the temporary regulator for the management of a successful/reliable diversion operation.

8.6 A study of the L-Section of left creek (Plate No. XIII) would show that the bed of the leading cuts at the outfall point in the left creek should be kept around R. L. 384 ±. To attain bed of the leading cuts at this level meant excavation of earth about 5 to 6 feet below the sub-soil water-table (average R.L. 390 ± experienced by the Highways Department in winter during the construction stage of the bridge). The bed of the leading cuts at the outfall points having been determined, the size/dimensions of the leading cuts were developed as briefly discussed below :–

i. Excavation of earth below the sub-soil water-table is economically viable upto a depth of only 3 feet by means of dragline excavators. The progress of the dragline work (appropriate type would be one cu. yd. bucket capacity, 80 feet boom length – 5 No. old machines available in the department) is about 10,000 cft. per shift of 8 hours in the normal dry/wet working conditions. This progress drops to about 65% for the portion of work below the sub-soil water-table. In case of smaller draglines (5/8 cu. yd. bucket capacity, 45' boom length-18 No. very old machines available in the Department mostly unreliable and in repairable conditions) the progress for normal and below S.S.W.L. working conditions drops to about 7500 cft. and 5000 cft. respectively per shift of 8 hours. Very few draglines could be spared by the Department for the Ghazi Ghat Works being engaged already on the excavation work of the drains in the Province. Even if these machines had been made available, the guantum of work would have remained beyond their capacity for completion in the given time schedule leaving apart the serious limitation of non-excavation beyond a depth of 3 feet below the sub-soil water-table.

ii. Hydraulic Excavators (BENATI – Italian Make) as available in the Department (10 No.) had luckily not yet been fully committed on the excavation of new drains or the river works of the Province. This machine having about 2.0 cu. yd. bucket capacity and throw reach of about 45 feet is capable of excavating earth as much as 5 to 6 feet below the sub-soil water-table without undue wastage on pulling out the bucket from the water. It gives a record progress of about 25000 cft. per shift of 8 hours under the conditions of working below sub-soil water-table. These machines are quite new and could therefore be easily relied upon for an efficient working. The machines being new and reliable could as well be taxed for over-time working from sun-rise to sun-set and thus get a daily progress of about 35000

cft. per machine. The obvious choice was therefore in favour of the using BENATI'S for the excavation work of the leading cuts.

iii. The limitation of boom length imposed a restiction on the width of excavation work which in the present case could be maximum of 95 to 100 feet ± at N.S.L. and about 70 feet ± at bed by an arrangement of workingtwo machines simultaneously in each cut (Plate No. XVIII). A wider section could only be manipulated by the process of re-handling/shifting of the excavated material which apart from being cost intensive would have been quite cumbersome as well unmanageable in relation to the constraint of time. The width of the leading cuts had therefore to be compromised with the type of the available machinery and to economise in cost.

8.7 Discussions revealed that out of the 10 hydraulic excavators, about 8 machines could be depended upon to remain operational continuously. These machines in the given time frame were not capable of excavating more than 20 to 25 million cft. of earth-work by working 25 days in a month in long shift from sun-rise to sun-set (even by working occassionally at night time also). The total excavation work of the six leading cuts being of the order of 55 million cft. (to be discussed later), the work over and above the capacity of the hydraulic excavators was therefore organized by other means i.e. labour force, dozer-scrapers, tractors with blades etc. as could be organized in public/private sectors. The portion of excavation below the sub-soil water table was however left to be done entirely by BENATI'S.

8.8 The boom length of the hydraulic excavator permitted excavation of 95 to 100 feet width only at the mouth with normal throw of the bucket without involving the process of rehandling. This too is possible by deploying two machines at one spot, working on either side of the leading cut as shown on Plate No. XVIII. BENATI hydraulic excavator is a heavy machine having track load of about 9 lbs. per sq. inch as against a relatively lighter load of about 6 lbs. per sq. inch track load of the dragline. The hydraulic excavator could not therefore be deployed for working in the boggy area or by positioning on the loose soil very close to the sub-soil water-table. These machines necessarily require an earth pad of atleast 2 to 3 feet above sub-soil water-table for a smooth/efficient operation. The excavation of the top soil of the leading cuts by other modes was therefore restricted to about 3 to 4 feet above the sub-soil water-table so as to ensure efficient working of the hydraulic excavators.

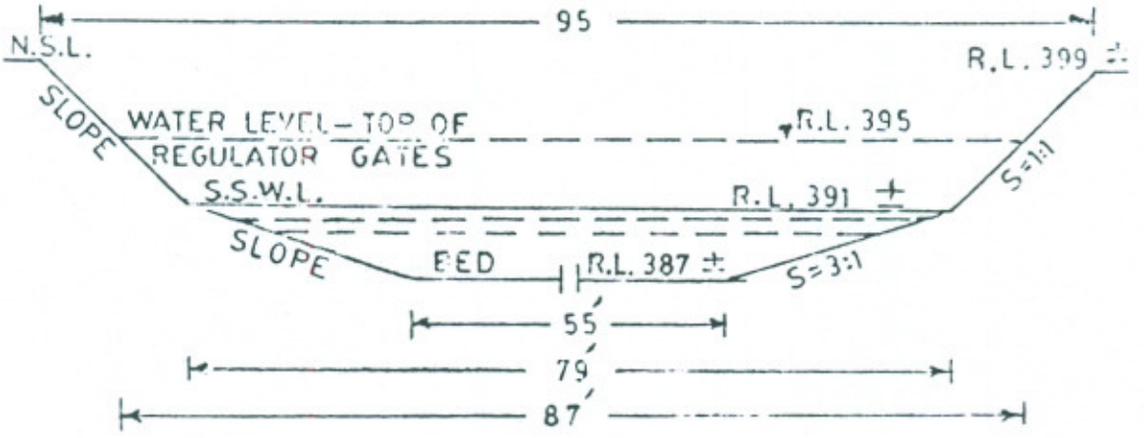
8.9 The sub-soil water-table in the zone of leading cuts during the month of October 1983 ranged from R.L. 388.0 on the outfall and to R.L. 391.0 at off-take point near the river. Visualising that excavation below sub-soil water-table by machines would more efficiently be done upto about 4 feet depth, the water-way of the leading cuts was accordingly worked out to cater for a discharge of about 8000 cs. by assuming that the river inflow will initially accumulate to form a pool of water upto about the top of the temporary regulator gates i.e. R.L. 395.0. In such conditions and at the initial stage of non development of leading cuts, a velocity of water not more than

3 feet per second is likely to be encountered (calculations by Manning's Formula for the given parameters confirm this assumption). The number and dimensions of the leading cuts were accordingly worked our as under :—

i)	Velocity (assumed, maximum by Manning's Formula).	=	3 feet per second.
ii)	Average bed of the leading cut near the offtake point	=	S.S.W.L 391 - 4 feet. R.L. 387.0
iii)	Average bed near the outfall point.	=	S.S.W.L. 388.0 - 4 feet
		=	R L. 384.0
iv)	Depth of flow in the leading cuts with water headed upto the top of Temporary Regulator gates.	=	R.L 395 - 387 = 8 feet.
v)	Flow per foot run.	=	8 x 3 = 24 Cs.
	Therefore water-way required	=	$\frac{8000}{24}$ = 333 feet.
	Assuming that 4 leading cuts are excavated in that case average width of each cut.	=	$\frac{333}{4}$ = 83 feet.

8.10 With the factors enunciaed in para 8.9 above the geometry of the leading cuts for the purpose of excavation near the off-take point was developed as under, details shown on the sketch:

i)	Bed width at R.L. 387	=	55 feet +
ii)	Width at S.S.W.L. 391	=	79 feet +
iii)	Width at water surface upto top of gates R.L. 395	=	87 feet
iv)	Width of cut at N.S.L.	=	95 feet +
v)	X-Section area upto R.L. 395	=	600 sft.
vi)	Discharge in each cut at flow velocity of 3' per sec.	=	600 x 3
		=	1800 cusecs.
vii)	Discharge in 4 cuts	=	7200 cusecs.

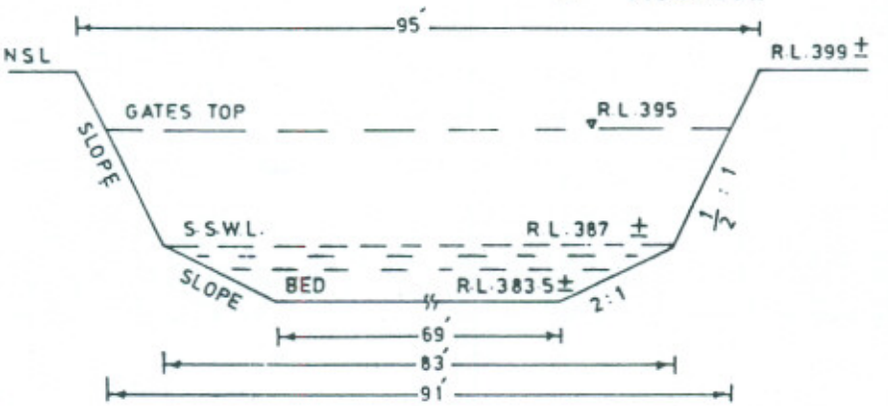


Experiments were carried on the model to study the performance of the leading cuts under these conditions and the results (Research letter No. 422-C/3130, dated 28.12.1983, Table I) confirmed the validity of the assumptions made (result of model studies are at Annexure A).

8.11 The upper portion of earth having been excavated by the labour force and tractors etc. the work by the hydraulic excavators was started from the outfall end. This provided an opportunity for the seepage water to flow to the left creek of which the water gradually dropped to R.L. 386 ± at the bridge site. This manner of working caused a general drop of sub-soil water-table as the excavation work progressively advanced upwards to the river edge. This enabled excavation of the four main leading cuts wider at bottom and deeper also (details shown on Plate No. XVIII).

8.12 With the passage of time, the sloughing of earth from the sides, heaving up of the soil in the bed and blowing of sand from the spoil banks slightly deformed the excavation work to form the geometry of the cuts generally as under, details shown on the sketch :—

i)	Bed width at R.L. 383.5 ±	=	69 feet ±
ii)	Width at S.S.W.L. 387 ±	=	83 feet ±
iii)	Width with water at top of gate R.L. 395.	=	91 feet ±
iv)	Width of cut at N.S.L.	=	95 feet ±
v)	X-Sectional area upto R.L. 395	=	962 sq: feet.
vi)	Discharge in each cut at a flow velocity of 3 feet per sec.	=	962 x 3 = 2886 cus.
vii)	Discharge in 4 No. cuts.	=	2886 x 4
		=	11544 Cus.



Studies carried out in the Research Institute amply confirmed the performance of the cuts in this fashion as would be seen from the model results at Annexure B. The deeper excavation of the leading cuts therefore permitted to attempt diversion at a river inflow of about 12000 Cs. without overtopping the gates of the temporary regulator. The model studies at Annexure B, also confirmed that a maximum flow of about 17000 cusecs could as well be handled for diversion without overtopping the gates (in extended position by 2 feet to attain water elevation upto R.L. 397 as actually manipuated at site – Refer para 7.23, thereby providing ample flexibility in working at the temporary regulator.

8.13 Mild curves in the leading cuts were introduced to spread the out-fall points in the left creek and also to reduce their lengths for minimising the excavation work. Cut No. 1 crossed the bridge almost in the middle to outfall about 1500 feet below bridge line. Cut No. 2 crossed bays No. 4 & 5 to outfall about 500 feet below the bridge. The cuts No. 3 & 4 were made to outfall in the left creek about 1000 to 1500 feet on the upstream side of the bridge. A small leading cut No. 1-A was also excavated along the right guide bank by removing obstructions of the tiny creek so as to maximise spread of the river flow in the bridge spans (lay out plan at Plate No. XIX).

8.14 Additional leading cuts by labour force and tractors were excavated on upstream side of the spur R-2 nose to attract flow towards the bridge via the natural creek on the firm bela. The leading cut No. 5 was primarily meant to connect the main river water with an existing depression along the left high bank to generate flow on upstream side of spur R-2 nose as soon as the sandy bela in its vicinity is covered by higher flow. Cut No. 5-A was aimed at connecting the water on sandy bela near spur R-2 with the natural creek on the firm bela for passage towards the bridge. Cut No. 6 in fact meant opening of the silted mouth of the natural creek on the firm bela opposite spur R-1. The detail of these additional leading cuts are also shown on Plates No. XVIII & XIX.

8.15 The leading channel on upstream of Spur R-1 which was partly excavated by the Highways Department in winter 1982-83 had silted up near the mouth in a length of about 2000 feet. The silt bar in this zone was removed to help development of this route to the bridge at higher discharge in the river.

8.16 The work on excavation of the four main leading cuts was taken in hand with the labour force and tractors without any loss of time from the beginning of October 1983 while the ground was still wet and slushy at places. By about mid-October 1983, the Benati Hydraulic excavators could also be partly shifted to site to begin the excavation work. All the Benaties were however, deployed towards end October 1983 when the excavation work gained full momentum. The labour force as well as the hydraulic excavators worked in long shifts (Beanaties occasionally worked at night also) and the excavation of the 4 main leading cuts could be completed with great difficulty by 10th January, 1984 (Plate No. XII). A width of about 200 feet in each cut was however left

in tact near the river edge to serve as plug and for maintaining the supply of stone, labour, machinery etc. to Spur R-2 where the work was still in progress. These plugs were removed in a bell mouth shape with the Benati's in 6 days working from 21st to 26th January 1984 (period coinciding with the completion of langar chhap and stone boom in the main river channel) to finally join the four main leading cuts with the deep channel of the river water. The excavation of leading cuts No. 5, 5-A, 6 and also clearing mouth of the Highways Department leading channel on upstream of spur R-1 was also completed by the first week of January 1984.

IX. CLOSING CREEKS

9.1 The main channel of the river or a prominent right arm of the same has been hugging along the right side high bank in the vicinity of the bridge for the past many years. This pattern of flow has been causing large scale erosion of the right high bank necessitating repeated set-back of Link No. 1 Canal to maintain the supply of Irrigation water in the lower down areas. The right channel at this site is usually called Dharrma Creek/arm of the river.

9.2 Prior to the commencement of the flood season 1983, the main river was flowing along the right bank near Dharrma (Plate No.VII). During the flood season, the main river however shifted on the left towards the bridge structure convertng right side channel into an arm herein after named as Dharrma Creek (Plate No.X). The flow in Dharrma Creek was being drawn from the main river at three points below spur R-1 nose as shown in Plate No. XIX. With the fall of river to a discharge of less than one lac cusecs towards end September 1983, the water in the two lower off-take points became knee deep, but had the potential of development if the river rose again (being on the outer side of the river curve). To obviate such fears, the mouth of these two creeks were plugged in early October, 1983 so as to stop contribution of river water towards Dharrma creek from these points. Luckily this plugging could be managed by the labour force only because a deep channel section of these creeks had still not been formed.

9.3 The upper creek just below the nose of Spur R-1 was however, attracting a large component of river flow being at the tangential point of the outer cruvature of the main river (Plate No. X). At a river stage of about 60,000 Cs. (from 5th October 1983) about 15% of the flow was entering this creek indicating at the same time a tendencey of its further development. In such a situation, it was extremely desirable to close the mouth of this creek without any loss of time failing which it had the potential to develop into a major arm of the river and thus become too much problematic.

9.4 The usual practice of closing river creek by erecting langer chhap (a colloquial name for a previous wall of bushing, pilchi etc.) and constructing earthen bund at its back was followed. The site for langer chhap was kept somewhat advanced in the river where-from the flow to the subsidiary Dharrma creek was taking-off from the main channel. This location was considered helpful so that the flow obstructed by langer chhap should find its way to the main river channel without causing excessive pressure on langer chhap itself.

9.5 The erection of langer chhap (in a length of about 1000' and water depth ranging from 3 to 15) feet was started from both ends of the creek, upper side joined with spur shank close to the J-head and lower side with the sandy bela. Full trees or main branches of bigger trees were cut from the canal banks and thrown along the alignment of the langer chhap each bundle held in position by the stone crates acting as anchor. The process of launching the trees one above the other was continued till they became visible above the water surface. Brush wood and pilchi rolls inter-woven with each other were then placed above the trees between the two rows of killas/ wooden pegs to form a previous barrier in the flow of water towards the Dharrama Creek. The process of loading and packing the langer chhap with pilchi rolls, stone, gunny bags filled with sand etc. was continued for some period which reduced the flow towards Dharrama Creek from original of about 9000 Cs. to about 3000 Cs. by mid-October 1984. The construction of earthen bund on the back of langer chhap was taken up from both sides by borrowing earth from long lead with the help of donkeys, tractors, tractor trollys and small D-6 dozers. The flow of the water in the creek being quite significant did not permit much advancement of the bund without the provision of pilchi/bushing cross spurs, along it. Even then the 200 feet gap in the centre could not be reduced any furhter because washing of the earth was observed to be quicker than the feeding rate by the labour force and tractors etc.

9.6 The reduction of discharge to about 40,000 cs. on 14th October 1984, provided an open area of sandy bela on right side of the river where-from the earth could now be borrowed in sufficient quantity. The feeding rate to the gap was now possible to accelerate, if some how the heavy earth moving machinery could be crossed over the flowing water on to the sandy bela. Continuous loading/packing of the langer chapp meanwhile caused further reduction in the flow of water towards the creek (discharge now fell to about 2000 Cs) and at a distance of 500 feet downstream side of the gap, a sand bar began to develop. At this place the depth of water was of the order of 2 to 3 feet only in a length of about 1000 feet. Walking on this alignment indicated sandy bed to be quite firm. This prompted for making an attempt to cross the heavy earth moving machinery along this route. Luckily this move proved successful and this considerably augmented the potential of rolling large quantity of earthwork from the sandy bela side.

9.7 With the augmentation of additional source of earth work by machinery, the tightening of the gap was taken from both sides up by protecting the ends with studs of stone, gunny bags and bushing etc. At a width of 50 feet the earth work was piled up on both ends and pushing with full force done on 17th October, 1983. The attempt however proved abortive. The gap widened to about 100 feet the next day and the langer chhap also got damaged in the middle portion. The water passing through the gap again rose to about 3000 cusecs.

9.8 Hectic efforts were made to quickly repair and reload the langer chhap and thereafter the gap in the bund was again tightened to about 50 feet with the help of stone studs etc. A stone boom was then constructed on the upstream side of the gap by dumping loose as well as in wire

crates/trangers. Meanwhile huge quantity of earth was stock-piled on both ends of the gap. After full preparation, operation for plugging the gap was taken in hand on 23rd October 1983 and this time it met with success.

9.9 The erstwhile feature of continuous flow in Dharrama Creek thus came to an end for ever and the river now began to flow in a single channel along the bridge alignment. An early closure of Dharrama Creek was also essential for the transportation of heavy earth moving machinery on the sandy bela for undertaking construction of the diversion-cum-road embankment in the bed of the river on the D.G. Khan side.

X. ROAD-CUM-DIVERSION BUND

10.1 With the shifting of temporary regulator along the alignment of the bridge, the Right Approach Road Embankment on D.G. Khan side was now to serve the dual purpose of Diversion Bund as well. The Highways Department intended to construct this embankment in 44 feet width at top R.L. 415.0 and adopt side slopes of 3:1. They however desired that the formation of earthen embankment should be kept 1 feet lower at top R.L. 414.0 to provide margin for the placement of sub-base under the road crust. This road embankment was required to be constructed in the riverine area over a length of 2.3 miles from the left bank of the main river channel (at R.D. 5030' from the bridge end to the high edge on the right near Dharrama at R.D. 16500). The construction of this embankment entailed about 45 million cft. of earth-work to form the road section.

10.2 Irrigation Department had a fleet of about 40 scrapers and 20 dozers to do this type of earthwork. This machinery is being operated in three groups under the charge of different Divisions of the Mechanical Circle. The two groups of Moghalpura Irrigation Workshop and Bhalwal Irrigation Workshop Divisions consisting of 26 scrapers and 13 dozers were shifted to Ghazi Ghat during the flood days i.e. by end September 1983. The third group of Excavator Division Faisalabad had however been kept in reserve by the department for carrying out emergent flood works of the Province. A small unit of the Highways Department (consisting of 5 scrapers and 3 to 6 dozers) was already available at site but the same could not be deployed on the construction of road embankment because of its pressing demand to repair the extensive damage of spur R–1 shank.

10.3 The usual output of scrapers under normal conditions of working is about 10,000 cft. per shift of 8 hours. In a long shift of working from sun-rise to sun-set, the output goes upto about 15000 cft. The machinery being old, can at best be made to work on long shift at an efficiency of not more than 75%. Assuming 25 working days in a month, the available machinery could thus hardly do about 20 to 25 million cft. of earth in a period of 3 months from end October, 1983 (when the area would be accessible and ground becomes workable) to end January, 1984 by working in long shifts from sun-rise to sun-set. Alternative sources for doing the remaining earthwork were, therefore, required to be developed for on time completion of the job.

10.4 A study of the survey plan at Plate No. XIX will indicate that immediately after the flood season the river along the road alignment was flowing in two parts i.e. right arm (Dharrama Creek) along the right high bank spread in 3 channels over a width of about 4000 feet and the main river channel about 2000 feet wide along the left bank. The heavy machinery could not be shifted on the sandy bela unless means of accessibility via a floating bridge or by closing of the Dharrama Creek had been established. This became possible in the last week of October 1983 on closing of Dharrama Creek as discussed in para 9.9. Meanwhile the labour force and light machinery i.e. tractors and D–6 dozers were shifted with the help of boats on the sandy bela as soon as the river discharge dropped to about one lac cusec in the last week of September 1983. The construction of the embankment was taken up with the labour force, tractors and D–6 dozers from the beginning of October to avail of the working season to the maximum. Immediately after closing of Dharama Creek in the last week of October 1983, the heavy earth moving machinery of the Department was shifted on the sandy bela to build the embankment. A floating bridge was also erected on the main channel of Dharama Creek near the right high bank to provide passage for the seepage water flow and to maintain supply of P.O.L. to the machinery.

10.5 The earthwork to the tune of about 15 to 20 million cft. was needed to build up the embankment in the portion of main river channel of about 2000 feet width. So much quantity of earthwork could not possibly be done in a short closure period of about 3 weeks (as agreed upon at inter-Provincial/Federal levels) for final stage of river diversion through the temporary regulator etc. particularly in a situation at that stage of deploying bulk of the machinery on the diversion operations. In these conditions, it was imperative to reduce the width of flowing water as much as possible and to advance the embankment formation into the water channel in a maximum length.

10.6 The river remained flowing at a discharge of about 40,000 Cs. in November which did not permit any significant advancement of the embankment into the main channel. Steps to tighten the water-way were however, initiated in November by erecting a series of langer chhaps on the upstream side of the road embankment in a bid to shift the main current of the river flow along the left bank. This process proved extremely advantageous particularly with the fall of river in early December 1983 to about 30,000 cusecs (Plate No. V) when the embankment could be extended into the river channel by leaving a gap of only about 800 feet. The process of advancement could however be continued only by protecting the upstream and downstream toes of the embankment by killa-bushing etc. to avoid undue wastage of earth by the gentle flow of water. With the tightening/constriction of the water-way, the depth of flow in the 800 feet width increased considerably by the scouring action and also the fast current of water along the outer curvature of flow began to erode the left bank (Section at R.D. 00 – Plate No. XIII). The erosive action along the left bank being violent was immediately controlled by the provision of stone studs and face protection with stone as shown on Plate No. XXII.

10.7 On further reduction of discharge to about 15,000 Cs. in the later part of December

1983, the embankment was more advanced into the river channel by repeating the process of langer-chhaps and killa-bushing etc. to reduce the gap width now to about 500 feet. The river fell to a discharge of about 8000 cs. in mid January when the gap width was reduced to 300 feet only. Tightening the river section to this width caused some swirling action on the outer curvature of the flow along the left bank. To check this action, a few additional stone studs had to be introduced apart from provision of a number of spurs of killa bushing in the lower reach of the left bank. Additional killa bushing and brush wood spurs had also to be provided along the projected portion of the embankment as shown on Plate No. XXII to protect the same from damages by eddies formation.

10.8 Huge quantity of earth was then piled up on both ends of the gap (Plate No. XXII) in preparedness for a final attack to close the river channel simultaneously with the first stage diversion of the river through the temporary regulator (expected in last week of January 1984). Gap in the road embankment at the crossing of Dharama Creek channel was also closed in the last week of January 1984 because its earlier closure would have inundated the borrow area on the upstream side on account of accumulation of water by the blockage of the seepage flow passage.

10.9 All the earth for the construction of the road-cum-diversion bund was borrowed from the upstream side of the embankment which was succeptibel to quicker siltation by river action. Only a nominal quantity of earth was borrowed from the downstream side and that too for building up the earth stock at the gap end. Extreme care was however exercised that the borrow area on the downstream side must not be within a distance of 1000 feet from the road embankment so that its safety is not affected from the consideraions of hydraulic gradient at any stage.

10.10 The section of the road embankment in the entire length was built up with the fine sandy soil as available within the easy reach. A cover of 1 foot thick pacca earthwork on top and slopes was therefore provided to avoid damage to the embankment from winds and to help growth of grass on it in due course.

10.11 The embankment being in the erstwhile main channel of the river was quite high and massive in size. At the initial stage water would remain standing along this embankment for a long time thus calling for some additional safety precautions. To avoid damage to the embankment from parallel flow action, cross bunds of about 120' to 175' length each were constructed all along the embankment on the upstream side at a regular distance of almost 1000 feet as marked on the plan at Plate No. XIX. The nose of these cross bunds were protected with sarkanda/pilchi pitching to avoid damage by any mild flow of water. Likewise to minimise damages from the wave action, the upstream face of the embankment in the deep segment (in the portion of main river channel and at crossing points of Dharama Creek) was protected with pilchi/sarkanda pitching as shown on the typical section on Plate No. XXV.

XI. DIVERSION CHANNEL

11.1 To divert/pass the river initially through the temporary regulator, a connecting channel is required to be excavated. This linkage known as Diversion Channel should have a minimum length so that the process of its development by retrogressive action from the outfall end gains quick momentum and thus exert least pressure on the diversion process. The lay-out of the diversion channel in relation to the shape of the guide banks of the temporary regulator and river position as obtaining at site was tested on the model to evolve an alignment most conducive to a stream line flow. The alignment finally adopted at site as shown on the layout plan at Plate No. XXII was 4075 feet in length, with the temporary regulator almost in the middle. The upstream side alignment was almost a continuation of the two guide banks joined with the river in a smooth curve from consideration of generating flow in it no sooner an obstruction is introduced in the river passage. On the downstream side, the channel was kept straight in a length of about 350 feet and then made to join with the river in a smooth curve to have an easy exit of water lower down.

11.2 The bed width of the channel was kept matching with the width of the temporary regulator i.e. 378 feet except in the small portion of 300 feet each at the off-take and outfall ends to give the bell mouth opening effect. The excavation work was done with the labour force to the extent permitted by the position of sub-soil watertable in the area. This became manageable in a depth of about 13 feet upto R.L. 387 ± i.e. about 6 feet higher than the crest level of the temporary regulator. The channel should have been excavated in the entire width upto bed R.L. 381 ± (crest level of the temporary regulator) so as to generate free flow of the water in the whole section but this was not feasible without large scale rehandling of the earth to be done by the hydraulic excavators. The process of rehandling of earth was not only cumbersome and time consuming but quite expensive as well. As a via-media, it was considered advantageous to excavate deep cunettes along the two sides of the channel (Plate No. XXII) so that at the initial stage the water could pass through them without any hinderance across the regulator. The intermediatory berm would then get washed away automatically as the flow of water in the channel increased in due course. In accordance with this planning, the excavation of cunettes along sides from R.L. 387 ± to R.L. 381 ± was done with the BENATI hydraulic excavators.

11.3 As already stated in para 8.8, the available hydraulic excavators of small boom length could excavate upto a width of about 95 feet only without entailing the process of rehandling. The size of the wider cunette was accordingly kept 95 ± at top and excavated by deploying three machines at one location i.e. two engaged on excavation work and the third to re-handle the earth for disposal on the spoils outside. The second cunette of 50 feet top width was excavated by single working of the machine with part rehandling to throw the earth on the outside spoils. In this way a high berm of about 260 feet width was left un-excavated at R.L. 387 ± between the two cunettes. Wider cunette of 95' top width was excavated on the inside curvature above the regulator so as to provide more passage of water close to the obstruction point in the river i.e. on the provision of langer chhap/stone boom. On the downstream side of the regulator, the wider cunette was

excavated on the outer curvature of the channel to expedite the process of scouring and development from the tail end. The placement of narrow cunettes on the other sides of the diversion channel (at outer curvature on the upstream and inner curvature on downstream sides) was meant to generate flow in a wider section of the channel to help quick washing away of the middle berm and also to provide free passage for water through out the width of the regulator. A typical cross-section of the diversion channel, the cunettes on the sides and the berm in the middle is shown on the Plate No. XXII.

11.4 The excavation of the diversion channel was taken in hand almost simultaneously with the excavation of the pit of the temporary regulator, where huge labour force had to be deployed to do the massive work in a very tight time schedule. The excavation in the pit of the temporary regulator was of intermittent nature, dependent upon the rate of lowering of the water-table by progressive installation/operations of the tubewells. In the relatively idle period, the labour force was kept engaged on the excavation of the diversion channel for ready availability of switching over to the regulator work. As soon as the excavation of the pit of the temporary regulator was completed in early November 1983 (Plate No. XI), the excavation of the diversion channel gained a lot of momentum. The excavation of channel by labour force upto R.L. 387 ± had been completed in the third week of December 1983 when BENATI hydraulic excavators were deployed to excavate the cunette as well. The channel excavation was completed in all respects in the first week of January 1984 (Plate No. XII), before undertaking the process of tightening the river passage by putting langer chhap across the river passage i.e. before the commencement of the closure operations.

11.5 The earth excavated from the diversion channel and also from the pit of the temporary regulator was dumped mostly on the river side i.e. on the island formed by the channel, to serve as stock of earth on the left bank for closing the river gap from both ends at the time of closure operations. About two-third of the excavated earth (roughly 20 million cubic feet) was thus stock piled along the left bank of the river on the island while the remaining one-third (about 8 million cubic feet) had been placed on the left side of the diversion channel mostly near the road alignment to serve as a stock-pile of earth for closing the gap at the back of the temporary regulator in due course.

XII. RIVER TRAINING

12.1 During the flood season of 1983, the river retained its pre-flood left handed curved posture in the vicinity of the road bridge on the upstream side. The pattern appeared rather favourable for a better layout of leading cuts as well as approach of the river towards the bridge (Plate No. VII). At the fag end of the flood season, the river however, unexpectedly rose again and remained in flood stage for a long period of over three weeks. This completely reversed the flow pattern near the bridge calling for a revision of the already chalked out diversion plan (Para 6.6).

The newly developed river course now having a right handed curvature (Plate No. X) was liable to cause at low flow stage, a further siltation/shoaling in the zone of inside curve i.e. along the left firm high bela, and also make the river to swing more towards the right side i.e. away from the road bridge. These trends if allowed to play their role freely could have been disastrous for the modified diversion plan. A careful watch on the behaviour of the river in the vicinity of the road bridge was therefore essential to thwart such ugly developments by timely training of the river appropriately to the extent possible.

12.2 With the fall of river to about 40,000 cusecs in mid-October 1983, the righthanded curvature began to erode its right bank causing the sandy bela on the inside curvature to gradually grow in width. In a short span of about two to three weeks only the deep channel of the river shifted more towards right side over a distance of 1500 feet at the crossing point of spur R–2 shank. This shift not only made the sandy bela on the inside curvature to grow in width but the same extended lower down as well masking the mouth of diversion channel at the temporary regulator as shown in dotted lines on Plate No. XIX. With this change, the river at the crossing point of road alignment bifurcated into two channels indicating tendency of progressive increase in discharge on the right side. This situation if allowed to continue any further would have blocked the water passage at the off-take point of divesion channel and thus completely failed even the latest scheme of diversion plan under execution. The process of tinkering with the river was therefore taken in hand immediately (in early November 1983) so as to maintain a flow pattern conducive for a successful diversion operation at the temporary regulator site.

12.3 Beginning of tinkering process was done by erecting a series of langer chhaps along the right bank of the river on upstream side of the road embankment as shown in green colour on Plate No. XIX, in a bid to shift the main flow towards the left high bank. This process began to show its effect soon, as the shoaling tip of sandy bela opposite the off-take point of the diversion channel started disappearing. To accelerate this action, the langer chhaps were extended further into the river channel and this made the main river to flow at the temporary regulator site again along the left high bank in early December 1983 as shown in red colour lines on Plate No. XIX. The shifting of the river channel in this manner also generated conditions conducive to advance the road embankment construction in the river bed under the shadow of the langer chhaps.

12.4 At the appex of the river curvature where the shank of spur R–2 was to cross the channel, erosive action was tending to threaten the safety of the spur shank on the western bank. A series of langer chhaps were erected at this site also to shift the main current away from the right bank (Plate No. XIX). This provision stopped erosive action of the right bank in the vicinity of the langer chhaps and also caused mild shift in the direction of flow at the spur alignment. Continued tinkering of the river here permitted to advance in a small distance, the construction of spur R–2 shank in the river bed from the right side.

12.5 The tinkering process initiated in early November and continued intermittently upto

end December 1983 not only generated very favourable conditions of river flow for diversion process at the temporary regulator, but it also permitted to advance the construction of the road embankment so as to reduce the river gap initially to a width of 800 feet and then to 500 feet in the month of December 1983. Similar treatment at the upper site created favourable conditions for the safety of spur R–2 shank on the western side and also made the main flow of the river to be at some distance from the right bank.

12.6 The river changes as a consonence of tinkering efforts became more clear in mid-January 1984 when the river at Ghazi Ghat fell to a discharge of about 8000 cusecs only. While favourable condition persisted as described earlier at the temporary regulator cum-road crossing site, a sandy shoal also appeared in the middle of the river channel at the crossing point of spur R-2 shank (Plate No. XIX). Of the two channels here, the right side flow was relatively less active and taking about 45% of the river discharge. The major flow, about 55% of the river discharge was however passing in the left channel. The right handed channel along the western bank was therefore closed at its mouth as quickly as possible by erecting a long langar chhap followed by a plug hund at its back as shown in detail on Plate No. XX. This operation permitted construction of spur R–2 shank for a length of over 3000 feet in the portion of the main river channel at low stage of the river flow from mid-January to 10th February 1984, by leaving about 200 feet wide gap for the water passage on the left bank. The two ends of the gap were then protected by stone studs & pilchi pitching to control its widening. A series of cross spurs were also constructed along the shank on both sides of the river to check damage from parellel flow of water. Lay out plan of the spur R–2, position of gap and protective measures devised along the shank are shown on Plate No. XX.

12.7 The gap for the water passage had originally been planned to be kept along the right bank of the river channel where concentration of flow on account of outer position of the curvature had persisted all the time. The tinkering of the river as per paras 12.4 and 12.6 however made it possible to advance the construction of spur R–2 shank from the western end into the erstwhile river channel in a length of over 3000 feet i.e. from R.D. 5350 to R.D. 8450 (Plates No. XIX & XX). This advancement was bound to generate relatively better conditions of flow pattern opposite the right road embankment in relation to the flow of water from the gap of spur shank. If tinkering of the river had not been made at this site, in that case, the main channel of river would have continued to flow along the right bank, which in turn necessitated leaving of gap in the shank of spur R–2 at the western bank i.e. in a retarded position of over 3000 feet. This situation was surely not desirable from consideration of the safety of western side of spur R–2 shank as well as the right road embankment.

XIII. WATER REGULATION

13.1 Large quantity of water continues to flow in river Indus below Taunsa Barrage

40 miles upstream of Ghazi Ghat) during the winter season also to meet the Irrigation requirements of Sind Province Canals. The flow is generally of the order of 30,000 to 50,000 cusecs except for a short period of two to three weeks from late December to mid-January when it drops to a range of 15,000 to 20,000 cusecs coinciding with the annual closure of Sind Canals (usually from 26th December to 10th January for Kotri Barrage Canals and 6th January to 20th January for Sukkur Barrage Canals). To cater for such a high discharge in the river, very massive diversion works were required to be executed i.e. large sized leading cuts, temporary regulator of higher strength and capacity, excessively large quantity of materials and machinery for the diversion operations etc. These provisions would have not only been very cost intensive but also not possible to accomplish in the tight time schedule of about three months only i.e. from end of flood season to about mid December. Even though all the foreseable arrangements had been provided for, still a complete reliance of securing the successful diversion at such a high discharge in the river would have remained to be rather doubtful.

13.2 For a successful diversion operation of such a complex nature, more so on account of peculiar conditions obtaining at Ghazi Ghat (bridge having been located on high bela away from the main river etc.), it was imperative to aim at reduction in the flow of the river upto the extent and for the length of time the system could permit. Low flow of discharge in the river was liable to generate very favourable conditions of working in the field as under :-

i. Fall of river discharge will resultantly lower the sub-soil water-table of the area. This shall allow deeper excavation of the leading cuts and also cause less pressure on pumping to dewater the working pit of the temporary regulator.

ii. The width of flowing water in the river will proportionately get reduced. This shall allow the construction of road embankment to advance in the main river channel portion and thus reduce burden of doing large quantity of earthwork at the critical time of undertaking the various diversion operations.

iii. The size of leading cuts as well as the capacity of the temporary regulator can b suitably compromised.

iv. Diversion of river at low discharge will be relatively less problematic and better t control.

v. Diversion effort and cost aspect will remain within manageable limits.

13.3 By having regards to the factors enunciated in para 13.2 above, a lengthy dialogue w made with the Province of Sind, WAPDA and Federal Government to evolve a system of regulati the flow of Indus and Eastern rivers, so as to generate conditions of least flow at Ghazi Ghat the critical junctures. Releases below Taunsa Barrage are meant exclusively for Sind Provi

Canals. As a first step, therefore, the Sind Government was requested to agree to the re-routing of their share of supply via Chashma-Jhelum Link (from Chashma Barrage on river Indus about 200 miles upstream of Ghazi Ghat) and Taunsa-Panjnad Link (from Taunsa Barrage on river Indus about 40 miles upstream of Ghazi Ghat) i.e. to meet their indent from the cumulative effect of discharges below Taunsa Barrage on river Indus and Panjnad Headworks on river Chenab (Plate No. XXI). The Province of Sind very graciously agreed to this suggestion subject to the condition that their demand of water is continued to be met with in full at all times. In accordance with this arrangement, the diversion of supply for the Sind Province via Chashma-Jhelum and Taunsa-Panjnad Links was commenced from 9th December 1983 and ended on 24th March 1984. In this way the discharge in the river fell to about 15,000 cus. by mid December 1983 (Plate No. V) which allowed the construction of road embankment to advance into the river channel and thus reduce the width of the gap to about 500 feet only as described in para 10.7.

13.4 To maximise the use of river flows and cause least burden on the preciously stored water at Mangla Dam (on river Jhelum) and Tarbela Dam (on river Indus) and also by having regards to the demand of crops in the various zones as well as from consideration of weather conditions etc., the annual closure of canals in the Provinces of Sind and Punjab are presently being staggard, usually as under :—

i)	Jhelum-Chenab Zone Canals in Punjab	From 21st Dec to 10th Feb.
ii)	Indus Zone Canals in Punjab.	From 1st Jan. to 6th Feb.
iii)	Indus Zone Canals in Sind (Sukkur Barrage)	From 6th Jan. to 20th Jan.

It usually takes about 10 days for water to reach from Chashma to Sukkur and about 7 days from Ghazi Ghat to Sukkur. The minimum flow of water for Sind Canals below Taunsa i.e. at Ghazi Ghat therefore occurs for about two weeks from 29th December to 13th January each year. In this period the entire demand of the Sind Province Canals can be met from the re-routing capacity of Chashma-Jhelum and Taunsa-Panjnad Links via Panjnad Headworks so as to generate almost Nil conditions of flow below Taunsa Barrage.

13.5 The diversion of river at Ghazi Ghat was planned to take effect in two stages i.e. first through the temporary regulator and then via leading cuts to the bridge. In view of limited capacity of the diversion works, it was imperative to generate Nil flow conditions below Taunsa for a period of three to four weeks (from 21st December to 15th January) to accomplish the mighty operations. The Government of Sind was accordingly approached to agree for a longer closure of 3 to 4 weeks for their canals as a special feature this year, so that the difficult task of diversion could be accomplished in a relatively congenial enivornment. The Sind Province did not agree to this

suggestion because arid weather conditions in that zone did not permit the standing crops to remain in dry conditions beyond two weeks without seriously effecting the agricultural yield.

13.6 The pattern of river flow in summer indicated that the construction activity could commence from early September as the flood stage in Indus usually ended by August. To coincide the diversion operations with the minimum flow of the river in early January i.e. at the time of annual closure of Sind Province Canals, it was necessary that the allied works must be completed by end December in a record period only four months. Steps were therefore taken and arrangements finalized to proceed with the construction activity at top speed from early September so as to complete the works on time. The late floods in September and consequently a drastic change in the river course completely upset this programme and delayed commencement of works by atleast one month. The construction schedule already chalked out being very tight, its re-examination for a further squeeze in time did not indicate any major area of flexibility. In a changed situation, the diversion works i.e. leading cuts and temporary regulator etc. were now to complete in late January necessitating undertaking of diversion operations from end January to about mid-February. To generate Nil flow conditions below Taunsa in this period required a postponment of Sind Canals closure by about 3 weeks. A request was again made to the Sind Government for an adjustment of their canal closures, but they declined to help in the matter because such postponement would have adversely effected the yield of wheat sown with late variety which needed second watering in the suggested period.

13.7 Sind Government was then requested to reduce their demand of water in the period from December to March to keep minimum flow of water below Taunsa when re-routing of supplies via Chashma-Jhelum and Taunsa-Panjnad Links would be operative. Surprisingly the demand placed by the Sind Province was even higher than the average of previous years (may be on account of desire to utilize maximum quantity of water from Tarbela Dam where storage position was quite favourable) as under :—

(Figures as per indent of Sind & Baluchistan Canals at Chashma – Unit 1000 Cusecs).

PERIOD		YEARS						
		1978-79	1979-80	1980-81	1981-82	1982-83	Average of 5 years	Demand for 1983-84
	1	2	3	4	5	6	7	8
DEC	16-20	31.2	34.0	34.0	32.0	39.5	34.1	40.0
	21-25	35.1	32.0	34.0	31.2	13.0	29.1	37.0
	26-31	15.6	14.0	21.0	17.4	18.7	17.3	22.0
JAN	1-5	44.0	16.5	21.0	23.4	25.1	26.0	24.0
	6-10	29.6	16.5	21.0	23.4	30.1	24.1	28.0
	11-15	32.0	33.6	36.0	35.2	36.3	34.6	42.0
	16-20	34.0	31.9	49.0	39.2	38.7	38.6	42.0
	21-25	36.0	33.0	46.2	41.2	37.5	38.8	42.0
	26-31	42.5	33.0	41.2	39.2	37.5	38.7	41.0

	1.	2.	3.	4.	5.	6.	7.	8.
FEB	1-5	49.0	31.0	37.2	39.2	36.6	38.6	42.0
	6-10	53.7*	33.0	37.2	39.2	38.4	37.0	42.0
	11-15	41.8	35.0	36.2	41.0	39.1	38.6	42.0
	16-20	59.9*	36.5	37.2	42.8	39.2	38.9	42.0
	21-25	40.0	36.5	36.2	40.8	37.0	38.1	42.0
	26-28/29	40.0	40.5	37.2	40.8	37.0	39.1	45.3
MAR	1-5	42.0	40.5	38.2	40.6	37.0	39.7	55.0
	6-10	77.5	40.5	39.0	40.2	40.0	39.9	58.0
	11-15	36.6	40.5	40.0	36.0	40.0	38.6	64.0
	16-20	35.0	39.5	42.0	36.0	41.6	38.8	59.0
	21-25	34.0	39.0	40.0	36.0	44.0	38.6	47.0
	26-31	116.6*	43.0	35.0	36.0	42.0	39.0	35.0

*Figures ignored due to rains contribution.

13.8 To meet Sind requirements in full by re-routing Indus supplies via the two Link Canals to the extent practicable (by taking into account the usual demand of Punjab Canals dependent on Indus river flows) required releases below Taunsa as per column 4 below :

Period		Indent of Sind	Available diversion* capacity for Sind via Chashma Jhelum & Taunsa-Panjnad Links.	Releases required below Taunsa.
1.		2	3	4
DEC.	16-20	40.0	10.2	29.8
	21-25	37.0	18.9	16.1
	26-31	22.0	18.9	3.1
JAN.	1-5	24.0	25.4	—
	6-10	28.0	25.4	2.6
	11-15	42.0	25.4	16.6
	16-20	42.0	20.6	21.4
	21-25	41.0	20.6	21.4
	26-31	41.0	20.6	20.4
FEB.	1-5	42.0	20.6	21.4
	6-10	42.0	20.6	21.4
	11-15	42.0	20.6	21.4
	16-20	42.0	20.6	21.4
	21-25	42.0	20.2	21.8
	26-28/29	45.3	20.2	23.1
MARCH	1-5	55.0	20.6	34.4
	6-10	58.0	20.6	37.4
	11-15	64.0	20.6	43.4
	16-20	59.0	20.6	38.4
	21-25	47.0	20.6	26.4
	26-31	35.0	20.6	14.4

*(i) Conveyance losses of the system assumed at 20%
(ii) Worked out as per Secretary, Irrigation and Power Department, Punjab, letter No. IWTR/83/2490/26/82 dated 27.8.1983 addressed to Sind Government.

Releases of the order of 16,600 cusecs to 21, 400 cusecs below Taunsa in the period from 11th January to 15th February had a clashing effect with our requirements of generating Nil flow conditions because of planned diversion operations in this span of time. To tide over the situation, the only choice left open was to deliver the matching supply from Punjab's exclusive share of Jheulum - Chenab Zone which historically had never been done before. To reduce excessive burden on this zone, the Sind Government was again approached to consider some reduction in their indent during this period but to no avail because of pressing demand of standing crops to get a good watering immediately after the dry spell of anual closure of their canals.

13.9 Faced by a difficult situation as explained in the preceding paras, Nil or minimum conditions of flow conducive for diversion operations at Ghazi Ghat (schematic diagram at Plate No. XXI) were created in the critical period from mid January to mid February as under :

i) The programme of annual closure of Punjab Canals was modified to reduce burden of our Canals on Indus water and to permit natural flow of the four eastern rivers (including release of water for power generation from Mangla Dam) to pass below Panjnad for Sind Canals. This became possible by grouping the closure of all canals of Punjab in the period of diversion operations at Ghazi Ghat as below :–

a) Jhelum-Chenab Zone Canals.	From 11th Jan. to 4th Feb. as against historical period of 21st Dec. to 10th Feb.
b) Indus Zone Canals.	From 16th Jan. to 5th Feb. as against historical period of 1st Jan. to 6th Feb.

ii) The closure of Taunsa Barrage was deferred from the month of January to end March (from 26th March to 15th April 1984) to maintain diversion capability of T – P Link for a maximum period.

iii) The closure of Chashma Barrage was deferred from mid January to next year again to maintain diversion capability of C-J Link for a maximum period.

iv) Utilize escape channels of Muzaffargarh and D.G. Khan Canals to reduce the burden of flow below Taunsa Barrage. The discharge from the escapes having a combined capacity of about 4000 cus. flows back into the river Indus a few miles on the downstream side of Ghazi Ghat.

13.10 With the adjustments enunciated in para 13.9 above, very favourable conditions of flow pattern at Ghazi Ghat had been generated as depicted on Plate No. V. The salient features of the water regulation are summed up as under :–

i) Re-routing of supply via C-J and T-P Link Canals was started on 9.12.83 and ended on 24.3.84. Requirement of re-routing the supplies for Ghazi Ghat works ended on 15th February 1984, but the process had been continued for carrying out emergent flood protection works along Magasson Canal below Taunsa Barrage :

ii) The discharge below Taunsa reduced to a historical rock bottom limit in the period from mid December to end March as would be seen from Col: 2 of the statement below :

(Unit 1000 Cusecs)

Period		Discharge below Taunsa	Discharge through escapes	Discharge below Panjnad	Total discharge for Sind	
					Actual	Demand
1		2	3	4	5	6
DEC	16-20	19.2	–	18.0	37.2	40.0
	21-25	15.4	–	18.2	33.6	37.0
	26-31	11.2	0.8	26.2	38.2	22.0
JAN	1-5	7.1	2.3	20.6	30.0	24.0
	6-10	9.8	4.0	20.6	34.4	28.0
	11-15	8.7	4.0	25.4	38.1	42.0
	16-20	6.0	1.0	52.3	59.3	42.0
	21-25	4.9	–	61.3	66.2	42.0
	26-31	4.5	–	59.3	63.8	41.0
FEB	1-5	4.9	–	49.6	54.5	42.0
	6-10	4.7	–	36.9	41.6	42.0
	11-15	4.5	–	22.8	27.3	42.0
	16-20	10.7	1.3	18.4	30.4	42.0
	21-25	19.3	2.5	18.8	40.6	42.0
	26-28/29	17.9	0.9	19.0	37.8	45.3
MARCH	1-5	22.9	5.1	16.0	44.0	55.0
	6-10	22.2	5.1	18.2	45.5	58.0
	11-15	33.5	5.1	15.8	54.4	64.0
	16-20	35.6	3.6	17.0	56.2	53.0
	21-25	38.7	–	13.5	52.2	47.0
	26-31	41.4	–	3.9	45.3	35.0

iii) In addition to re-routing of supplies via C-J & I-P Links, large quantity of flow of the four eastern rivers was allowed to pass on to Punjnad Headworks (combined effect Col: 4) to meet the Sind Province requirements (Col 6) in this period.

iv) Re-routing of water via the escapes of Muzaffargarh and D.G. Khan Canals eased the situation at Ghazi Ghat to the extent shown in Col : 3.

v) The discharge of 4500 cus. to 5000 cs. in the period from mid January to mid February at col : 2 is in fact a condition of Nil flow stage below Taunsa. In this period at the Barrage gates remained closed while the leakage from their bottom and sides gave an escapage of this order. The reporting of flow in this period was done on the basis of actual discharge observations below Taunsa.

vi) A daily observation of discharge was made from mid January to mid February at Ghazi Ghat to know the contribution of valley storage from Taunsa to the site of diversion. From the data recorded on Plate No. V, it will be seen that the discharge at Ghazi Ghat did not fall below a limit of 6500 cus. in the low flow stage period.

vii) A Wireless Station was set up and kept operational at Ghazi Ghat in the month of January and February to know the pattern of flow in the river on the upstream and to communicate on urgent matters with Lahore and other stations. This wireless set was obtained on loan basis from the Food Bund Divsion of Drainage Circle, Lahore being spare in the winter season. This facility proved immensely helpful in monitoring the flow of the rivers and for maintaining liaison with the Regulation authorities of the Province and WAPDA.

XIV. DIVERSION – FIRST STAGE

14.1 The first stage of river diversion entailed plugging of the main river course and to route the incoming water through the temporary regulator. For this purpose a diversion channel 4075' long had been excavated to detour 2000' straight length of river passage (Plate No. XXII). Recovery to the loss of head via longer path of diversion channel demanded construction of an obstruction across the river course to artificially raise the water elevation and force the water to flow partially or wholly in the new route. The normal slope of water in the river with free passage of flow was of the order of 1 in 4700 at Ghazi Ghat (PlateNo. XIII). With the restriction of flow width to about 500' at the crossing point of road embankment and tightening of the passage by langer chhaps/ stone studs etc. the depth of flow increased considerably in the reach of the river from off-take to outfall point of the diversion channel. This made the river to acquire a steeper slope of about 1 in 3500 in this reach. For water to flow in a curved path of 4075 length in the diversion channel as against the straight natural flow length of 2000 in the river, therefore, required a drop of at least 1.2' in the water elevations (i.e. $\frac{4075 \times 1}{3500} = 1.164'$).

This meant that the obstructon in the natural water-way must raise the water by about 0.6' (i.e. $\frac{4075 \times 1}{3500} - \frac{2000 \times 1)}{3500}$ to make the water to flow in the diversion channel. This rise will only tend to bifurcate the discharge in the two paths, with majority of water still to flow along the natural route. To generate a sizeable flow in the diversion channel, therefore demanded a greater raise of water elevation in the range of 1.5' to 2.5'.

14.2 The obstruction for raising the water elevation near the off-take point of the diversion channel could be introduced as under :–

i) Constructing an earthen bund :– With about 8000 cus. discharge of the river flowing in a deep channel in relation to the geometry and longer length of the laternative route, the provision of an earthen barrier alone across the river passage appeared to be an impossible proposition.

ii) Erecting a langer chhap :– Experience elsewhere and also testing on the model at Nandipur indicatted that a barrier of trees, brush wood and pilchi rolls duly packed and loaded by sand filled gunny bags etc. could raise the water elevation by about 9" or maximum of 12" if the chhap can be thoroughly packed and fully loaded in the entire length and depth. This provision therefore could make some water to flow into the diversion channel, but not in sufficient quantity as to get a substantial relief in the main flow. The behaviour of langer chhap is quite often eratic due to unpredictable settlement of the brush-wood and break-through with excessive pressure of water at any point as had been observed in case of closure of Dharama Creek (para 9.7). Full packing of the chhap having a base of tree branches is not possible to achieve even though maximum effort is made to load it from the top. With somewhat loose packing condition in the deeper section the raise in water elevation could not be expected to take place beyond a limit of about 9" at stage of about 8000 cusecs discharge in the river. The barrier of brush wood/ pilchi rolls alone can therefore be expected to generate only a creeping flow in the diversion channel and hence could not serve the full purpose.

iii) Constructing stone boom :– Provision of a stone boom barrier is reported to be capable of raising the water elevation in the range of 1.0' to 2.0' depending upon the extent of filling the voids with spawl, shingle etc. The formation of stone wall in the free flow conditions of the river was necessarily to entail a huge quantity of stone on account of the rolling effect by fast currents and formation of excesive scour depths. It is well known that free flow of water has a capacity to roll the stone at a lesser velocity than that required to roll the same stone in submerged/obstructed flow conditions (Paper published in 1936 by S.V. Isbach - title "Construction of Dams by depositing rock in running water"). Therefore to avoid undue wastage

of stone and also for reducing the velocity of flow of water, provision of an obstruction in the form of a langer chhap barrier on the upstream side of the stone boom would be extremely advantageous.

14.3 The methodology adopted for the first stage diversion of the river through the temporary regulator was therefore a normal practice of constructing a langer chhap followed by a stone boom barrier and then to block the passage of the river by erecting a cross/closure bund. The location of barriers very close to the off-take point of the new route is most essential because in a flowing stream, the effect of rise of water elevation remains confined just at the site of obstruction and tapers off quickly in a very short distance upstream. With these features in view, the lay-out of langer chhap, stone boom and closure bund at their back was fixed butting with the left high bank just at the downstream lip of the diversion channel as shown on Plate No. XXII.

14.4 Diversion was known to be an arduous, intricate and risky operation and therefore required an advance careful planning and preparatory work. Matters of particular significance are briefly discussed here under :–

i) Training of the river course in a manner that it developes/acquires an approach conducive for entry into the Diversion Channel immediately an obstruction is created in the natural water-way. A careful eye on this aspect was maintained from the beginning of the wroking season (i.e. after floods) and tinkering process continued upto the diversion stage as discussed earlier in chapter XII and partly in Chapter X. A perusal of the survey plan at Plate No. XIX will reveal that by mid December 1983, the river had been made to develop a course striking along the left high bank facing the temporary regulator site. With the constriction of water-way at the approach road site to initially 800' and then 500 feet in the month of December, the river had started eroding the left bank being on the concave side of the bend. To avoid encroachment of the left high bank, face protection with stone and a series of stone studs had to be provided. Tightening of the river gap at road embankment alignment to a width of 300' in mid-January 1984 created swirling action also along the left bank due to development of sharp left handed bend here. This situation had to be controlled by addition of more stone studs to avoid encroachment of the high bank. With the tinkering process already enunciated in Chapter XII, the approach conditions of the river had no doubt developed a position almost ideal in relation to the off-take point of Diversion Channel (Plate No. XIX and Plate No. XXII).

ii) Stock piling sufficient quantity of stone on both banks of the river to check erosive action along left high bank and for the construction of stone boom. Rough calculations for handling a discharge of about 10,000 cusecs at the time of diversion and under a condition of right angle river approach, indicated requirement of about

12 lac cft. stone for the construction of stone boom. Assuming that about 2 lac cft. stone might be needed to check the erosive action of left bank, procurement of roughly 14 lac cft. stone was expected to serve the purpose. In view of the active erosive action of the river on the left side, more quantity i.e. about 11 lac cft. stone was stock piled on this side and the balance 3 lac cft on the right bank.

iii) The stone was proposed to be dumped under water in loose form upto a point where shooting velocities may not roll it down below. Beyond it the stone was proposed to be dumped by filling in crates/trangers so that the heavier mass can withstand the rolling velocities. Sufficient number of wire-crates of variable sizes were therefore got manufactured in advance and stock piled at site.

iv) Essential stores like Mung trangers, Larmahls (date palm leaf rope), manila rope of sizes, gunny jute bags, nylon (fertilizer) bags, steel rope of sizes, bamboos, wooden ballies, wooden pegs, wooden sleepers, tarpualin etc. were also stock-piled in sufficient quantity at site for ready availability as needed.

v) Designate places for the procurement of green trees, brushwood and pilchi in sufficient quantities for the construction of langer chhaps. This stuff was procured from the plantation of Muzaffargarh Canal Branch, Forest Plantation Ghazi Ghat and surrounding bela.

vi) Keep ready a good number of country boats for carriage of trees, brush-wood, Pilchi and stone etc. for dumping at designated location in the formation of langer chhaps and stone boom. The river training process carried out in the months of November-December (described in Chapter XII) kept some boats handy and this fleet was augmented suitably by hiring more boats from the adjoining river crossing points.

vii) Stock pile sufficient quantity of earth within easy reach of rehandling/shifting on both banks of the river for narrowing the gap of flow and then to make a final rush for closing the same in running water. Visualizing its huge demand and in view of lack of free accessibility to the area on account of diversion channel excavation, a large quantity of earth excavated from diversion channel and the temporary regulator (about 20 Million cft) had been dumped on the left bank of the river to serve as stock-pile area on this side. On the right bank, there was no restriction of the borrow area or any accessibility problem for the movement of earth moving machinery. As such no separate stock piling of earth on this side was done except forming heaps of earth on the farthest ends of the road embankment and the diversion bund as they advanced into the river channel on progressive tightening of the river gap.

viii) Creation of Nil or very low flow conditions in the river during the stage of diversion operations, this aspect has already been discussed in Chapter XIII. Observation of discharge on daily basis was done at Ghazi Ghat to know that actual pattern of flow at site (data recorded on Plate No. V).

14.5 With the commencement of re-routing of Indus water for Sind Province via C-J and T-P Links with effect from 9.12.83, the discharge below Taunsa Barrage dropped below 10,000 cusecs by end December, 1983. The flow in the river upto mid January 1984 was expected to remain low on account of annual closure of Sind Province Canals in this period. Thereafter by suitable manipulation of systems regulation (adjustment of Canals closure in Punjab etc.) Nil or minimum flow conditions in the river had been agreed to be generated at Ghazi Ghat from 21st January to 10th February 1984. With the agreed pattern of low flow in the river in this manner, diversion activities could be started from eary January 1984. A crash programme of diversion operatons on daily basis was accordingly chalked out from 1st January to end February 1984 (Plate No. XXIII).

LANGAR CHHAP

14.6 By end December 1983, the river had been trained to flow along the left high bank at the site of diversion and squeezed to width of about 500 fet at the crossing point of the road emabnkment. At that time, the width of flowing water opposite the off-take point of diversion channel was about 1000 feet (see river edge marked on Plate No. XXII). To squeeze the width of the river at this site, construction of langer chhap with pilchi rolls held between wooden pegs was started from the right bank. Progressive advancement of the Langer Chhap and its packing/replenishment as well as loading with sand filled gunny bags etc. enabled a further shift of the river flow towards the left bank and thus reduced the width of flowing water to about 500 feet. Beyond this point, further advancement of langer chhap by the customary manner of driving wooden pegs etc. no langer remained practicable.

14.7 Progressive advancement of langer chhap brought about a change in the pattern of river flow also. The fast currents now tended to flow almost parallel to the langer chhap, hit the left high bank and then take almost a right angle bend causing a lot of swirling action. To shift the currents away from the alignment of langer chhap and deflect in a direction guided towards the mouth of diversion channel, a cross chhap was constructed protruding into the river in a direction oblique to the active river currents as shown on Plate No. XXII). This cross chhap proved very effective to shift the water currents away thus bringing about a change of flow pattern suited for entry towards the diversion channel as well as for flowing down the river.

14.8 The flow of water and zone of diversion operations was quite turbulent due to right angle bend of the river. To advance the chhap along the pre-determined alignment, two

rows of steel wire ropes and two of manila ropes were stretched across the river flow as marked on Plate No. XXII to facilitate the movement of boats and to hold them in position for dumping the trees/stone crates etc. at designated locations.

14.9 Full trees or main branches of trees with 2 to 3 feet girth were cut from canal banks/ forest plantation and carried to the river edge by trollies. This stuff was loaded in the boat alongwith one or two wire crates filled with stone, carried to the site of langer chhap and the boat held in position by tying with the steel rope. A piece of about 100' long 3/4" dia manila rope was then tied at one end with the tree stem and the other end with the stone crates. This load of the boat was then tipped into the river in such a way that the trees role down to the alignment of langer chhap. The process of launching the trees one above the other was continued till the wall of trees bushing became visible above the water surface in the entire length of the langer chhap. The bushing was then packed with brushwood and pilchi rolls of about 15' length each tied together by larmahs (rope made of palm leaves). The process of packing was continued till the entire mass attained a height of 5 to 6 feet above the water. The chhap was then loaded with gunny/nylon bags filled with sand in as many rows and layers as could sink the mass down. The replenishment of brush wood, pilchi rolls as well as loading with sand filled bags was continued till maximum packing took place at all points.

14.10 The construction of langer chhap in the initial length of about 500' was speedily completed in the first week of January and the cross chhap by about 10th January 1984. Excavation of the Diversion Channel had been completed on 3.1.1984 and the plug bunds from its cunettes removed on 8.1.1984 (Plate No. XXIII) to make it worthy of accepting the discharge via temporary regulator. At this stage practically no discharge from the river entered into the diversion channel being a longer route of flow. The abrupt bend of the river however caused some silt to deposit at the mouth of upper cunette being in the siltation zone.

14.11. The construction of wall of trees/brush wood in the balance passage of river flow (about 500 feet width) was taken up on 7.1.1984 and became visible above water by 15.1.1984. This made the water to rise by about 3" on the upstream side and generated a very mild flow of water in the diversion channel. The process of replenishment and packing was continued in a bid to further raise the water on the upstream side of the langer chhap and to reduce the pressure of water on the stone boom construction lower down. The completion of langer chhap on 20.1.1984 (Plate No. XXIII) could generate a maximum differential head of 8" and this made about 750 cusecs i.e. about 10% of the river discharge (about 7500 cusecs on 20.1.1984) to flow through the diversion channel.

STONE BOOM

14.12 The construction of stone boom was taken up almost simultaneously with the erection

or trees/brush wood barrier in the passage of the river i.e. w.e.f. 7.1.1984. By tightening of the river passage to about 500' at the langer chhap site, the abrupt bend of flow caused excessive scours along the left high bank and generated violent swirls/back eddies (Plate No. XXII). The construction of stone boom at the toe of langer chhap was therefore initially started from the eastern end to protect the left high bank and push deep current of flow away from the river edge. Loose dumping of the stone did not prove effective and hence dumping of stone filled in wire-crates had to be done. A number of stone studs close to each other had also to be introduced to check the damaging effect of swrils/back eddies.

14.13 As soon as the swirling action along the left bank had been controlled by extending stone boom in a length of about 75' from that end, the construction of stone boom was taken up from the right bank at the toe of langer chhap. The stone boom was advanced without much difficulty in a length of about 225 feet by dumping loose or in wire crates. The boom was kept 10' wide at the top to provide working space for the labourers dumping the stone and about three feet above the water surface then prevailing in the river.

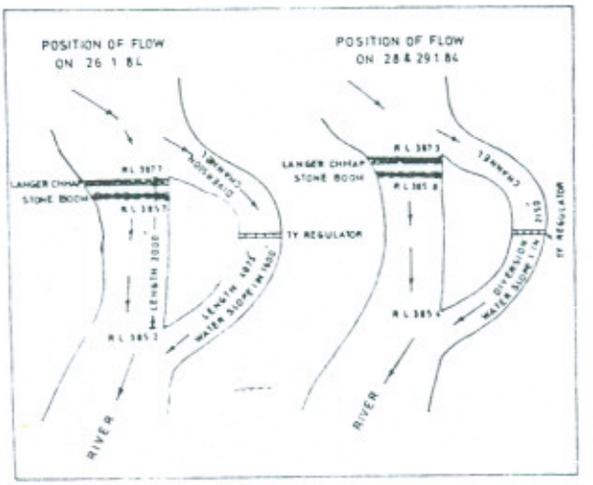
14.14 The central width of about 200 feet became problematic because advancement from the two ends became extremely slow due to rolling effect of stone in fast current and settlement by progressive increase of scouring bed. A strong steel wire rope 1" diameter was stretched across the width to firmly hold the boats in position by treating it as an anchor line (Plate No. XXII). The boats tied with this rope were positioned in a row just downstream of the line fixed for the construction of stone boom. These boats were then connected with each other by wooden sleepers to form the boat bridge. The last boat on each end was connected with the completed portion of the stone boom through a ramp of wooden sleepers. The stone was now carried to the boats, filled in crates and then tipped into water along the alignment of boom to pave the river bed in the gap. As soon as the bed was paved with stone crates in a width of about 150' along the flow line (water depth ranging from 35 to 50') stone filled in crates was then rolled into water from both ends of the boom and also by tipping the crates from the boats. In this way the gap was narrowed to about 50' width when the velocity of water became so fast that even the crates began to settle or roll down.

14.15 In the 50' gap width, stone boom was advanced from both ends by tipping 2 to 3 crates joined together as one mass. In this way the gap width narrowed to about 20'. Beyond this point even this system of dumping did not work. Now 2 to 4 crates were joined together and tied by manila rope with the wire rope. This mass was then tipped from the boat into the water which naturally could not roll down having been tied with a solid anchor of wire rope. By repeating this process quickly, the last gap of 20 feet was also filled with stone on 26.1.1984 (Plate No. XXII) to mark the completion of stone boom.

14.16 The dumping of stone and stone crates in water acquired a slope of 1:1 approximate on the upstream side. On the downstream side, the rolling/displacement of stone was quite sig

ficant and it therefore acquired a variable slope depending upon the intensity of flow. In the initial boom length of 225' on the right edge, the downstream slope ranged from 1:1 to 1:3 averaging at 1:2. In the initial boom length of 75' on the left edge, the downstream slope ranged from 1:2 to 1:4 averaging at 1:3. In the central portion of 200 feet the stone dumping had almost totally been done in crates which acquired a slope ranging from 1:3 to 1:5 averaging at 1:4. The overall consumption of stone for the construction of stone boom was of the order of 1.1 million cft. The boat bridge erected for the construction of stone boom in the central portion was dismantled/ removed after its completion of 26.1.1984 A.N. (Plate No. XXIII).

14.17 Immediately on completion of stone boom, there was a significant rise of the water elevation on the upstream side of langer chhap. The differential head across the two pervious barriers was observed to be 2.0 feet i.e. water R.L. 387.7 on upstream and R.L. 685.7 on the downstream side. The head of water created by langer chhap being 8" (as observed already), the remaining head of 16" was thus generated by the stone boom. The water now began to flow in the diversion channel with speed and started erosion of the intermediatory berm. In the next two days weaker sections of the stone boom were adequately strengthened. Attemps were also made in the two days to fill the voids of the stone by dumping spawl and tipping sand filled bags on the upstream face of the stone boom. The effect was however nominal as the tree bushing did not allow this stuff to go down much. Nylon tarpaulines and khajji mats (made from plam leaf) were also laid to cover the upstream face of the stone boom, but even these did not prove much effective inspite of loading with sand filled bags, because the trees bushing did not allow them to go lower down. Any how the flow through the diversion channel progressively increased as the channel section developed with the washing away of the middle berm. In a period of just two to three days the water elevation on the upstream dropped by about 0.4', the slope of water in the diversion channel became flatter i.e. from initial of 1 in 1600 to about 1 in 2150, the head across the pervious barriers reduced to 1.5' (against 2.0' initially) and the water at the outfall point of diversion channel rose by about 0.2'. The sketches below will make this position more clear:



14.18 Soon after completion of stone boom construction, the flow in the diversion channel gradually increased to about 2800 cusecs which was approximately 40% of the river discharge of 7000 cusecs then flowing at Ghazi Ghat. The remaining 60% discharge of about 4200 cusecs still made its way through the voids of the previous barrier to flow lower down in the river channel. Had the two pervious barriers been allowed to play their role fully for a week or so, the discharge in the diversion channel might have increased further as to cause a more favourable bifurcation of flow along the two routes. The time frame of completing the diversion operations in a tight schedule however, did not permit to remain in waiting for creation of still better conditions of flow distribution towards the diversion channel.

CLOSURE BUND

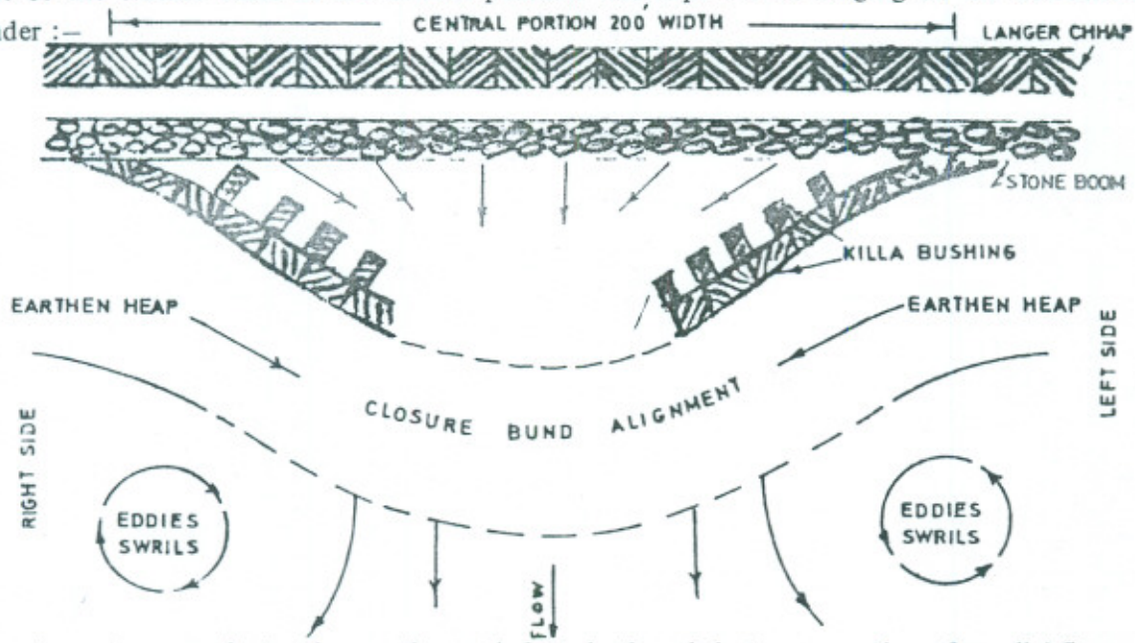
14.19 60% discharge (about 4200 cusecs) still flowing in the main river channel, it was not possible to close the gap of approach road embankment at a distance of about 1000 ft. below the site of langer chhap-cum-stone boom barrier. Attempt for closing this gap with earth would have been a complete failure on account of development of excessive hydraulic pressure at the distant location from the diversion point i.e. the month of diversion channel. Closure effort just below the stone boom barrier appeared to be the most appropriate choice because the hydraulic pressure on the bund at this site was bound to be the minimum. On the left side the river bank was quite high (average R.L. 400 ±) and the earth could therefore be advanced directly into the flowing water of the river. On the right side, the sandy bela was low (average R.L. 390 ± against water R.L. 386 ±) and hence the closure bund had to be tied with the high bank of approach road embankment as per alignment shown on Plate No. XXII so as to completely block the water passage from this end.

14.20 The earth moving fleet of dozers/scrapers of the Highways Department was shifted to the left bank of the river on the island formed by the diversion channel in the first week of January 1984 i.e. before removing the plug bunds of the cunette of diversion channel so as to be sure that subsequent access to the area only via road decking of temporary regulator may not pose any problem of inadequate strength. This machinery was engaged to stock-pile huge quantities of earth on the water edges at the sites of approach road embankment (i.e. river and diversion channel sides) and closure bund by borrowing earth from the stock pile area on the island (Plate No. XXII). A portion of the Irrigation Deptt: earth moving machinery was deployed on the right bank to construct the closure bund from the approach road embankment upto the river edge and then to stock pile earth there.

14.21 Initial advancement of the closure bund was made from the right bank in the shadow of stone boom by leaving a gap of about 300' width for the water passage. The damage to earth by flowing water and back eddies/swirls was kept under control by killa bushing and tiny langer chhaps (Plate No. XXII). This projection almost completely checked the flow of water from the voids of stone boom in this reach. Further advancement was deferred till the completion stage of stone boom to avoid undue wastage of earth.

14.22 The earth available for the construction of closure bund composed of very fine loamy sand particles (Research Report No. 1786/SM - April 1984 grain size 0.12 mm coefficient of permealability 5.62 x 10^{-6} and 36.9% prosity) without any cohesive ingradient of clay to act as binder. This type of soil offers practically no resistance to water pressure and gets washed away easily as well as quite rapidly (in contrast to red clayey earth which was not available nearby). Lot of wastage of earth at the closure time had therefore been anticipated. Since the closure effort now depended purely on the sufficient quantity of earth available for dozing work, large heaps of earth were therefore piled up on the two ends (Plate No. XXII). In view of the loose and porous texture of soil and to account for wastage, it was decided to heap up earth at least double in quantity than that required to form the embankment in water under normal conditions.

14.23 By the time the stone boom was completed on 26.1.84, the heaps of earth had been advanced into the river channel by leaving a gap of about 200' for the water passage. More quantity of earth was piled up at the two ends simultaneously with their advancement into the river channel. The width of earth at the two ends was kept ample so that 3 to 4 dozers could work toegether and push the material jointly in a row. Visualizing that the vast extent of stone deposition on the river bed may not provide open windows to the passage of water within the bank formation, the lay out of the closure bund in the central position was kept curved bulging on the downstream as under :—



An attempt was made to advance the earth from both ends but severe action of parallel flow on the upstream face, progressive deepening of the bed by scouring and violent velocity of eddies caused by shooting jets at the back of bund foiled this effort. From 27.1.84 afternoon to 28.1.84 noon, long bamboos were driven in 2 to 3 rows on the upstream side of the bund alignment and the inervening space filled with brushwood. Cross spurs by a combination of brushwood, pilchi and sand filled bags were then constructed on the upstream side of this bushing wall to push the violent currents away. The brushwood in the middle was also loaded with sand filled bags to have a barrier effect in the water passage. The closure bund was thus advanced on 28.1.84 A.N. from both ends

by deploying about 18 dozers all working together in rows of 3 dozers each. The scrapers kept on feeding the earth from the rear. With great effort the two ends of the earth joined together, but the success could not be sustaned for a duraition longer than a few minutes due to unfortunate bogging of the two dozers working in the front line on steep ramps. While these machines were being dragged out with the help of other dozers, the bund gave way in the middle where the section was still not adequate.

14.24 Efforts were then concentrated to control undue widening of the gap and to rebuild earthen heaps at the two ends. This action continued throughout the night in preparation for the next attempt to be made on 29.1.84 morning. Now the strategy was changed to follow straight alignment of the bund just at the back of stone boom. The bund was now advanced in greater width and height so as to maintain huge quantity of earth stock in the front lines and also to avoid formation of steep ramps at both ends towards the finishing operations. This system worked much better as the flow through the voids of stone boom also got supressed as the bund advanced on its back. By toiless working with dedication and vigour, the gap was totally closed at about 11.30 hours on 29.1.1984 (Plate No. XXIII). This marked the completion of first stage of diversion when the rebellious Indus surrendered and accepted to flow through the temporary regulator like a tamed and trained stream. The closure bound was then suitably widened raised and strengthened to be safe against overtopping, sloughing and coverage of the hydraulic grade.

14.25 Immediately on completion of the closure bund, the 300' wide gap in the approach road embankment was also closed the same day i.e. on 29.1.84 in almost stagnant water conditions by pushing the earth from heaps at both ends. In the next few days this portion of the road embankment was suitably strengthened by borrwing the earth mostly from the stock pile area along the diversion channel.

XV. DIVERSION – SECOND STAGE

15.1 The second stage of diversion meant closing gates of temporary regulator, putting plug bund on its downstream side in the alignment of road embankment and thus force the incoming river water to flow under the bridge via the leading cuts.

15.2 The earthen plugs from the mouth of the leading cuts were removed totally on 26.1.84 (Plate No. XIII) i.e. the day on which the construction of stone boom across the river flow had been completed (Plate No. XXIII). With the rise of water elevation in the river at the previous barriers (langer chhap and stone boom), only a nominal discharge of about 400 cusecs began to flow in the four leading cuts. In the next two days, this flow reduced to about 200 cusecs only because of drop in the water elevation of the river (by about 0.4' – para 14.17 and its sketch) i.e. on development of the diversion channel. The construction of closure bund on 29.1.84 again raised the water elevation by about a a foot (R.L. 388.3) for a short period when the flow in the leading cuts increased to about 800 cusecs. With the progressive development of the diversion channel and also some reduction in the river discharge, the elevation of river water dropped to

R.L. 386.6 (i.e. by about 1.7') and then the leading cuts stopped taking any flow in the first week of February 1984.

15.3 The plugging of the temporary regultor at its back required about 4.0 million cft. earth work to be dozed in a small period of one to two days. The dozer and scraper unit of the Highways Department was deployed on the work of piling of earth - first on the western bank by borrowing earth from the stockpile area of the island formed by the diversion channel and then by shifting the same machinery on the eastern bank via the bridge decking of the temporary regulator. The machinery of the Irrigation Department was deployed on yet another important work of constructing earthen portion of spur R-2 shank in the main river channel section where the conditions of working at low stage of river flow had become favourable on account of appearance of an intermediary sandshoal as already discussed in paras 12.6 and 12.7. This machinery was withdrawn from the spur shank on 10.2.84 and deployed the same day on the construction of the plug bund at the back of temporary regulator from the western bank of the diversion channel.

15.4 The lowering of the temporary regulator gates was planned to be done on 5th February 1984 so as to complete the construction of plug bund at its back by 10th February 1984 i.e. within the period limit of Nil/Minimum flow conditions agreed for Ghazi Ghat Works. The systems regulation of water in the rivers however permitted continuation of low flow conditions upto 15th February 1984. This provided more time to work on the construction of Spur R-2 shank in the river portion and hence the operation of lowering the gates of the temporary regulator was accordingly shifted to take effect on 10th February 1984.

15.5 To have an idea of the extent of rise of water elevation on closing down of the regulator gates at vaious stages of river flow, model studies (Research letter No. 422-C/3130 dated 28.12.83 - Annexure B) were carried out in the Irrigation Research Institute with results as under :–

River Discharge (Cusecs)	Maximum Water Level (R.L.)	Time Lag (Hours)
5,000	391.7	45.67
7,000	392.2	38.10
10,000	393.4	60.90
12,000	394.7	53.30
15,000	395.3	38.10
20,000	399.2	49.50
25,000	400.4	49.50
30,000	401.0	34.27
35,000	401.7	38.10
40,000	402.2	45.67

15.6 With the pattern of river flow (discharge of 6500 cusecs at Ghazi Ghat on 10.2.84 – Plate No. V), it was therefore known almost with certainty that on closing down of the regulator gates, the water will not head up to a level as to overflow the gates (top R.L. 397.0 with extension piece of 2 feet) and that 38 hours would be available to achieve the maximum effect of head across the structure. However to gain more time for the construction of plug bund under minimum condition of hydraulic pressure, the following pattern of regulating the gates was chalked out :–

i) Divide regulator gates in 3 segments of 10, 15 & 5 gates from right to left side.

ii) Start closing the 10 gates of Bay No. 30 to Bay No. 21 one after he other from the right flank and advance the construction of plug bund under its shadow from the western bank to the extent possible. Closure of these gates was expected to generate almost stagnant conditions of flow in the zone on the inner bend of the diversion channel.

iii) Close 5 gates of Bay No. 1 to Bay No. 5 from the left flank one after the other and advance construction of plug bund from the eastern bank. It was hoped that the plug bund may be possible to advance in a length of about 50 feet only from this side being on the outer curvature of the diversion channel.

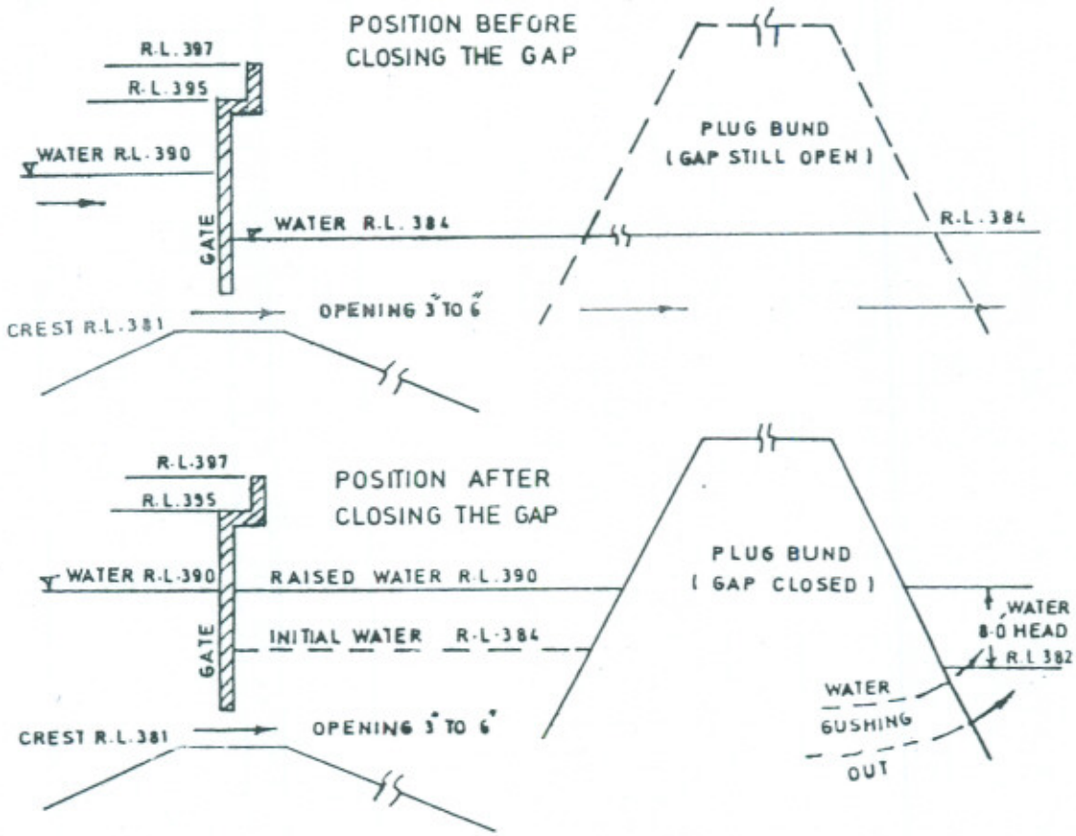
iv) Close the middle 15 bays by uniform lowering of the gates gradually from the two ends. The opening of these gates should be adjusted according to the pace of advancement of the plug bund from both sides.

15.7 The lowering of the gates according to the criteria laid down in para 15.6 above was started on 10.2.84. After closing the gates of bays No. 30 to 21, the plug bund was advanced into the water during the day light in a length of about 150'. At night time earth was stockpiled on the extreme end in preparation for the advancement of next day. On 11.12.84 morning the gates of bays No. 1 to 5 were closed and plug bund advanced in a length of about 50 feet. On this day plug bund from the right side was advanced in a further length of about 50' to reduce the gap width in the middle to about 150' by partial lowering of the middle 15 gates in such a way as to keep the flow conditions on the downstream floor and lower down in the desirable fashion. Earth stock was again built on the two ends at night time in preparation for the final assault on next day.

15.8 Further lowering of the middle gates was taken up on 12.2.84 and gap width reduced to about 100 feet with gate opening of 1.5' each. Complete closing of the 5 more gates (bays 6, 7, 18, 19 & 20 from the two sides) made it possible to reduce the gap width to about 60' In a bid to further advance the earth, the middle 10 gates (bays No. 8 to 17) were first lowered by 6" to reduce the gate opening to 12" each. While lowering these gates further so as to completely shut the bays, the concrete anchor blocks of hoisting girders platform got discloated and caused the adjoin-

ing masonry of the piers at top to crack as per details down on Plate No. XXIV The verticality of the ten gates No. 8 to 17 in this way got disturbed and under the hydraulic pressure they could not be lowered fully. Water with estimated discharge of about 500 cus. started gushing with speed from the bottom opening of 3" to 6" from these 10 gates.

15.9 A desperate attempt was now made to close the remaining gap of about 60' width in the plug bund by advancing earth from both ends in the manner already described for closing the gap of closure bund i.e. by deploying the total fleet of 18 dozers working as a team with 3 dozers in a row, while the scraper supplemented the earth at back. The two ends of earth were made to join three times in a sufficient width, but the water soon gushed out at the back like a volcanic erruption. In fact no sooner the flow passage was blocked, the water gushing from the bottom opening of the middle 10 gates caused a sudden building up of about 8 feet of water head against the bund (6 feet from the differential head at the regulator and 2 feet by evacuation of water in the river channel lower down) and punctured the same in no time as illustrated below :–



15.10 The closure of the gap under the conditons narrated in para 15.9 above seemed almost impossible to accomplish. It was felt that unless the water along the upstream face of the plug bund is made to rise slowly to gain time for fortification of the embankment, the chances of success would remain bleak. Efforts were therefore made to attempt for closing the 10 middle gates completely at a stage when the rise of water on the downstream side (on closing the gap of plug bund for a short while as experienced earlier) would be cuasing almost no hydraulic pressure on

the gates. Luckily the manipulation of gates in this situation became workable and in this way the middle 10 gates were also closed completely. The earth was now again dozed from both ends in a sufficient width with speed and this time the attempt became fruitful, because the embankment could now be made stronger in the time taken by water to slowly rise on its upstream from a nominal leakage of the completely closed gates. The completion of the plug bund on the back of temporary regulator at about 15.00 hours on 12.2.84 (Plate No. XXIII) thus marked the accomplishment of the gigantic task of the river diversion operations at Ghazi Ghat.

TEMPORARY REGULATOR

15.11 The provision of temporary regulator performed the function in the manner it had been contemplated, but towards the concluding stage of its operation, very anxious moments had to be encountered on account of dislocation of cement concrete anchor blocks of the steel girders platform supporting the gates hoisting machines of the ten central bays. This dislocation caused hinderance in the closing of these bays at a stage of 3" to 6" opening of the gates as already explained in para 15.8. A close examination of the situation revealed that the shooting jet of water from 3" to 6" opening at a differential head of about 6 feet formed an unstable moving hydraulic jump just close to or at the back of the gates. This caused a serious viberation of the gates which coupled with the back thrust of water from the hydraulic jump shook the cement concrete anchor blocks and made the gates to tilt slightly on the downstream side (Plate No. XXIV). This phenomina made the adjoining top masonry of the pier on the downstream side to crack by crushing force of the cement concrete block's tilting movement in the downwards direction. The design of the anchor block and the layout of hoisting mechanism had been evolved by the Mechanical Circle, Lahore while the Project authorities confined their role to the provision of related civil works only. A proper design of the system could have averted this situation as under (Refer Plate No. XXIV)

i) The size of C.C. block i.e. 12" x 12" at surface end 33" in depth was totally inadequate to securely hold 4 No. anchor bolts spaced at 8½" and 7" centre to centre.

ii) Instead of providing separate foundation for each anchor bolt, the single C.C. block gave inadequate surface area of skin friction for bondage with the adjoining masonry and to withstand the shearing force of the two gates causing viberating action on either side of the pier.

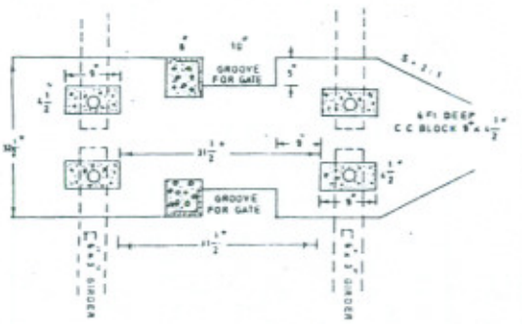
iii) The two channel section girders of the hoisting platform were placed too close to each other (7" centre to centre and clear spacing of 4") which made it obligatory to restrict the spacing of anchor bolts as well. Had the two girders been placed at a respectable distance from each other, the mutual distance of anchor bolts would have also increased for provision of independent concrete foundation to each anchor

bolt.

iv) The depth of C.C. anchor block was less in relation to forces acting on it to dislocate its position.

v) The pier thickness at the site of C.C. anchor block had reduced due to recesses of grooves for the gate. In fact a cover to the concrete block by 4½" thick masonry on sides was provided with great difficulty by projecting steps within the groove as shown at section A-A on Plate No. XXIV.

15.12 In the opinion of the author, separate concrete blocks of adequate depth for each anchor bolt spaced at a respectable distance from each other should have been provided for as per general arrangement shown below :



15.13 The temporary regulator was subjected to a maximum differential head of 6 ft (Refer sketch para 15.9) which would have increased to 8 ft. initially and then to 11 ft. ultimately (R.L. 392–RL 381), if provision of plug bund at its back had not been possible to erect simultaneously (water had ponded upto R.L. 392 on 12.2.1984 evening – table para 16.1, and tail water evacuated to R.L. 381 – Para 16.13 & sketch plate No. XXV). In this way the assumption of the differential head of 12 ft in the design of this structure appeared to be very realistic/ appropriate.

XVI. POST DIVERSION EVENTS

LEADING CUTS.

16.1 The passage of water along the natural course having been closed, the mighty river Indus was tamed on 12.2.84 to flow through the leading cuts and pass under the road bridge. Gradually a lake was formed on the upstream side of the right approach road embankment and by the same evening water rose to an elevation of R L. 392.0 as indicated by the model studies for a discharge of about 6500 cus. in the river. The velocity of flow in the leading cuts was initially slow as it took quite some time to fill the long empty channel of left creek joining the main river at a distance of about 12 miles lower down the bridge. The rise of water elevation at the temporary regulator and slope of water in the leading cuts indicating their pace of development) would be clear from the

following data :—

Date	Discharge below Taunsa (Cusecs)	Water levels at Ty. Regulator	Bridge	Head of flow in the leading cuts length 9000' (ft:)	
10.2.84	4572	386.6	386.3	0.3	
11.2.84	4592	389.0	388.2	0.8	
12.2.84	4572	392.0	390.3	1.7	
16.2.84	4692	392.2	390.4	1.8	
19.2.84	14281	394.2	392.4	1.8	
23.2.84	16932	398.6	395.4	3.2	
29.2.84	19882	398.3	395.2	3.1	
1-10.3.84	26,000	399.0	396.0	3.0)	
11-20	35,000	399.8	396.9	2.9)	Average
21-31	40,000	400.0	397.0	3.0)	
1-10.4.84	39,000	398.8	396.2	2.6)	
11-20	44,000	399.0	396.6	2.4)	Average
21-30	47,000	398.7	396.3	2.4)	
1-10.5.84	52,000	398.3	396.1	2.2)	
11-20	62,500	398.5	396.2	2.3)	Average
21-30	70,000	398.9	396.5	2.4)	
1-10.6.84	1,14,000	399.3	396.6	2.7)	
11-20	1,46,000	399.7	397.2	2.5)	Average
21-30	2,12,000	400.9	398.2	2.7)	
1-10.7.84	2,40,000	399.6	397.3	2.3)	
11-20	1,84,000	398.0	395.6	2.4)	Average
21-30	2,33,000	399.6	396.7	2.9)	
1-10.8.84	2,82,000	400.7	397.7	3.0)	
11-20	3,49,000	400.2	398.0	2.2)	Average
21-25	4,89,000	403.5	399.2	4.3)	
26-31	4,22,000	401.7	398.2	3.4)	
1-10.9.84	3,23,000	399.8	396.3	3.5)	
11-20	91,000	394.0	391.9	2.1)	Average
21-30	68,000	392.5	391.2	1.3)	

16.2 A statement showing the rise of water elevation as predicted on model overleaf will further clarify this position :

Discharge	Water level at Temporary Regulator		Water level at Bridge		REMARKS
	Predicted on model.	Actual	Predicted on model	Actual	
7000	392.2	392.2		391.0	
10,000	393.4				
12,000	394.7				
15,000	395.3	394.2		392.2	
* 20,000	399.2	398.3		395.2	
25,000	400.4)	399.0	395.4	396.0	
30,000	401.0)				
35,000	401.7) Note	399.8		396.9	Note :– Spilling over the flood plain to cover the high bela had been expected.
40,000	402.2)	400.0	396.0	397.0	
1,00,000	402.6	399.2	398.2	396.5	
** 1,50,000	403.4	399.7	398.5	397.2	
2,00,000	403.6	400.8	398.7	398.2	
2,50,000	404.2	399.6	399.8	397.8	
3,00,000	404.5	400.8	400.3	397.8	
4,00,000	405.5	401.7	401.2	398.2	
5,00,000	406.5	403.5	402.7	399.2	

16.3 A study of statements at para 16.1 & 16.2 will reveal that the rate of increase of discharge in the river has been very slow at the initial stage. This pattern of increase made the leading cuts to gradually grow in size and accommodate the entire discharge of the river to flow within their devloped sections. The rate of increase of discharge at initial stage of diversion has been accordingly to normal expectation (River rose from a discharge of 4692 cus. on 16.2.1984 to 14281 cus. on 19.2.1984 and 16932 cus. on 23.2.1984) and in this period the pattern of rise of water elevation at the temporary regulator site was almost in line with the predictions made by the Irrigation Research Institute as per statement at para 15.5 i.e. in the non-developed stage of leading cuts. From 23rd February 1984 to 10.3.1984 the increase of river discharge was very nominal and thereafter too quite slow. With river flow at a discharge of 18000 to 60,000 cus. (from last week of February to end May 1984 - statement para 16.1 and Plates No. V & IX), the elevation of water at the temporary regulator site remained fluctuating between R.L. 399.0 to R.L. 400.0 i.e. without at any time spilling over the flood plain to cover the high bela on upstream and downstream sides of the bridge. The entire river discharge in this period therefore kept flowing within the progressively devloped sections ofthe four main leading cuts, by sucking almost all the flow from the gap of spur R-2 shank.

16.4 The effect of pond of water was prominently visible upto a distance of about 5 miles on the upstream side. Beyond this limit, the direction of flow currents could distinctly by noticed. In a condition of non-inundation of the high bela till end May 1984 as explained in para 16.3 above,

* Research Report No. 422-C/3130 dated 28.12.1983 – Table II – Annexure B.

** Research letter No. 422-C/894 dated 21.3.1984

only a nominal discharge was drawn by the leading cut No. V-A while the two tiny leading cuts No. V & VI (which were in fact meant to link the pond water across the nose of spur R-2) remained almost dormant. The leading channel on the upstre m side of spur R-1 as excavated by the Highways Department in the year 1982-83 also began to take some discharge at a river flow stage of above 40,000 cs. from April 1984 onwards because of its location on the outer curvature of the river bend and off-take point being just outside the zone of pond effect.

TEMPORARY REGULATOR

16.5 The gap of spur R-2 Shank, as discussed in Paras 15.3 & 15.4 and shown on Plate No. XIX, could not be closed due to:

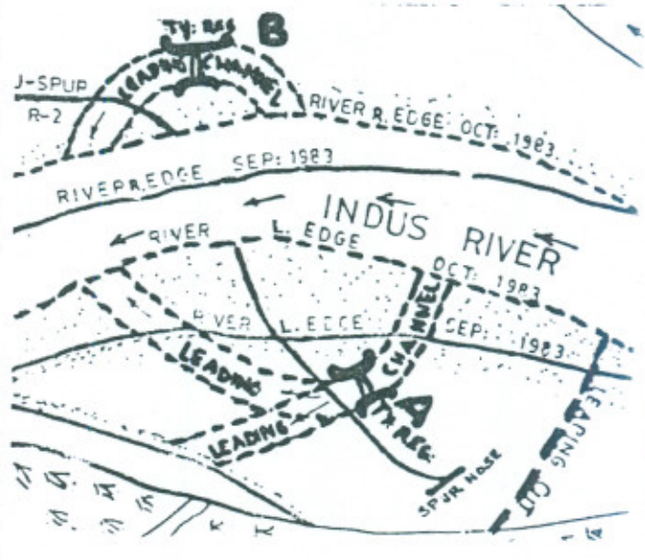
(i) prolonged low flow stage of the river after the diversion operaton,

(ii) non-covering of the flood plain to permit development of alternative routes of flow towards the bridge ; and

(iii) resultantly excessive development of the leading cuts by sucking almost the entire flow from the spur gap.

Certain quarters expressed an opinion that if the temporary regulator had been located near the spur gap, the same would have served the dual purpose of diversion as well as construction of spur R-2 in the total length. Probable sites for the locations of the temporary regulator in such a situation as well as the related arrangement of ancillary works are shown in red on the sketch below :—

Placing of the temporary regulator in this manner meant provision of the leading cuts having off-take points on the upstream side of the spur nose as per path marked in zig-zag lines on Plate No. X. The feasibility of excavating the leading cuts along this route has already been ruled out as discussed under Para 8.1 (i) in detail.



16.6 As discussed in chapters V & VI, the site for the location of the temporary regulator had remained under constant review of the senior engineers and deliberated in length at many forums. All the feasible proposals were studied on the model in detail

and location finally decided upon in line with/close to the road embankment as shown on Plate No. X. Leaving aside the impracticable aspect of excavating the leading cuts with off-take points on the upstream side of Spur R-2, the consturction of temporary regulator itself at the sites shown on the sketch were not feasible on account of the following :-

i) In the flood season of the year 1983, the river on upstream side of the bridge has been flowing almost in the entire width of the channel between firm high bela on left and high edge on the right. (Refer Plate No. VII). The growth of low sandy belas in the middle (Plate No. X) became visible in mid-September when the discharge in the river dropped to about 2.0 lacs cusecs. In this situation no idea of placing the temporary regulator at a site in the middle of river channel could have been conceived.

ii) The two sites of the regulator marked A & B on the sketch, are prone to action of the river by high flow which could take place by winter freshets or local rains in the sulaiman range hills. Protective measures against such eventuality were therefore required to be devised in both the cases.

iii) Consideration of the alternative to place the temporary regulator on the left bank at position 'A' was possible towards end September, 1983, when the discharge of the river reduced to about 75,000 cus. (Plate No. IX). Even if a spontaneous decision of locating the regulator at this site had been made (without any detailed analysis of the related matters), the development of access road and extension of transmission line etc., was bound to take their own time causing a resultant delay in the commencement of the work. The feasibility of on-time completion of the structure in this situation would not have been practicable in view of the magnamity and intricate nature of the work explained earlier.

iv) The river in the Shank portion of Spur R-2 had a right handed curvature with tendency to erode the right bank and shoal formation on the left. By end October, the deep channel of the river had shifted about 1000 ft. towards the right side causing the sandy bela on the inside of the curvature to grow in a width of over 1500 ft. (Refer Para 12.2 and Plate No. XIX). In this situation, the lay-out of the diversion channel for the position 'A' of the temporary regulator was to be a minimum of one & a half mile length as against 4075 ft. excavated in the scheme of works implemented upon. The excavation of such a lengthy channel to the lines and

grades conforming to the arrangements similar to those depicted in the sketch at Para 16.5 and Plate No. XXII was not only impracticable in the given time schedule, but also extremely cost intensive. In addition the off-take point of the leading channel at inside curvature of the river would have always remained prone to the process of siltation and this factor alone might have frustrated the attempt of initial stage of river diversion through the temporary regulator.

v) Consideration of an alternative to locate the temporary regulator on the right bank at position marked 'B' on the sketch, could also be made towards end-September, 1983, when the sandy bela in the centre of the river channel because prominently visible. The erosive action on the outer curvature however negated this idea because the foreshore in a length of about 1000 ft. had been lost in a short span of one month during October, 1983 (Plate No. XIX).

vi) The access to the central bela could have been developed after 23rd October 1983, when the flow of Dharrama Creek along the right side high edge became possible to block (Para 9.8). The construction work at location 'B' was therefore not possible to commence earlier than November 1983, even though the cumbersome process of stretching lengthy transmission line from D.G. Khan side and time taken to shift the machinery/materials via a long route of Taunsa Barrage had been ignored. Such a belated start was bound to delay the completion of the temporary regulator to end February 1984, calling for undertaking the diversion operations in March 1984. This surely did not fit in with the pattern of low flow that could have been managed on this river for the diversion operations discussed already in Chapter XIII.

16.7 The conditions obtaining at site as explained in Paras 16.5 & 16.6 thus rules out any idea or consideration of placing the temporary regulator near the gap of Spur R-2 Shank being technically non-feasible.

SPUR-2

16.8 The provision of this spur, although not forming a part of the diversion plan was entrusted to the Irrigation Department through a special request made towards end-September, 1983. This important training work on the right side had not been constructed ever since the construction of the bridge was taken in hand, perhaps due to non-favourable river flow condition viz-a-viz the alignment of this spur. The appearance of central sandy bela in the flood season of the year 1983, made it possible to construct this spur in parts i.e., Spur nose on left bela and earthen shank on either side of the river as per arrangement shown in Plates No. X, XIX and XX. The 200 feet wide gap in the shank had been planned to be filled up at an appropriate time after the diversion operations were complete and alternative passages of flow beyond the spur nose had developed towards the bridge to create almost lull conditions at the gap site. With this end in view

the earth work of shank in the river poriton over a length of 3000 ft. (from R.D. 5350 to R.D. 8450-Plate No. XX) was built upto maximum limit as could possible by manuplated with the available resources in the period from mid-January, 1984 upto 10th February 1984 i.e., when minimum flow conditions occurred below Taunsa Barrage (Plate No. V) to generate desirable working conditions in this area and upto a time the closing of the temporary regulator gates was taken in hand to head up the supply for pushing the water through the leading cuts. In this short span of less than a month (in addition to river training/tinkering efforts detailed in Paras 12.6 & 12.7 and concurrent works of diversion at closure bund, right approach road gaps discussed in Chapters XIV & XV) earth work to the tune of 12 million Cft. involving long lead of even over a mile was done in the stretch of river channel from Spur R.D. 5350 to R D. 8450, by leaving about 200 ft. wide gap along the left bank for water passage. This gap was the limiting width as tightening of the same any further tended to cause excessive bed scour and erosive action at the two ends.

16.9 Studies were carried out in the Research Institute to work out the modality of closing the gap in the earthen shank of spur R-2 with various incoming river discharges. Results indicated that suitable time for closing of the gap would be at a river stage of above 25 thousand cusecs when soon after the completion of diversion operation (i.e., on closing of the temporary regulator gates and the gap of the road-cum-diversion bund at its back), the heading up of water by the backing effect would cover the surrounding ground/bela (Table 16.2 & Annexure 'B') to generate alternate routes of flow towards the leading cuts & the bridge. At this stage, as further revealed by the model studies (Annexure 'C') minimum velocities of flow through the spur gap had been expected to be encountered while nearing the process of closing this gap.

16.10 The closing of the spur gap was thus contingent upon certain anticipated pattern of flow in the river envisaging a rise in discharge exceeding the developing capacity of the leading cuts. so as to create a pondage of backing up effect to generate almost lull conditions in the gap, during which time the closure was to be attempted. At this stage, te water would have formed alternate routes of flow towards the leading cuts & the bridge by spilling over the bela. Due to unprecedented low flow in the river, the actual flow pattern at site did not register a quick rise which had been anticipated to take place below Taunsa Barrage as per previous years for meeting the requirement of the canal systems lower down, (Plate V, Tables at paras 13.7 & 13.10). It was only after one month of the diversion that the river discharge touched 30 thousand cusec mark, a stage at which shortly after the diversion operation the above conditions were expected to be achieved (Table para 16.2). Even subsequently the rise in the discharge of river has been very slow (Table para 16.1) which gave ample time to the leading cuts to develop at the same pace at which the discharge have been rising. Under these situations the spur gap could not have possibly been closed as also briefly explained in Paras 16.3 to 16.5.

16.11 The widening of the spur gap and confinement of the river flow in it subsequently created a crisis situations on the works lower down by accentuation of the right handed river loop there.

In this situaion, some quarters expressed an opinion that the closing of the gap should have been attempted simultaneously with the closing of the temporary regulator gates when heading up of the water was under-way and the leading cuts had still not developed. The operation for closing the gates of temporary regulator was taken up on 10th and completed on 12th February 1984 (Plate No. XXIII. In this period the water level on its upstream side rose by about 5.5 ft. from R.L. 386.6 to R.L. 392.0 (statement Para 16.1). This rise of water neither covered the sandy bela around spur nose (ground R.L. 398.5±) nor the firm high bela facing it (ground R.L. 403 ±). The leading cuts No. V, VA & VI thus remained high and dry in this period as would be clear from the excavation data at Plate No. XVIII. In fact only a nominal quantity of water began to flow in these cuts afte 23rd February 1984, when discharge in the river increased and water rose further to R.L. 398.6 (statement Para 16.1). Throughout the period from 12th February to 23rd February 1984, the only passage for the water to flow in the leading cuts was via the spur gap. This phenomena progressively developed the water carrying capacity of the four main leading cuts by sucking all flow from the gap of Spur R-2 shank. Later on although the river discharge gradually rose to about one lac cusec towards end May 1984, but the water elevation remained fluctuating between R.L. 398.0 to R.L. 400.0 without covering the flood plain or causing a significant bifurcation of flow via the upper leading cuts No. V, VA, VI and the Highways Department channel on upstream of Spur R-1 (Plate No. X). With these flow conditions, the entire river discharge virtually kept flowing through the Spur Shank by widening its gap during the flood season of the year 1984. At no stage therefore stagnation of flow or conditions of lull prevailed in the gap portion to enable its closing according to the plans; which had been devised under the condition that the incoming water would acquire alternate routes of flow at the initial development stage of the four main leading cuts.

ROAD EMBANKMENT

16.12 On completion of the diversion operation on 12.2.84, entire effort was concentrated to strengthen the diversion-cum-approach road embankment in the portion of main river channel and at the back of temporary regulator. With the gradual rise of water on the upstream of this embankment, at a differential head of 11.5 feet (Upstream water R.L. 393.2 and downstream R.L. 381.7 on 18.2.1984), phenomena of excessive seepage as well as some boiling effect was noticed at the toe end. The process of raising the embankment was therefore deferred and instead efforts were concentrated to quickly construct a strong saddle of pushta at the back. To have a scientific base for the design of pushta, piezometer pipes were installed in the entire section of the embankment at representative locations to monitor the effect of seepage and hydraulic grade of the soil texture. These observations established hydraulic gradient line of 1 : 21 to 1 : 33. The construction of pushta to cover hydraulic grade of 1 : 33 entailed huge quantity of earth-work which appeared difficult to do in a limited time because the borrow area was rapidly becoming boggy by the gradual rise of sub-soil water-table. With the deposition of some silt in the river bed on the upstream side of the embankment during the months of May to June and onwards, an improvement in the hydraulic gradient line could be expected to take place. To economise in cost, the size for the construction of pushta was restricted to provide coverage against hydraulic grade

of 1 : 20 for the high and 1 : 30 for low flood stage of river flows.

16.13 At low stage of river flow and till the flood plain (low sandy and high firm bela) on the downstream side of the bridge is not covered by water, the embankment will be subjected to a maximum pressure of differential head on account of gradual building up of the pond on the upstream side and evacuation of water from the empty tail channel of the river on the donwstream side. Upto a stage of non-coverage of the downstream belas by water, it was anticipated that the road embankment in the portion of main river channel could be subjected to maximum differential head of about 20 feet. At this juncture, the pond of water at bank full stage of the river i.e. nearing the point of inundating the high bela will be at R.L.401 ± while the tail channel on the downstream side of the embankment will have evacuated to R.L. 381 ± (minimum tail water actually observed at site was R.L. 381.2 on 13.2.1984). The formation of pushta to cover hydraulic grade of 1 in 30 did not entail much earthwork in the normal stretch of bund on sandy bela. In the deeper section of the embankment (R.D. 4200 to 4600 at the back of regulator and R.D. 5030 to 6000 in the main river channel portion), coverage of this grade required construction of an abnormally long pushta, which neither seemed practicable in the given time frame nor considered desirable from economic point of view. To tide over the situation, the seepage flow on the downstream side was trapped by constructing a subsidiary bund at the site of boat bridge (about 2000 feet downstream – Plate No. X) so that gradual rise of water in this pocket may reduce the differential head across the main embankment. This provision with a controlled out-flow of water from one side on the higher sandy bela through the openings of the R.C.C. Pipes proved very effective in reducing the built up of hydraulic pressure across the main embankment. With this system, the tail water level on the downstream side was gradually riased from R.L. 381.2 to R.L. 393.0, which reduced the differential head across the road embankment by 11.8 feet (R.L. 393 minus R.L. 381.2) and made it safe for the hydraulic gradient of 1 in 30 at low stage of river flow.

16.14 The design of road embankment with pushta, safe against hydraulic grade of 1 in 20 during high flow stage of river flow and 1 in 30 at low river discharges was evolved in the manner discussed in para 16.12 and 16.13 above. Typical cross sections of the embankment and lay out of pushtas, as constructed at site, showing the water elevations at high and low stage of river flow and corresponding coverage of the hydraulic grade lines are given on Plate No. XXV.

16.15 Blowing of moderately strong winds in the months of March and April 1984, caused damage to the upstream slope of the right approach road embankment by the generation of waves of the headed up water along the same. This damage was likely to accentuate during the high flows in the river by blowing still stronger winds/wind storms in the summer months. The pocket in front of this embankment is not expected to get appreciably silted soon due to non-flow water condition in this zone being in the shade of Right Guide Bank and the shank of Sspur R-2. One way of tackling the situation could be to place additional earth aong the upstream face to be sucked-in by the waves for development of a beach slope. This treatment could not be totally depended upon to ward off any serious action. As the pool of water along this embankment will stay on for a few years (till high bela is formed by siltation) it was considered appropriate to

remedy the situation on the permanent basis by providing stone facing (1.3 feet stone pitching over 0.7 feet spawl) along the upstream face in the entire length of the river zone i.e. from R.D. 5000 to 16,500.

XVII. GENERAL

17.1 Mighty River Indus, one of the largest rivers of the World, flowing in a single or a number of streams oscilates in a Khadir width of seven to fifteen miles. Large quantity of water continues to flow in the river below Taunsa during winter season also to meet the irrigation requirements of Sind Province Canals. Construction of a bridge on such a river entails high skill of multi-disciplinary character. No single agency or department can claim to possess the required expertise of investigation, planning, research, design & construction in the fields relevant to such Projects. Each situation has its own pecularity and offer a variety of solutions requiring examination by expert hands to arrive at a most desirable option. A project of such a multi-directional type requires a continuous examination/over-view by expert hands of the related fields to incorporate modification by the changing situations. While reviewing the history of bridge construction at Ghazi-Ghat, absence of such a forum is rather more vividly felt particularly in respect of the following :–

(a) The ground/river survey of the area was done in the year 1974 to carry out the model studies for determining the location/lay out of the project works. No repeat survey were undertaken to know the behaviour/trends of the river untill the stage for diversion through the bridge arose in the year 1983. Such a long gap in the knowledge of river developments, around the bridge structure situated in the middle of the flood plain, did not provide an opportunity to train the river for facilitating the ultimate diversion phases.

(b) The model studies carried out in the Research Institute at the conceptual stage, was done rather in isolation as there had been no critical examination of the proposals or feed back for alternate solutions. Such discourse might have been instrumental in bringing about a change in the location/lay-out of the bridge works.

(c) Option for provision of bridge foundation on massive wells or piles.

(d) The effect of afflux of water on account of constriction of the water way by bridge construction and consequent strengthening of the flood embankments on the upstream side remained in doldrum due to divisiion in the areas of responsibility.

17.2 While conceiving the work of this size/type, in future, formation of a Committee of experts in the related fields would be desirable for decision making and to over-view the implementation from coonception to completion stage. A project approach for construction of these works should be adopted and all the agencies involved in the process be made to work under

a unified command for speedy decision and action.

17.3 A continuous dialogue of the experienced hands was maintained in the development of the river diversion plan and facility of carrying out the model studies at the Irrigation Research Institute also availed to the maximum. Throughout the diversion operation a very close liaison was kept with the Research Institute for a quick feed back of the data and to organise field visits. As many as 12 reports were made available by the Research Institute for the implementation of the diversion plan which has never been the case in the history of the Institute before. Inspite of such an awareness the element of retrogration in the leading cuts and left channel/creek joining the main river ten to twelve miles lower down was lost sight of due to confinment of the model tray to a limit of about 2 miles below the bridge. Similarly no advice from the Research could be obtained to ascertain the behaviour of gap in shank of spur R-2 in case the river discharge did not follow the anticipated pattern or non-plugging of the same due to any eventuality.

XVIII. ACKNOWLEDGEMENTS

18.1 The diversion of mighty river Indus through the road bridge at Ghazi Ghat was no doubt a very intricate, hazardeous and challenging operation. It required extremely careful planning and dedicated hard work to complete herculean job in a given situation and a tight time schedule of only four and a half months. The completion of this gigantic task entailing tremendous quantities of men, material and machinery as well as working with precision like a clock, will indeed be remembered as a land mark in the development history of the Province. Execution of about 200 Million cft. earthwork, 5 Million cft. stone work and construction of an intricate hydraulic structure having foundation 25' to 30' below sub-soil water-table including provision of gates gearing arranements in a short span of 3 to 4 months is a land mark of human effort and indigenous resources.

18.2 The diversion of river virtually marks the completion of road bridge project. The successful completion of this operation became possible due to judicious planning, concerted efforts and dedicated hardwork of all the agencies associated with the Project. The commissioning of the bridge as a sequel of river diversion, has ushered in a new era of plenty and prosperity in Dera Ghazi Khan and Rajanpur districts, an area endowed by nature with rich mineral resources. This road bridge will not only revolutionize the existing communication facility or the travelling people of Punjab, Sind and Baluchistan Ptovinces, but will also yield immense socio-economic benefits by facilitating the all round progress of the local population. It will also provide a major impetus to the required industrial and progressive farming activities because inaccessibility of the area has been responsible for its past neglect and backwardness.

18.3 The authors wish to record with thanks the cooperation of the field and office staff in compilation of the relevant data and the preparation of the drawings. The authors appreciate the role of Irrigation Research Institute whose timely advice on all facets of operation has been of

immense value. The authors are also thankful to Director Regulation for managing reduction in the river flows exceedingly well failing which the job would not have been possible to accomplish. The authors are particularly indebted to the dynamic leadership of the Honourable Governor Punjab (Lt. Gen. Ghulam Gillani Khan) whose visits to the Project works at critical junctures and patting the staff/workers gave tremendous enthusiasm to work with more zeal, vigour and dedication. Above all the almighty God has been extremely benevolent and kind to us in maintaining most favourable weather conditions in the area. The work had not to be stopped even for a single day on account of bad weather or rains. There was only an odd casually of one greaser in the machinery yard (outside the working zone) by a stray movement of scraper whose brakes had leaked enroute.

18.4 River Indus is one of the biggest rivers of the world. The construction of various structures on this river and its diversion works have always entailed a herculean effort and large scale deployment of men, material and machinery. The complex nature of the diversion phase and its invisible character in the ultimate shape of permanent works attracted attention of the Government to launch a compaign of wide publicity in the press. This was intended with a view to provide necessary information and education of the masses about the gigantic efforts being put in to ameliorate the lot of back-ward area. As a sequel of this compaign, a wide section of society including large number of students, teachers, public representatives, social workers, traders, doctors, engineers, Govenment functionaries, local and national press etc. paid a visit to the works in progress and lauded the efforts of Pakistani Engineers for the accomplishment of the goal. The following remarks on the Visitor's Book by a Retired Civil Servant convey a gist of the impressions :

کس شخص نے کس دل سے یہاں کام کیا ہے
تحسین قد حسن ادا ہم نے بھی کی ہے

ANNEXURE 'A'

DIVERSION OF RIVER INDUS AT GHAZI GHAT

TIME TO ATTAIN DIFFERENT WATER LEVELS UPSTREAM OF DIVERSION BUND NEAR TEMPORARY REGULATOR AT DIFFERENT DISCHARGES

WITH 4 NO. SEMI-RIGID CUTS HAVING 55' BED WIDTH, BED R.L. 387 (AT MOUTH) & R.L. 383.5 (AT TAIL) – ORIGINAL PROPOSAL

Discharge in Cusecs	To attain R.L. 395.0		Maximum Water Level		
	Model Time in Minutes	Proto type time in Hours	Maximum R.L.	Model Time in Minutes	Proto type time in Hours
5,000	-	-	-	-	-
7,000	-	-	394.0	100	76.2
10,000	55	41.9	95.4	80	60.9
12,000	32	24.4	95.7	70	53.3
15,000	15	11.4	97.5	90	68.5

SOURCE : Irrigation Research Institute Lahore letter No. 422-C/3130, dated 28.12.1983.

ANNEXURE 'B'

DIVERSION OF RIVER INDUS AT GHAZI GHAT

TIME TO ATTAIN DIFFERENT WATER LEVELS UPSTREAM OF DIVERSION BUND NEAR TEMPORARY REGULATOR AT DIFFERENT DISCHARGES

WITH 4 NO. SEMI-RIGID CUTS HAVING 70' BED WIDTH, BED R.L. 386 (AT MOUTH) & R.L. 384 (AT TAIL) – ORIGINAL PROPOSAL

Discharge in Cusecs	To attain R.L. 395.0		Maximum Water Level		
	Model Time in Minutes	Proto type time in Hours	Maximum R.L.	Model Time in Minutes	Proto type time in Hours
5,000	-	-	391.7	60	45.67
7,000	-	-	392.2	50	38.1
10,000	-	-	393.4	80	60.9
12,000	-	-	394.7	70	53.3
15,000	36	27.42	395.3	50	38.1
20,000	5.5	4.19	399.2	65	49.5
25,000	2.5	1.9	400.4	65	49.5
30,000	1.5	1.14	401.0	45	34.27
35,000	0.25	0.19	401.7	50	38.1
40,000	-	-	402.2	60	45.67

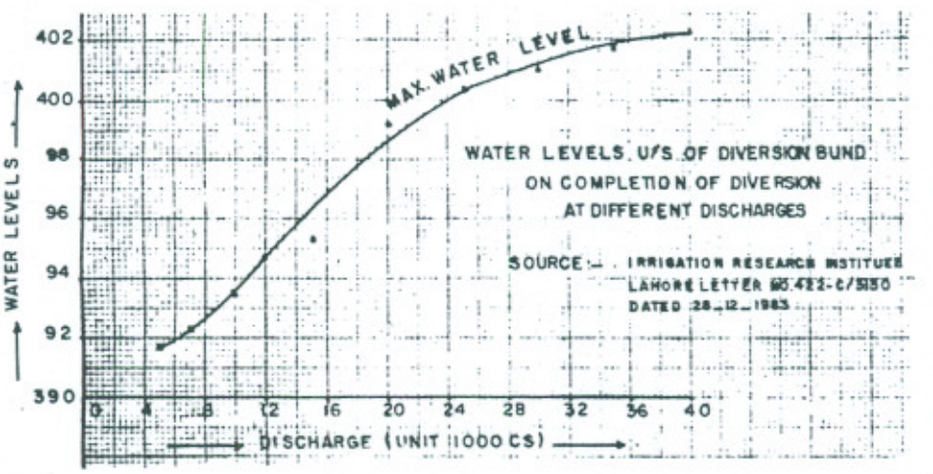
ANNEXURE 'C'

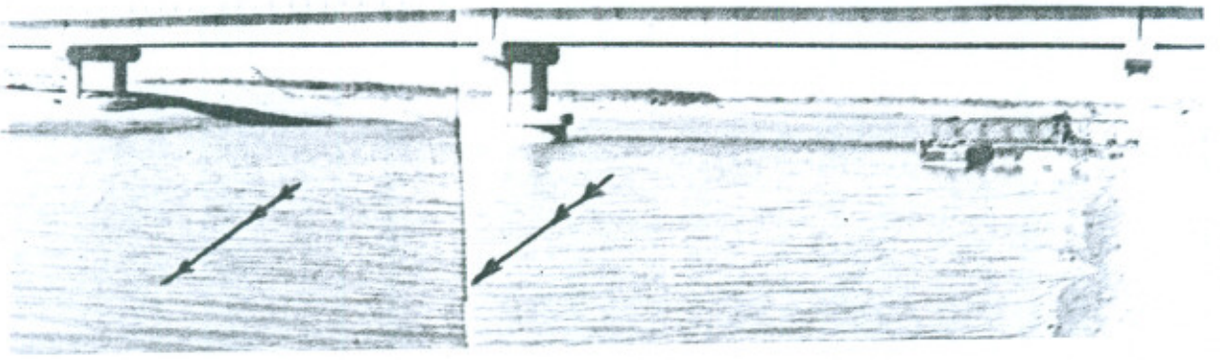
DIVERSION OF RIVER INDUS AT GHAXI GHAT
VELOCITIES IN FEET/SEC IN THE GAP OF SPUR R – 2 SHANK

AT DIFFERENT DISCHARGES

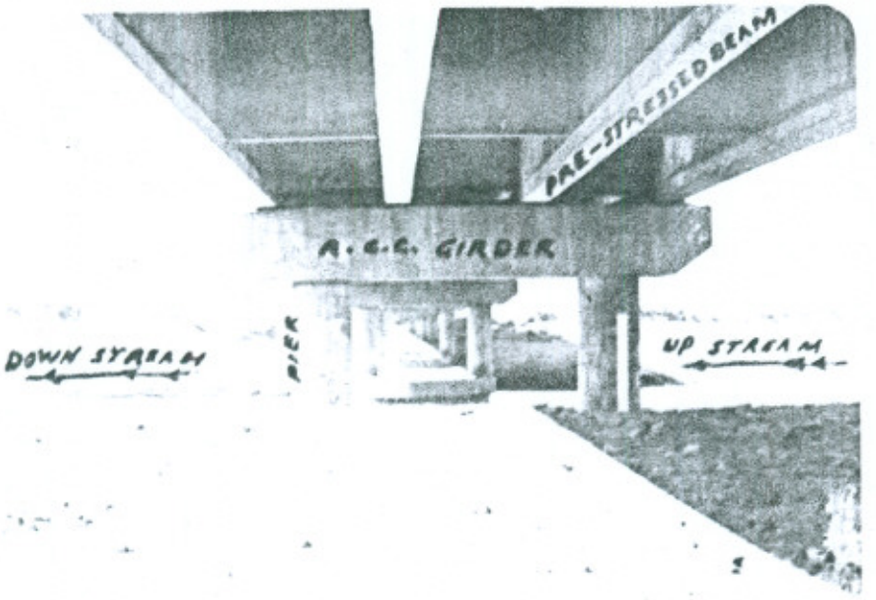
Discharges in Cs.	Water Level	Percentage Closure of Gap %	80%	Remarks
1	2	3	4	5
5,000	391.7	2.35	5.62	
7,000	392.2	3.13	8.93	
10,000	393.4	3.96	10.15	
15,000	95.3	3.96	10.15	
20,000	99.2	2.75	5.62	Sandy Bela R.L. 398.5 5±
25,000	400,4	2.75	4.96	
30,000	401.0	3.12	5.62	
35,000	401.7	3.13	4.78	
40,000	402.2	3.55	5.62	

SOURCE :– Irrigation Research Institute
Lahore letter No. 422-C/3130,
dated 28.12.1983.

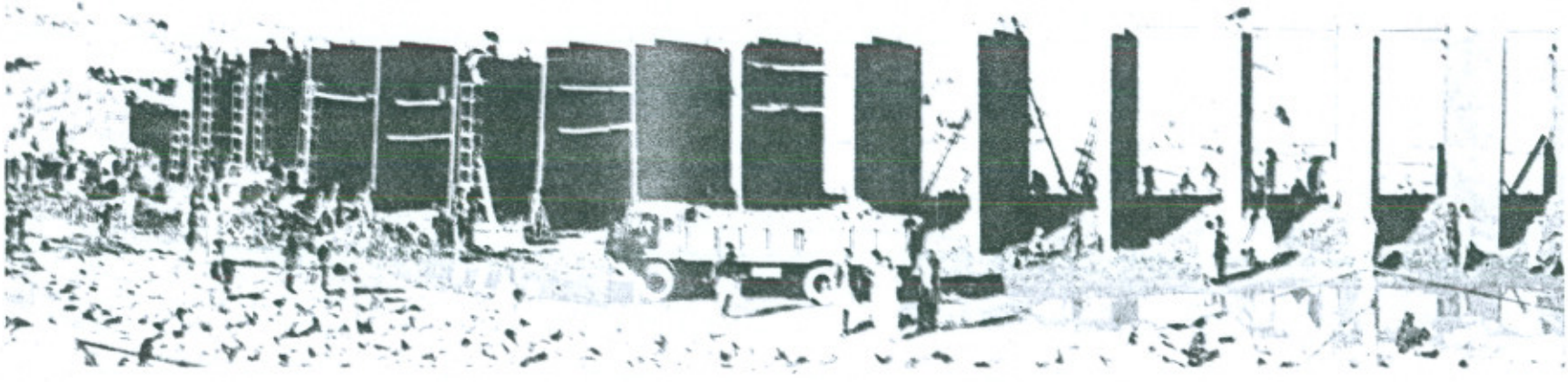




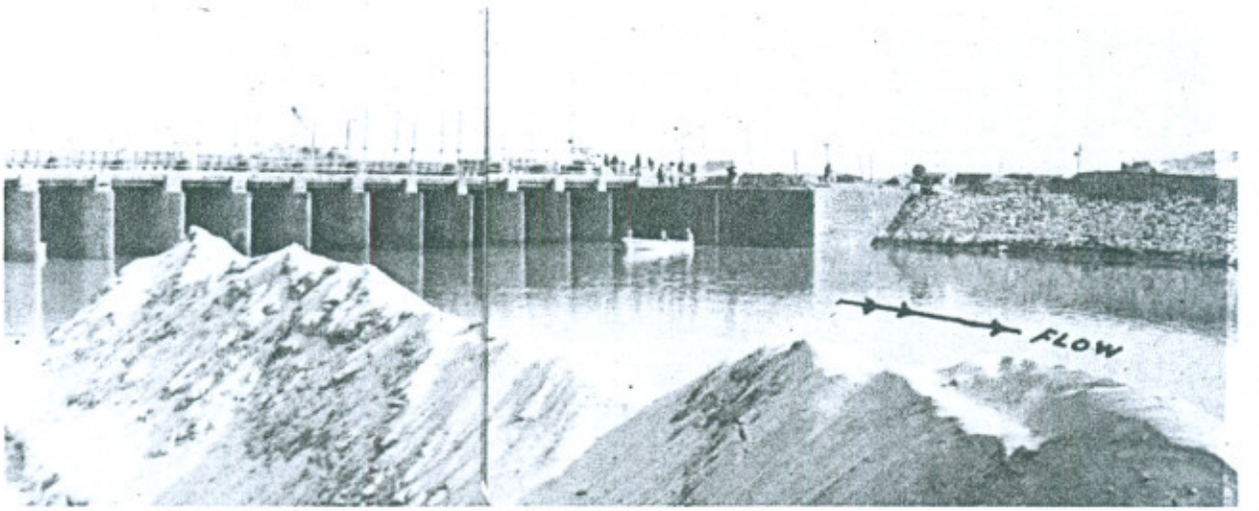
General view of Road Bridge from downstream side
(foundation & decking details)



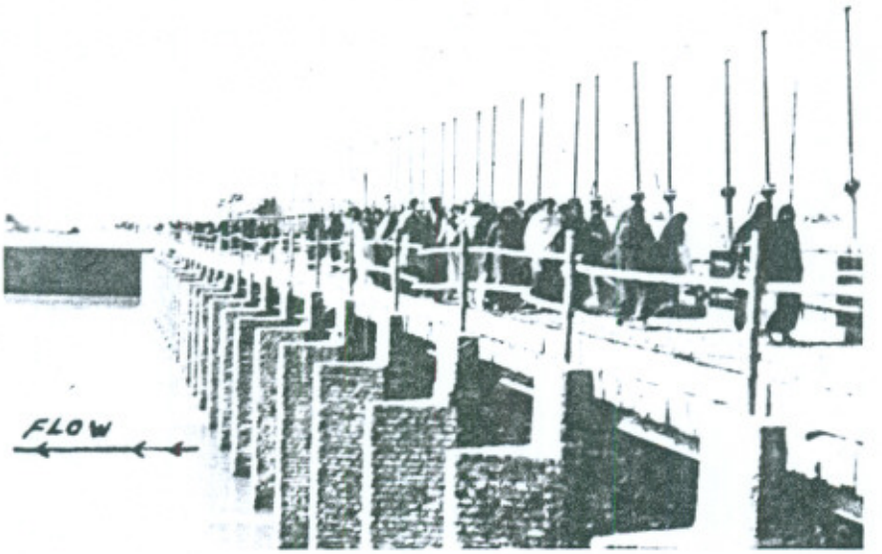
Road decking supported on concrete columns,
R.C.C. girder and four pre-stressed beams.



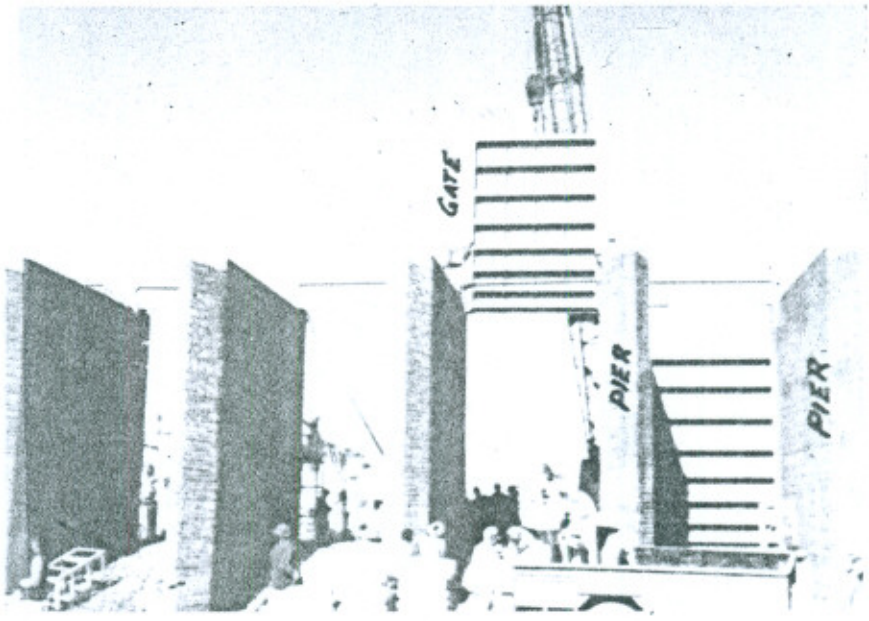
Temporary Regulator under construction.
(view from downstream side).



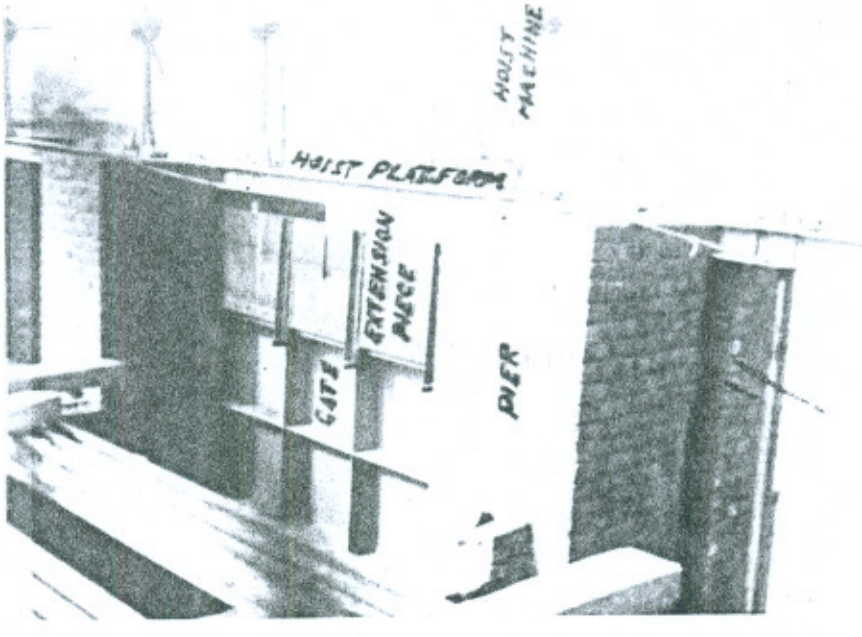
Temporary Regulator – View from downstream side.



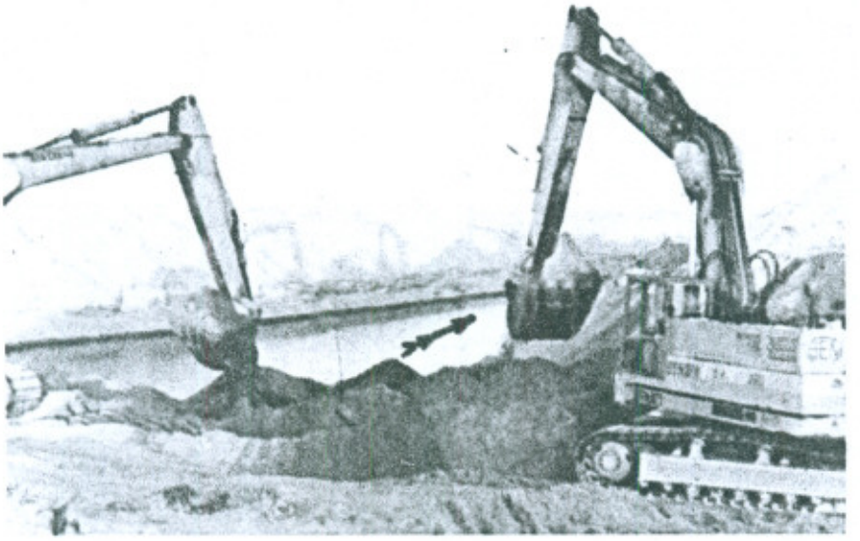
Temporary Regulator – Piers & Road decking.



Temporary Regulator – Placing gates in position.
(view from downstream side)



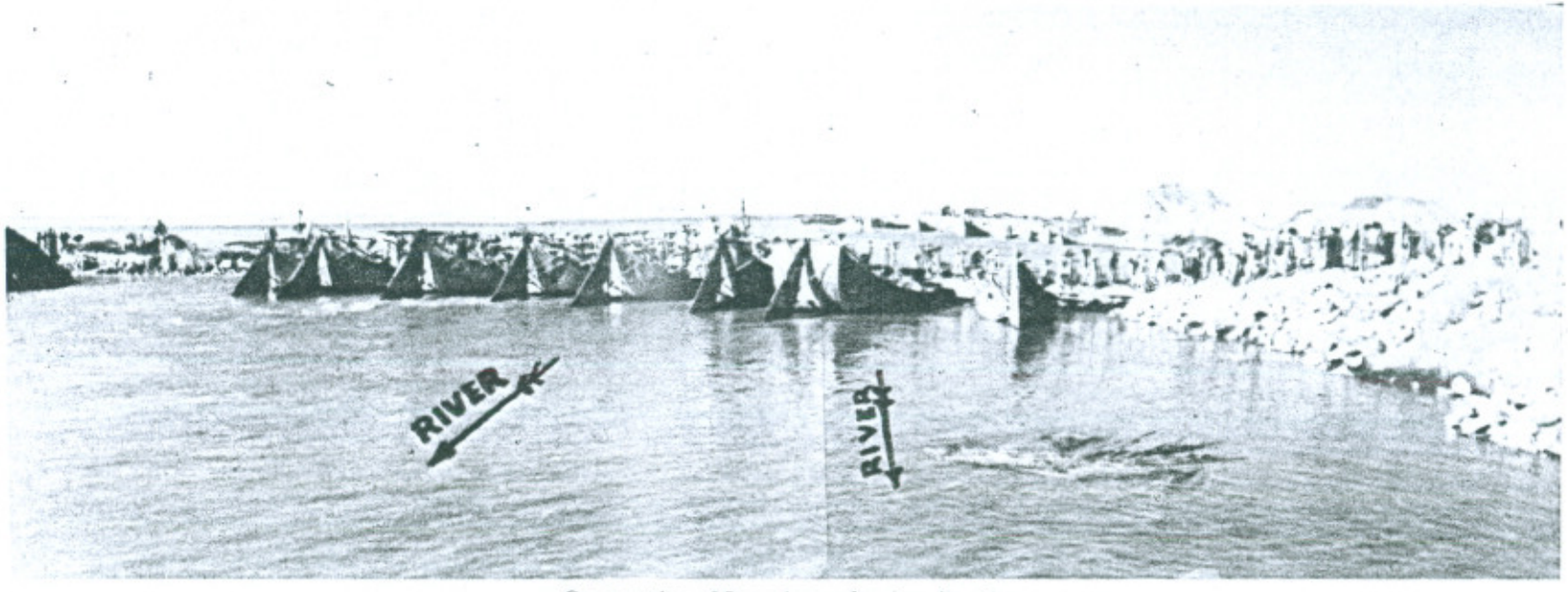
Temporary Regulator – Gate with 2 feet extension piece.
(view from downstream side)



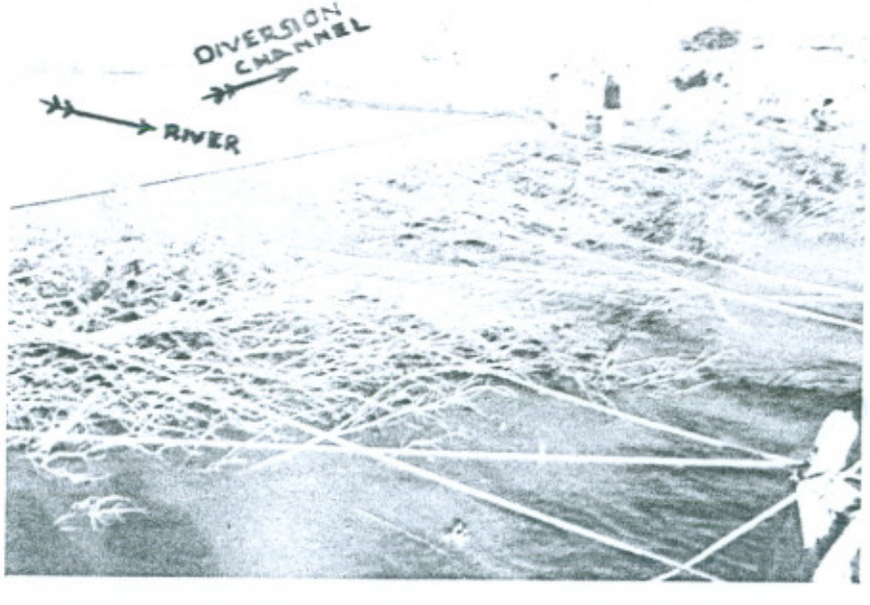
Excavation of leading cuts by Hydraulic Excavators.



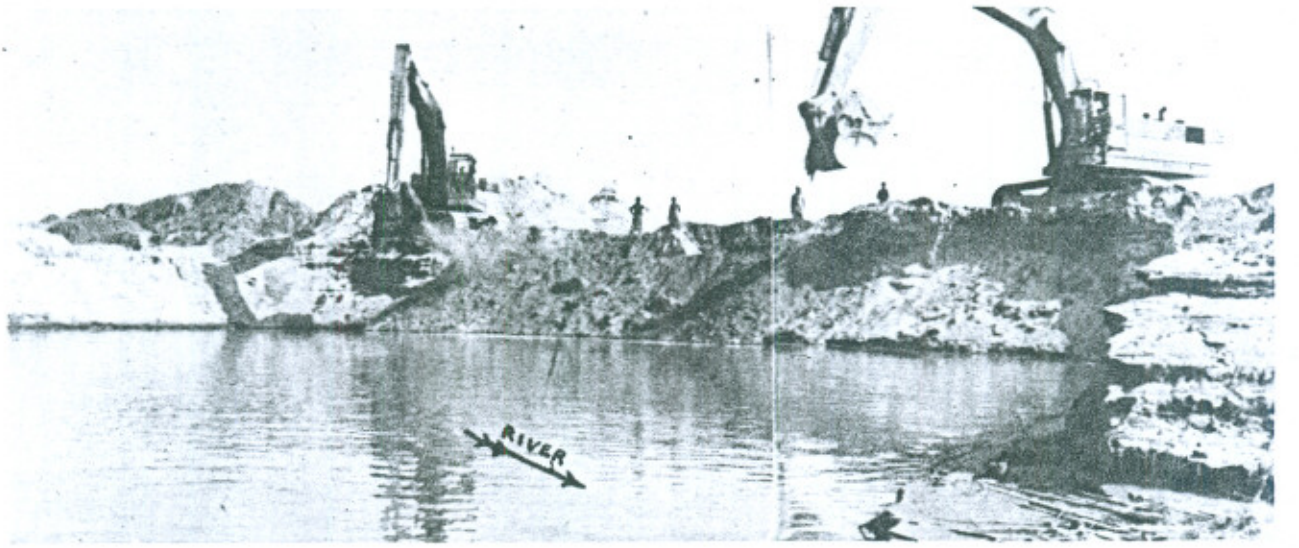
Excavation of leading cuts by Hydraulic Excavators.



Construction of Stone boom for river diversion.



Erecting a barrier of trees for langar chhap in the river.



Removing plug from the mouth of leading
cuts by Hydraulic Excavators.



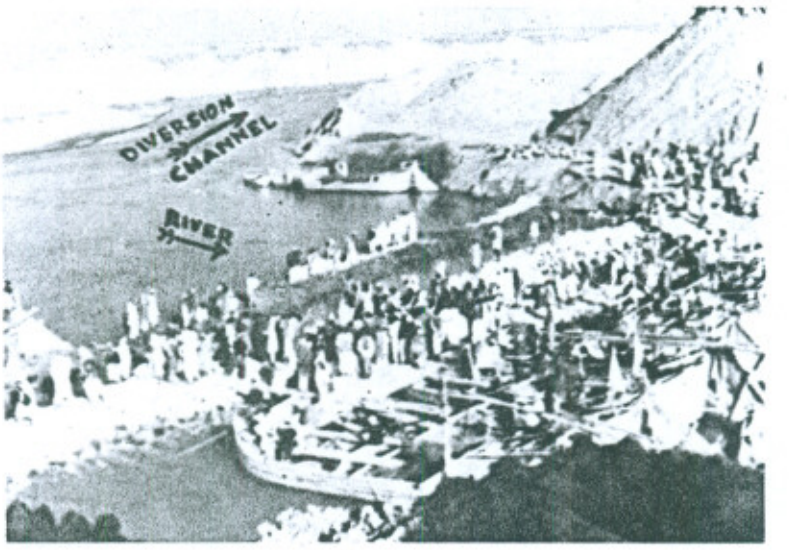
Opening mouth of diversion
channel by hydraulic excavators.



Construction of langar chhap for river diversion
(Inspection by Governor Punjab & Minister for Irrigation).



Construction of stone boom on the
downstream side of langar chhap.



Construction of stone boom in the river.



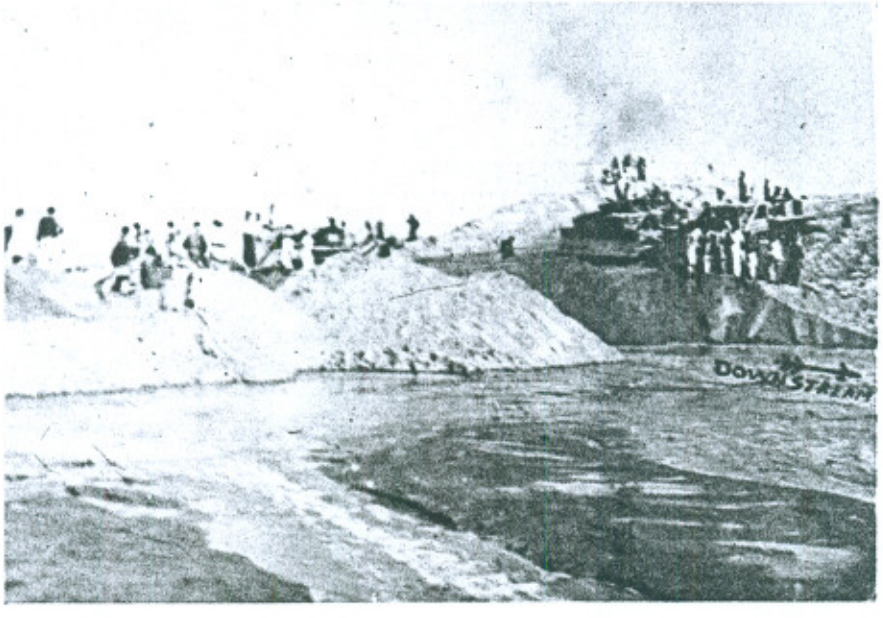
Langar Chhap, Cross chhap and stone boom construction.



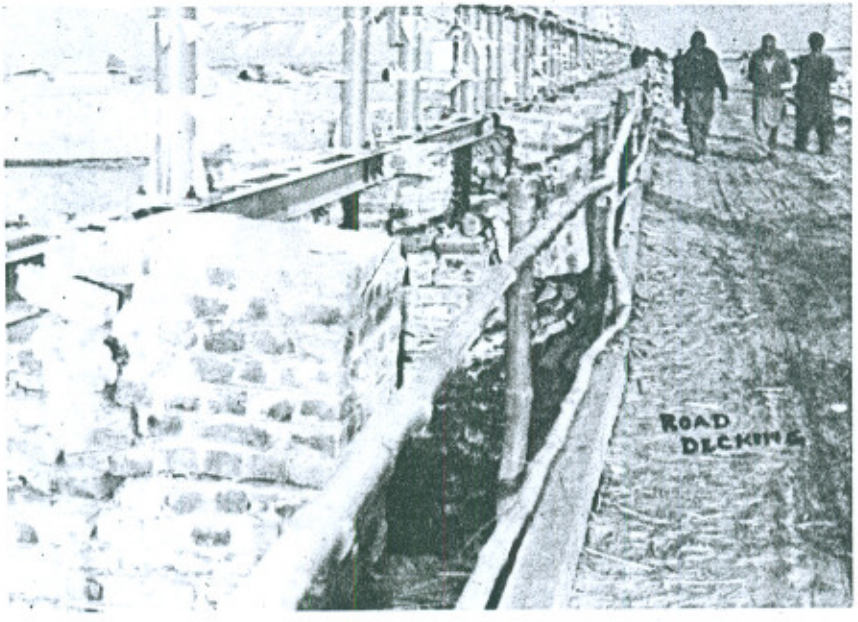
Closing final gap of stone boom.



Closing gap at the back of temporary regulator.
(Water makes its way underneath the plug
bound on the downstream side).



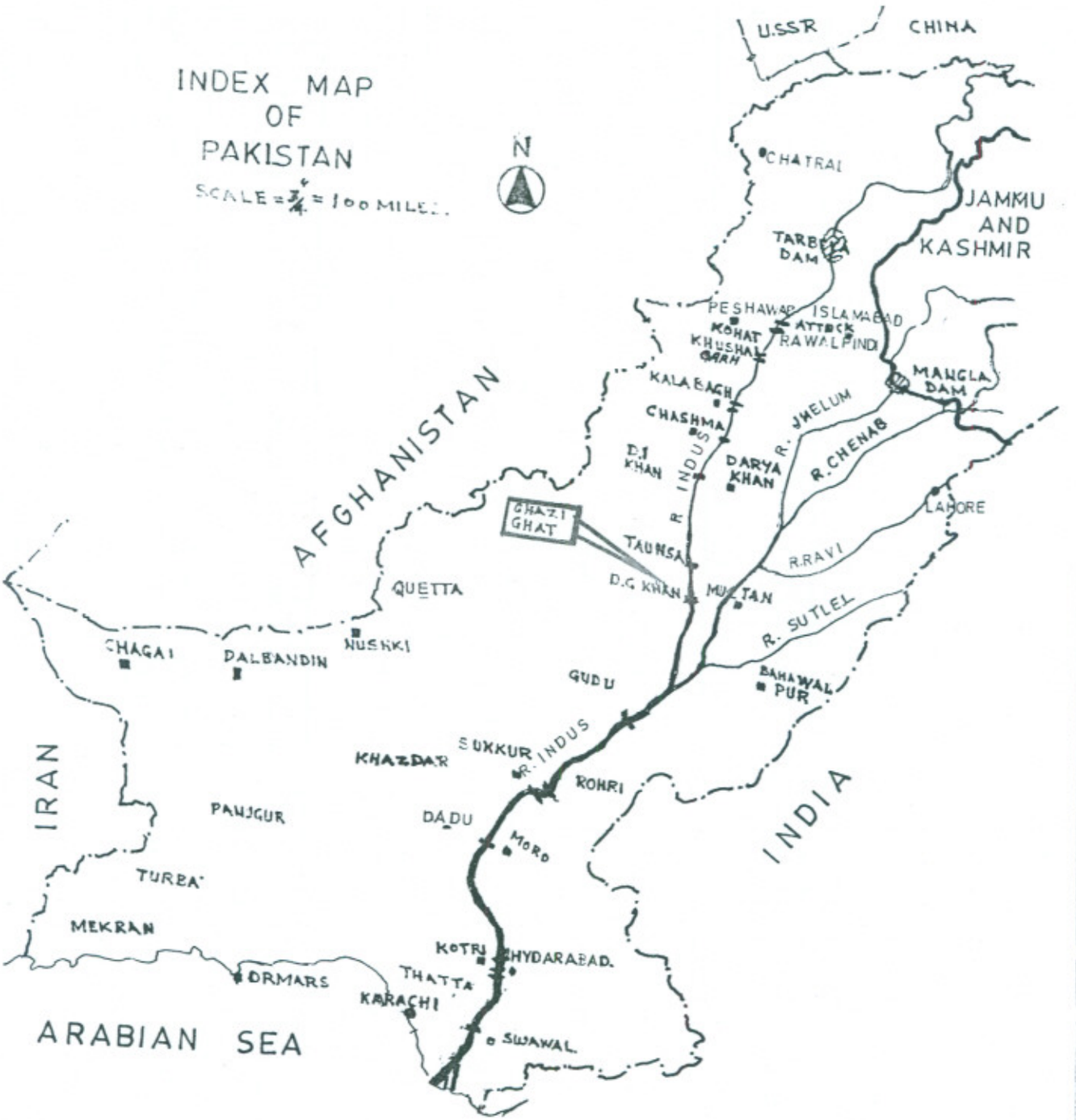
Closing gap at the back of temporary regulator
(Water gushing out in the middle).

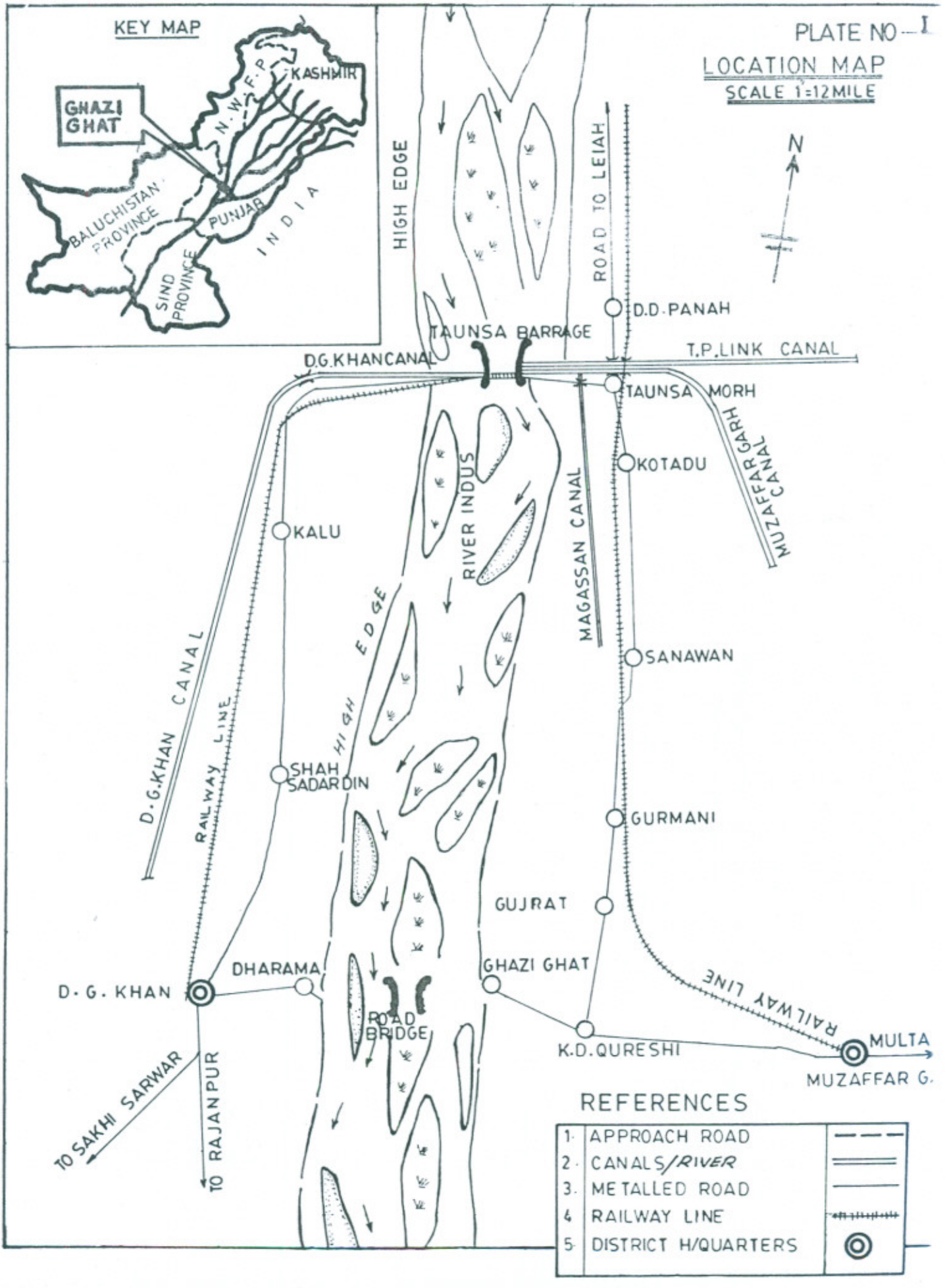


Gracks in the masonry of piers at top
by the displacement of concrete anchor
block supporting the hoisting machines.



Cracks in the masonry of piers at top
by the displacement of concrete anchor
block supporting the hoisting machines.


INDEX MAP
OF
PAKISTAN
SCALE = 3/4" = 100 MILES
N
U.S.S.R
CHINA
CHATRAL
JAMMU
AND
KASHMIR
TARBELA
DAM
PESHAWAR
ISLAMABAD
KOHAT
ATTOCK
KHUSHAL
GARH
RAWALPINDI
MANGLA
DAM
KALABAGH
CHASHMA
R. JHELUM
R. CHENAB
D.I
KHAN
R. INDUS
DARYA
KHAN
LAHORE
GHAZI
GHAT
TAUNSA
R. RAVI
AFGHANISTAN
D.G KHAN
MULTAN
QUETTA
R. SUTLEJ
CHAGAI
DALBANDIN
NUSHKI
GUDU
BAHAWAL
PUR
KHAZDAR
SUKKUR
R. INDUS
ROHRI
IRAN
PANJGUR
DADU
MORO
INDIA
TURBAT
MEKRAN
KOTRI
HYDARABAD
ORMARS
THATTA
KARACHI
SWAWAL
ARABIAN SEA


KEY MAP
GHAZI GHAT
N.W.F.P
KASHMIR
BALUCHISTAN PROVINCE
PUNJAB
INDIA
SIND PROVINCE
PLATE NO — I
LOCATION MAP
SCALE 1=12MILE
N
HIGH EDGE
ROAD TO LEIAH
D.D.PANAH
TAUNSA BARRAGE
T.P.LINK CANAL
D.G.KHANCANAL
TAUNSA MORH
MUZAFFARGARH CANAL
KOTADU
KALU
RIVER INDUS
MAGASSAN CANAL
D.G.KHAN CANAL
RAILWAY LINE
HIGH EDGE
SANAWAN
SHAH SADARDIN
GURMANI
GUJRAT
DHARAMA
GHAZI GHAT
D.G.KHAN
ROAD BRIDGE
RAILWAY LINE
K.D.QURESHI
MULTA
MUZAFFAR G.
TO SAKHI SARWAR
TO RAJANPUR
REFERENCES
1. APPROACH ROAD
2. CANALS/RIVER
3. METALLED ROAD
4. RAILWAY LINE
5. DISTRICT H/QUARTERS

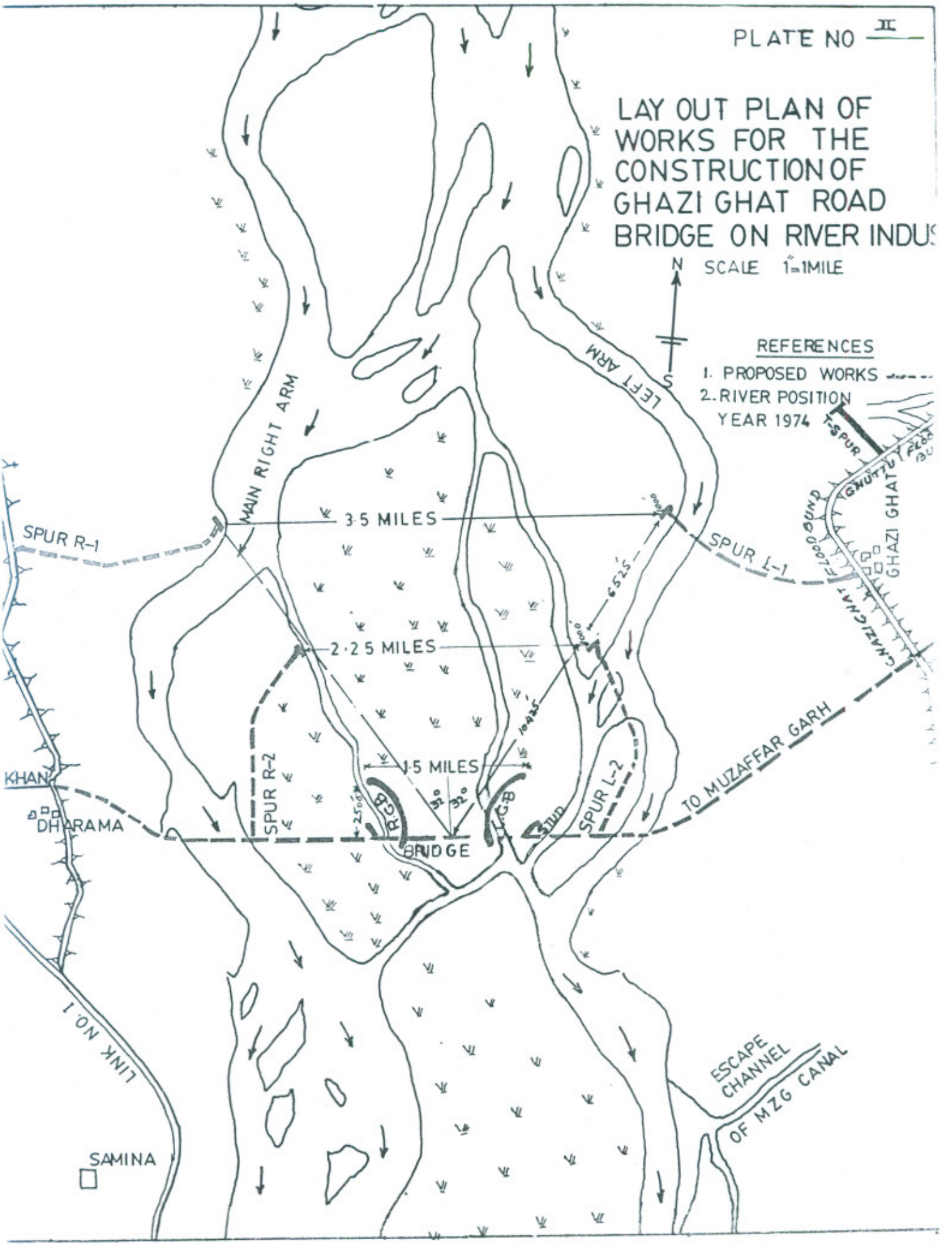
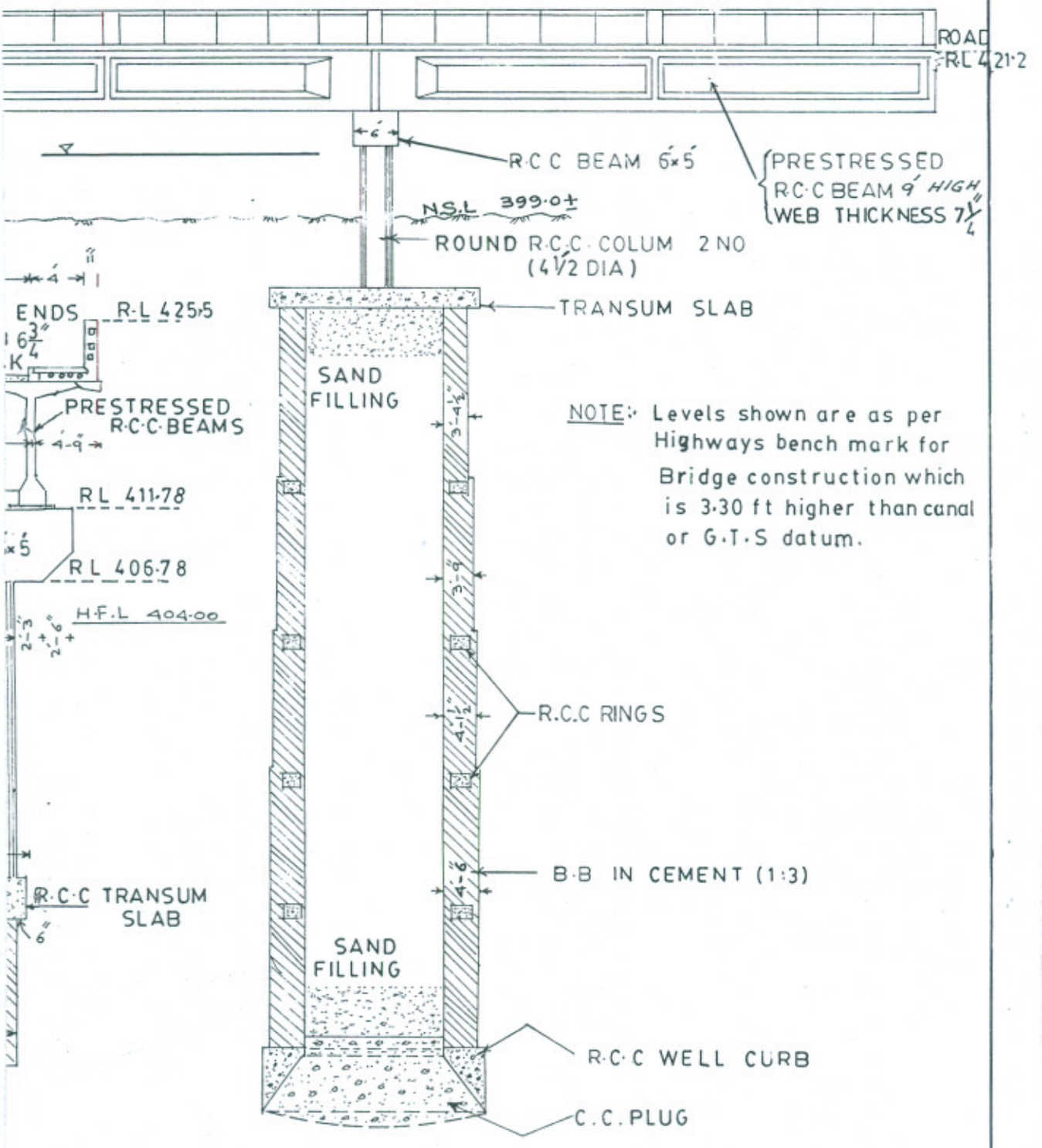

PLATE NO II
LAY OUT PLAN OF WORKS FOR THE CONSTRUCTION OF GHAZI GHAT ROAD BRIDGE ON RIVER INDUS
N
SCALE 1"=1MILE
S
REFERENCES
1. PROPOSED WORKS
2. RIVER POSITION YEAR 1974
T-SPUR
GHUTTU
FLOOD BUND
GHAZI GHAT
MAIN RIGHT ARM
LEFT ARM
3·5 MILES
2·25 MILES
1·5 MILES
SPUR R-1
SPUR L-1
SPUR R-2
SPUR L-2
6525'
10425'
32°
32°
R.G.B
L.G.B
BRIDGE
KHAN
DHARAMA
TO MUZAFFAR GARH
LINK NO. I
SAMINA
ESCAPE CHANNEL OF M.Z.G CANAL

PLATE NO III

ROAD BRIDGE SPAN AND FOUNDATION DETAILS



NOTE:- Levels shown are as per Highways bench mark for Bridge construction which is 3·30 ft higher than canal or G·T·S datum.

ELEVATION OF ROAD BRIDGE

SCALE 1/10" = 2 FEET

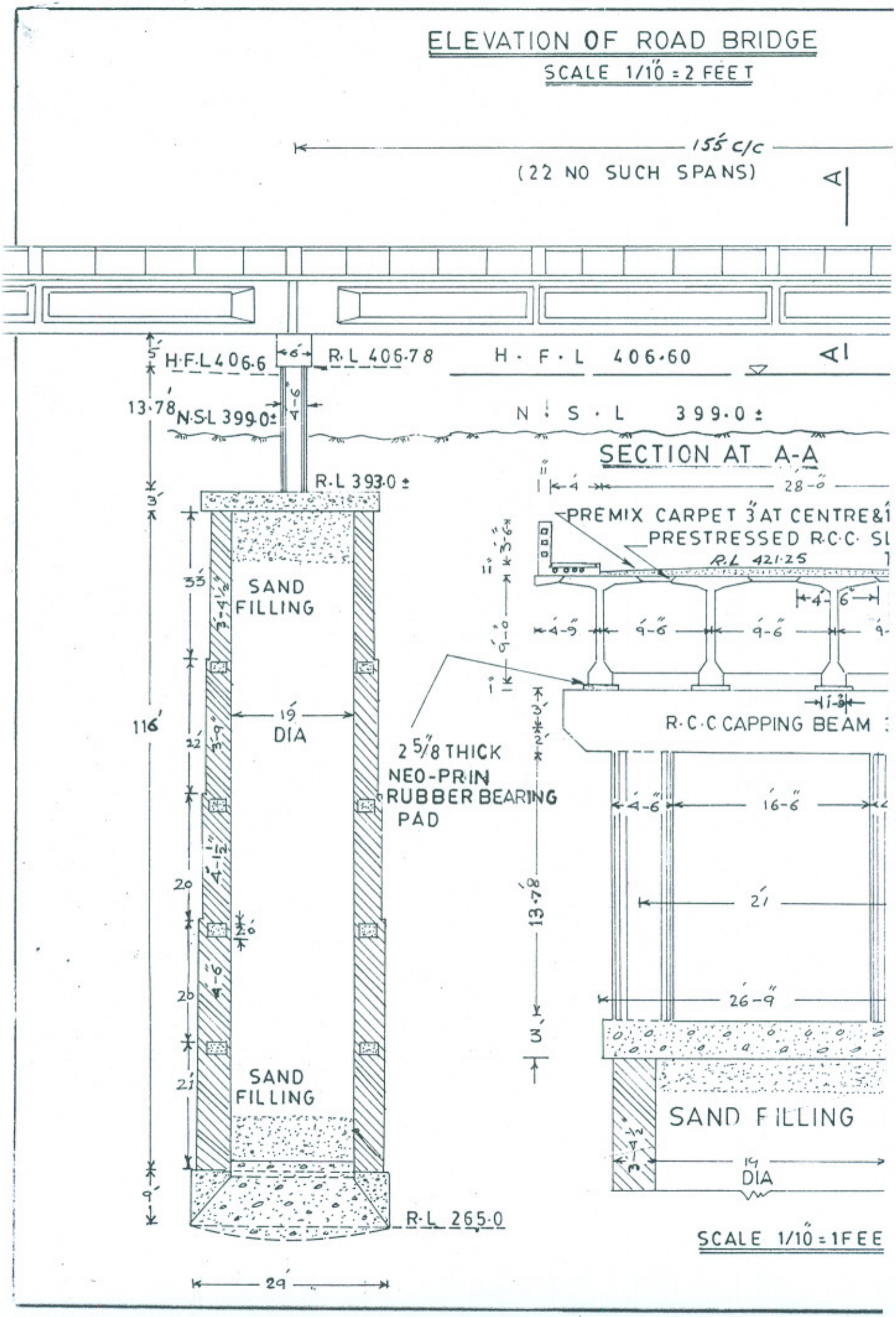
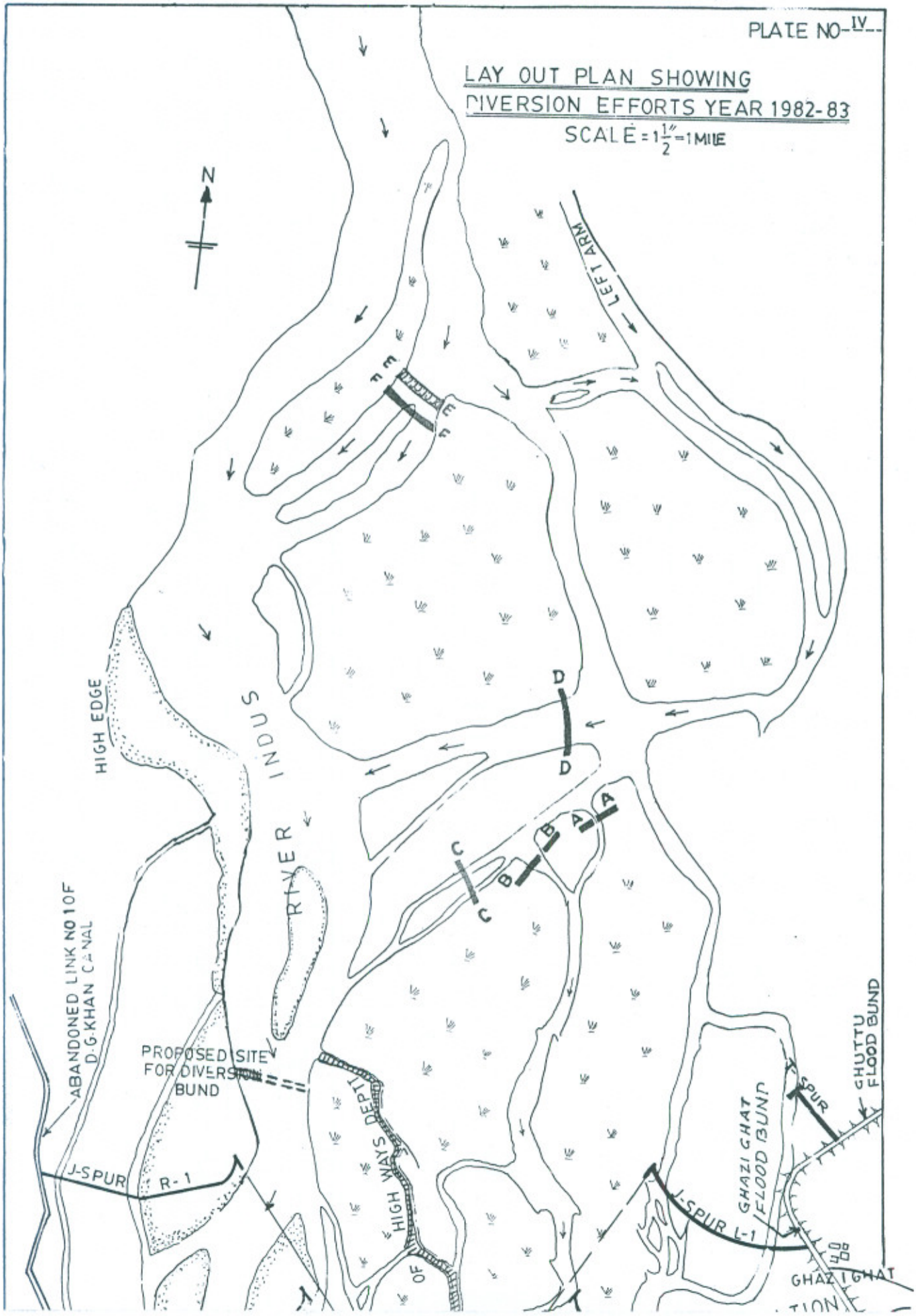


PLATE NO-IV

LAY OUT PLAN SHOWING DIVERSION EFFORTS YEAR 1982-83

SCALE = 1½" = 1 MILE



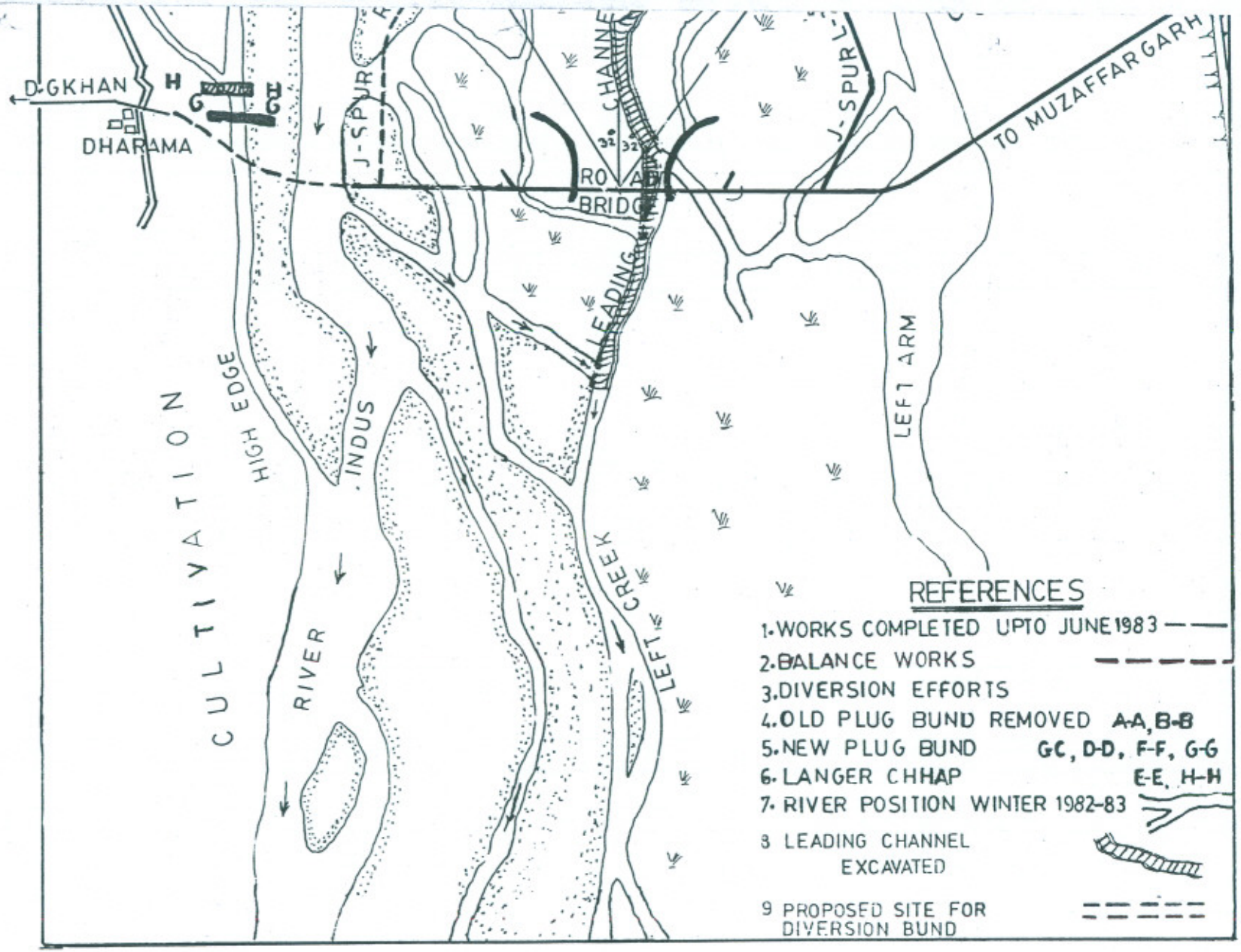
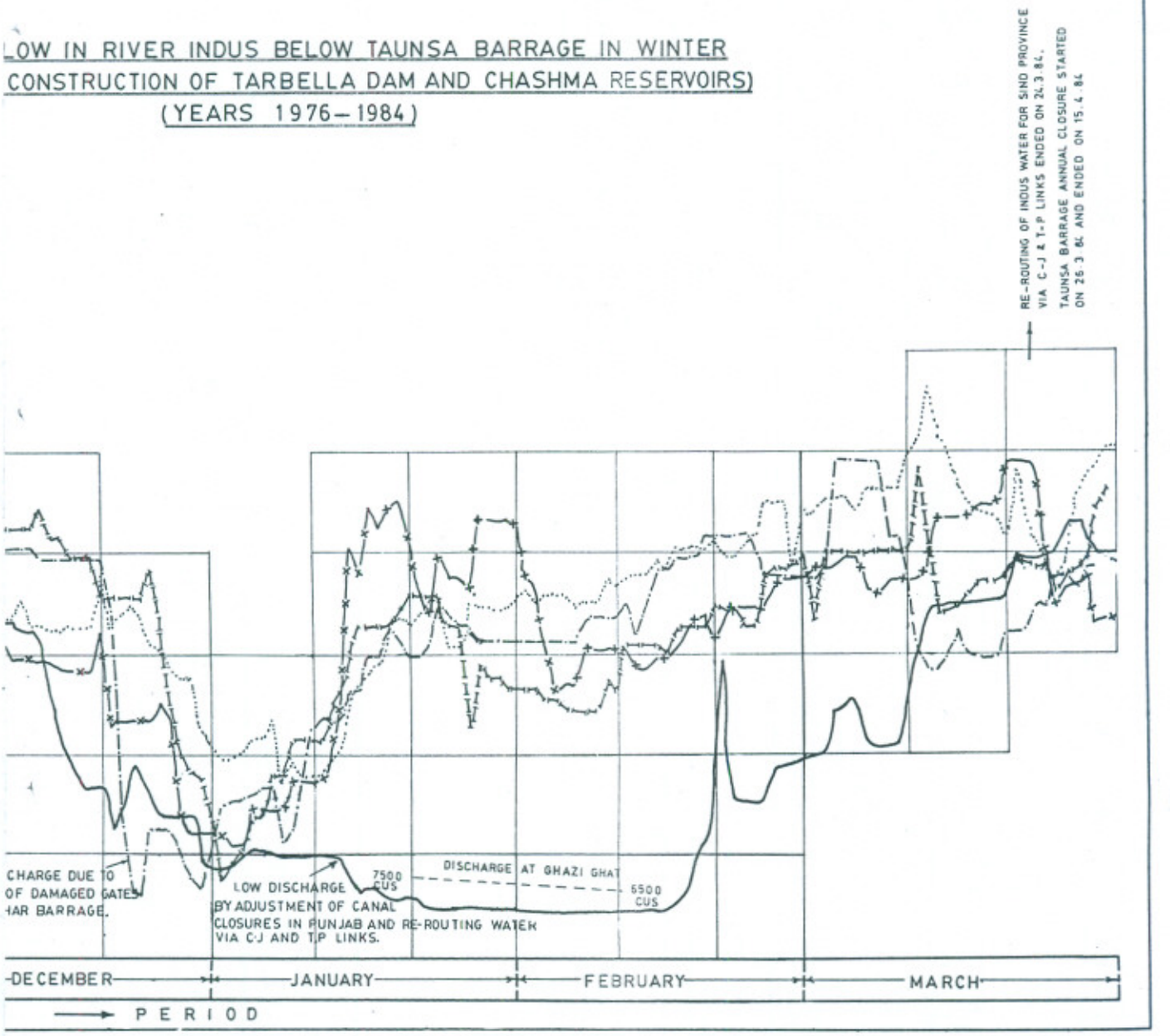

D.G.KHAN
DHARAMA
J-SPUR
CHANNEL
J-SPUR
TO MUZAFFARGARH
ROAD
BRIDGE
LEADING
CULTIVATION
HIGH EDGE
INDUS
RIVER
CREEK
LEFT
LEFT ARM
REFERENCES
1. WORKS COMPLETED UPTO JUNE 1983
2. BALANCE WORKS
3. DIVERSION EFFORTS
4. OLD PLUG BUND REMOVED A-A, B-B
5. NEW PLUG BUND C-C, D-D, F-F, G-G
6. LANGER CHHAP E-E, H-H
7. RIVER POSITION WINTER 1982-83
8 LEADING CHANNEL EXCAVATED
9 PROPOSED SITE FOR DIVERSION BUND

PLATE NO. V

LOW IN RIVER INDUS BELOW TAUNSA BARRAGE IN WINTER
CONSTRUCTION OF TARBELLA DAM AND CHASHMA RESERVOIRS)
(YEARS 1976–1984)



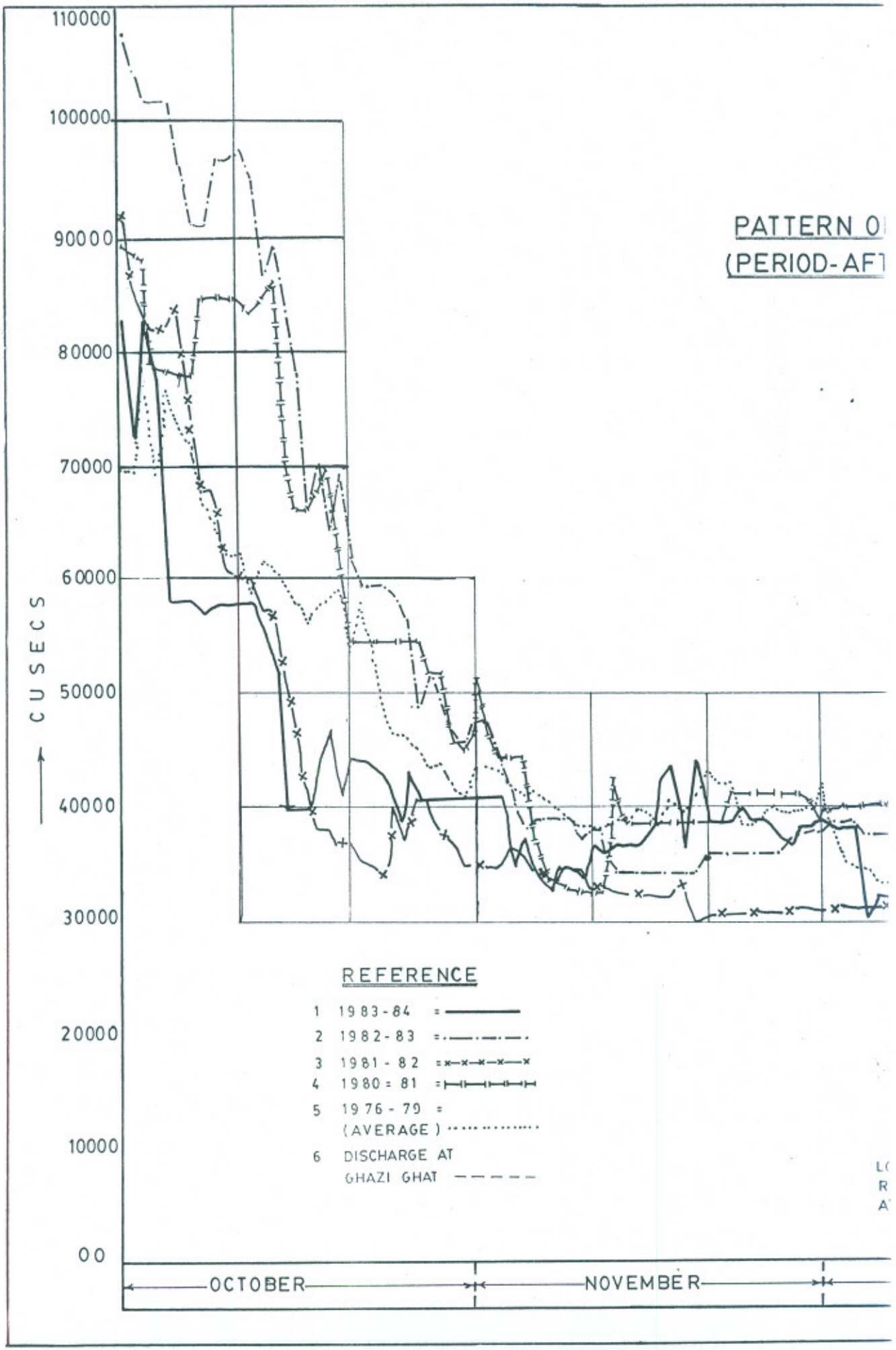
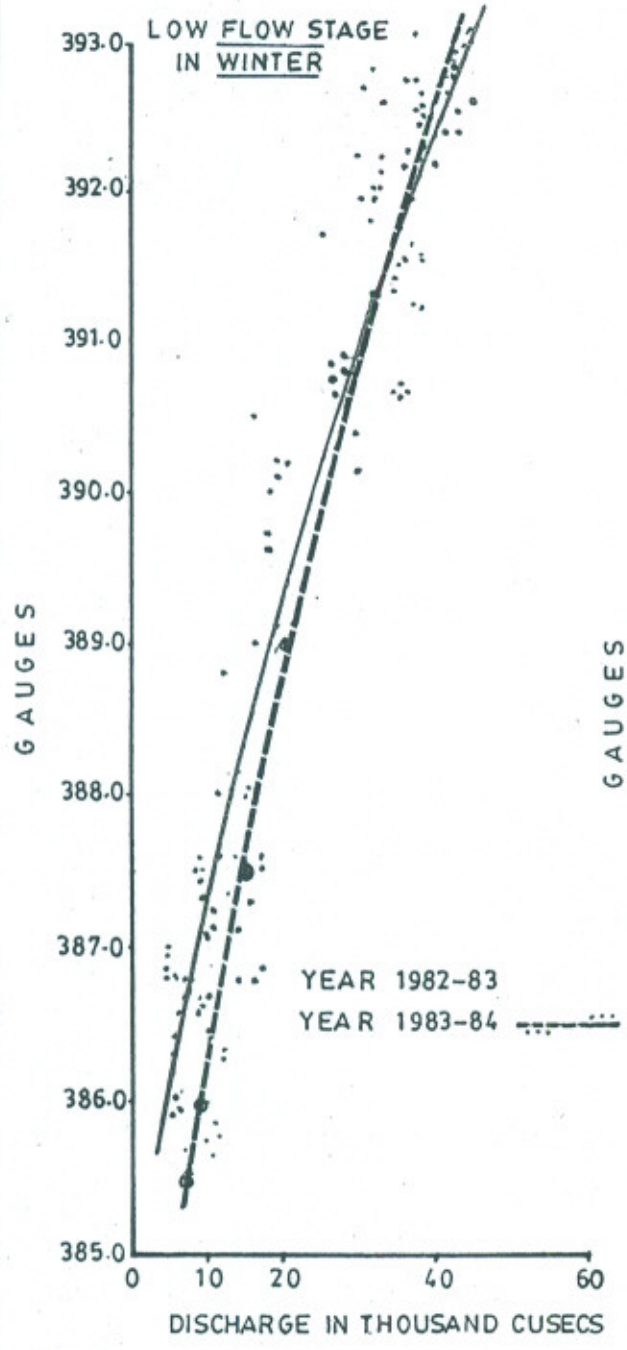
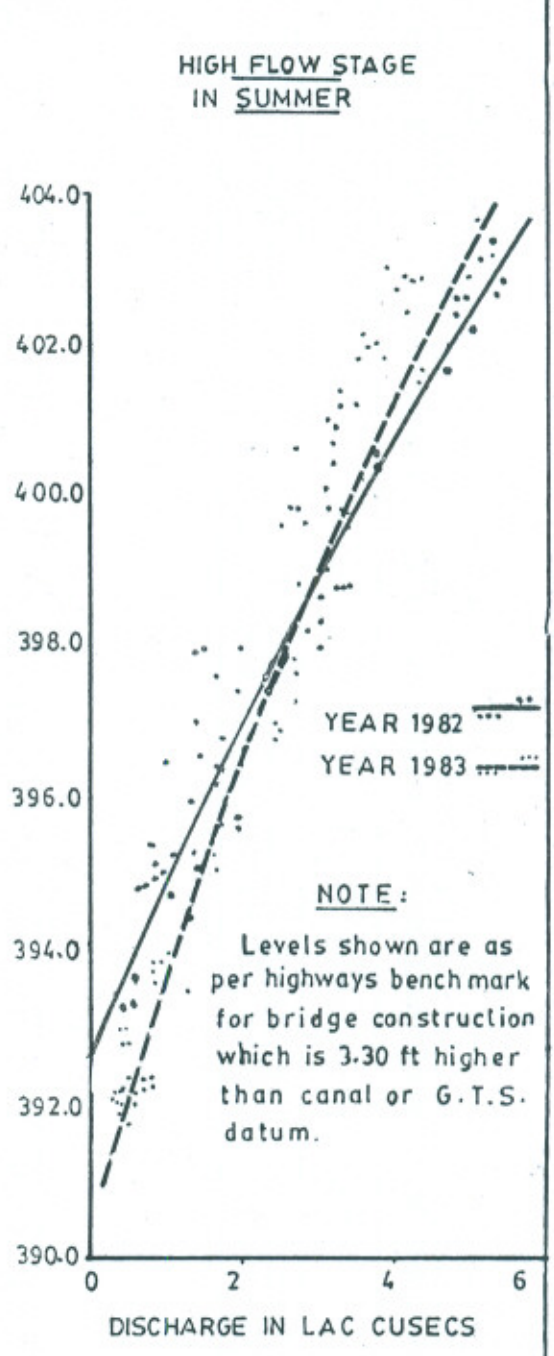

PATTERN 0
(PERIOD-AF
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
00
CUSECS
REFERENCE
1 1983-84 =
2 1982-83 =
3 1981-82 =
4 1980=81 =
5 1976-79 =
(AVERAGE)
6 DISCHARGE AT
GHAZI GHAT
OCTOBER
NOVEMBER

PLATE NO. VI

GAUGE DISCHARGE CURVE AT GHAZI GHAT ROAD BRIDGE





NOTE:

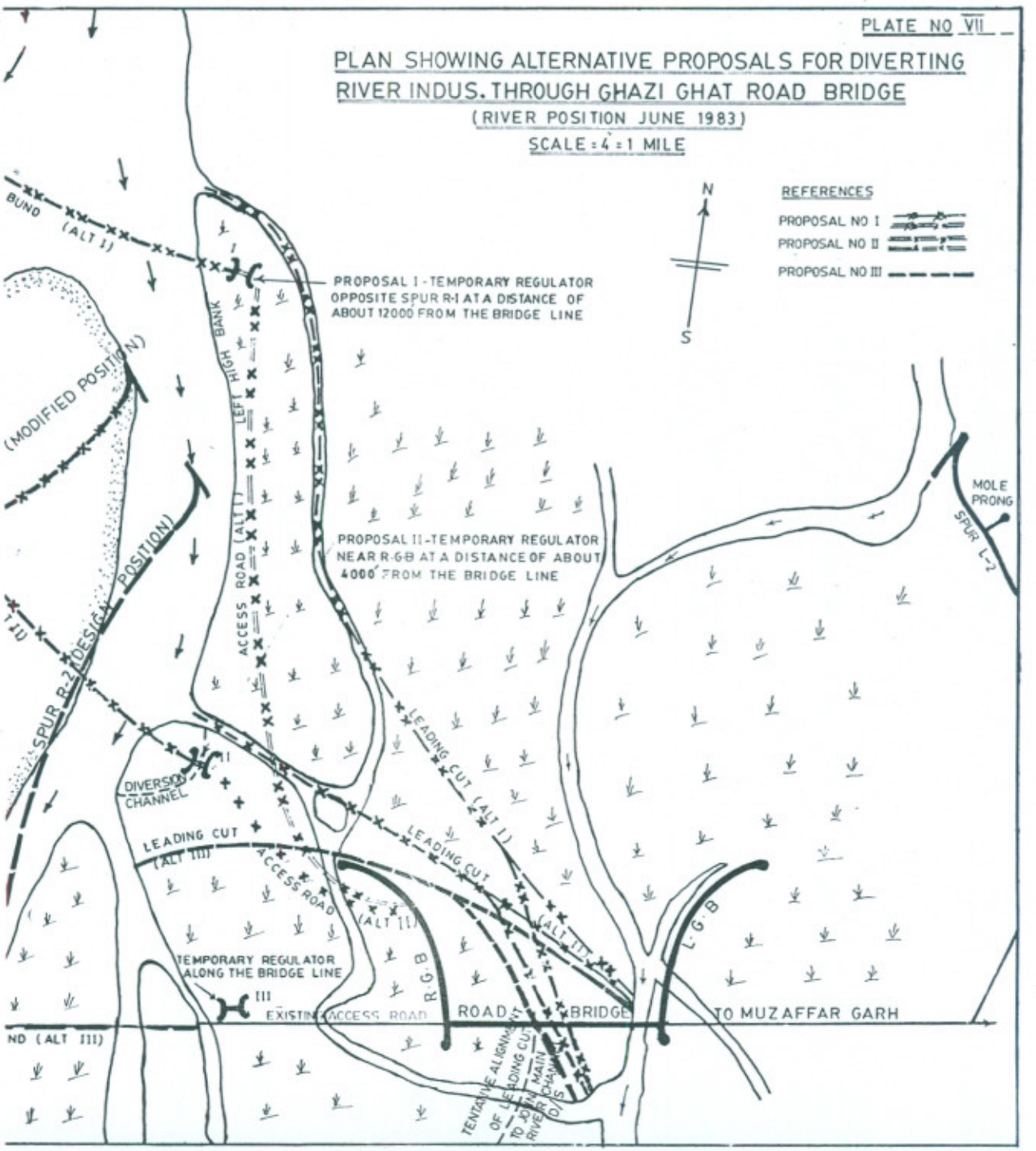
Levels shown are as per highways bench mark for bridge construction which is 3.30 ft higher than canal or G.T.S. datum.

PLATE NO VII

PLAN SHOWING ALTERNATIVE PROPOSALS FOR DIVERTING RIVER INDUS. THROUGH GHAZI GHAT ROAD BRIDGE

(RIVER POSITION JUNE 1983)

SCALE = 4 = 1 MILE



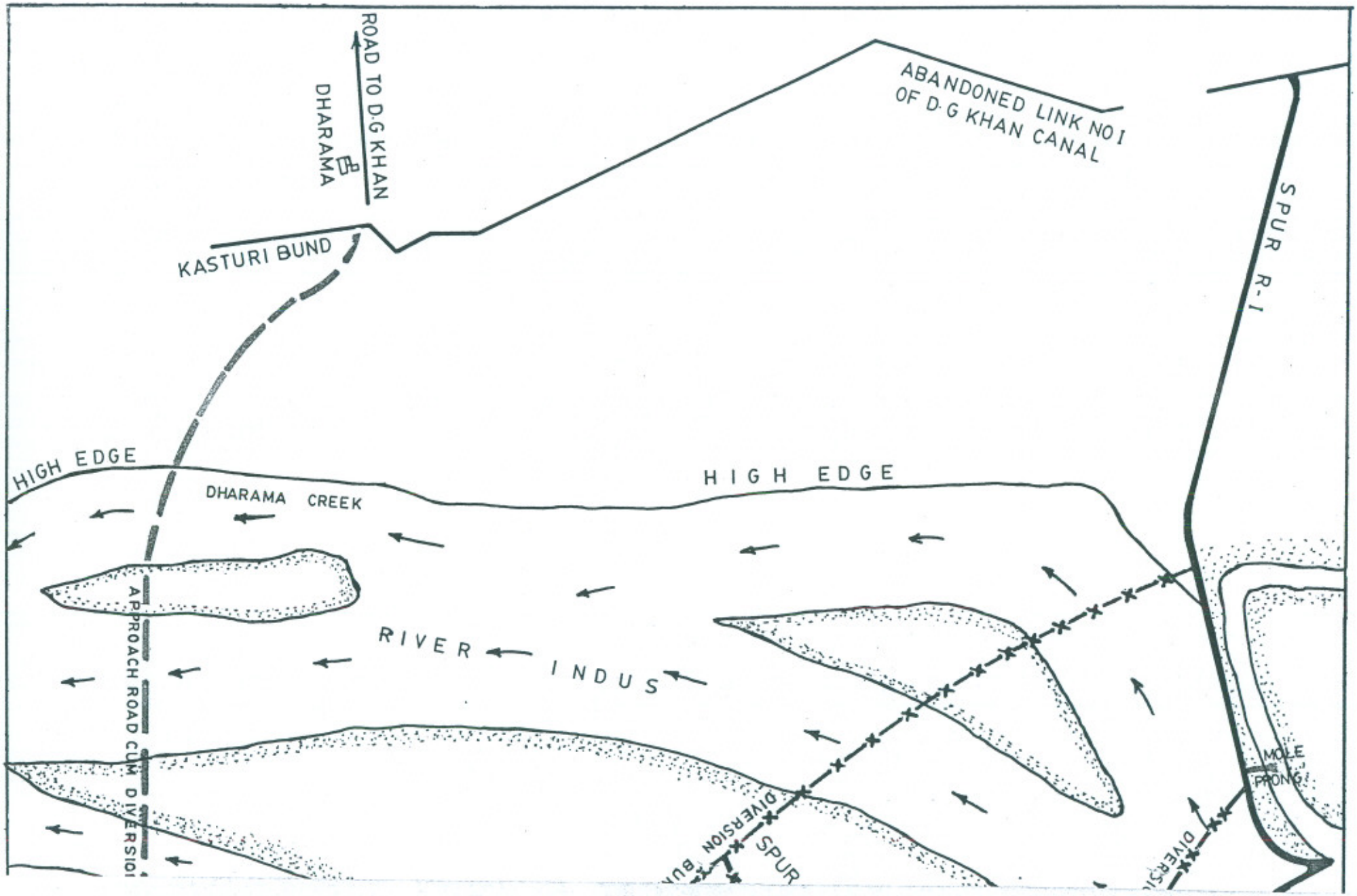
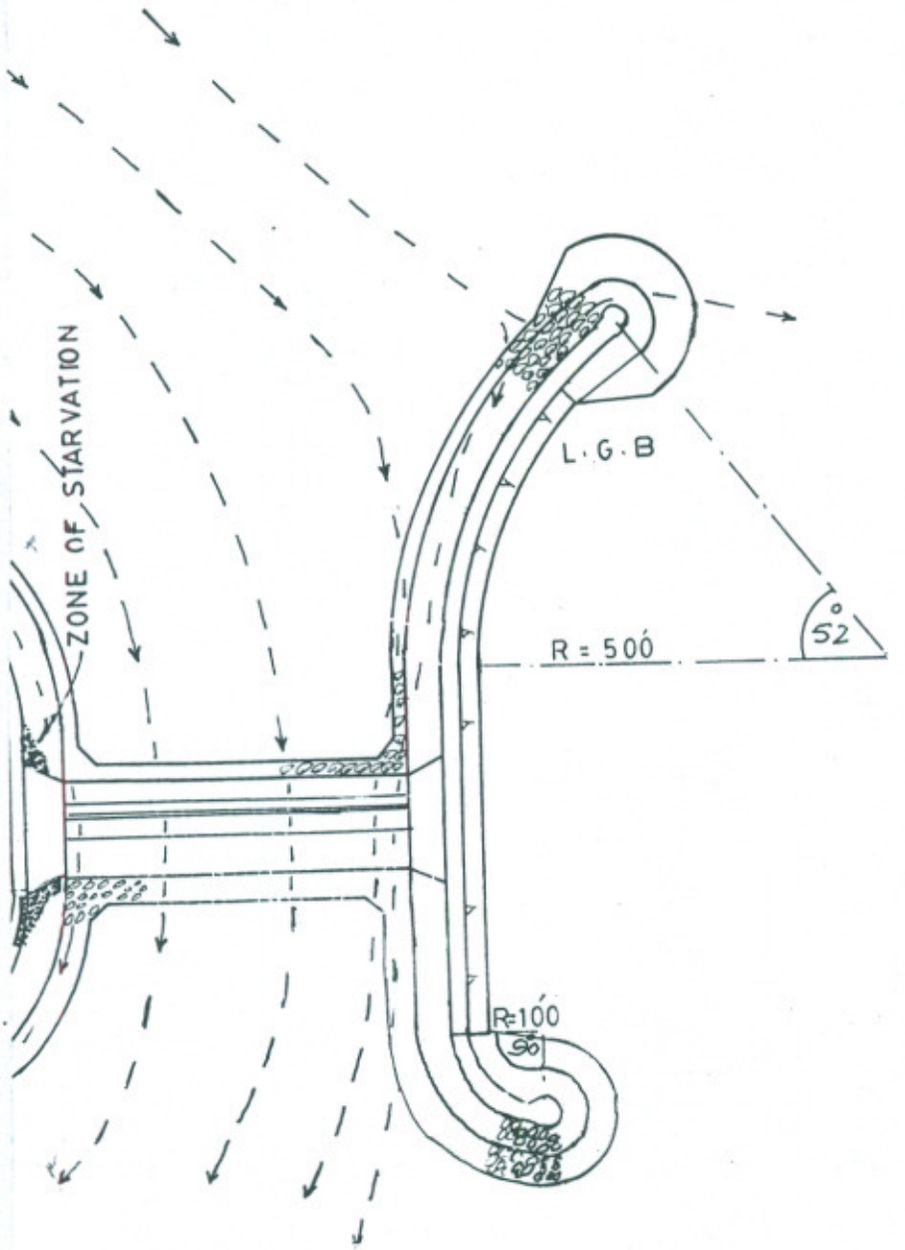

ROAD TO D.G KHAN
DHARAMA
ABANDONED LINK NO I
OF D.G KHAN CANAL
SPUR R-I
KASTURI BUND
HIGH EDGE
HIGH EDGE
DHARAMA CREEK
APPROACH ROAD CUM DIVERSIO
RIVER INDUS
DIVERSION SPUR
MOLE PRONG

PLATE No VIII

FICATION. NO III

HANNEL



TEMPORARY REGULATOR GUIDE BANKS

IGHT GUIDE BANK GHAZI GHAT ROAD BRIDGE

N SHOWING PATTERN OF FLOW)

SCALE = 1" = 200'

MODIFICATION NO I

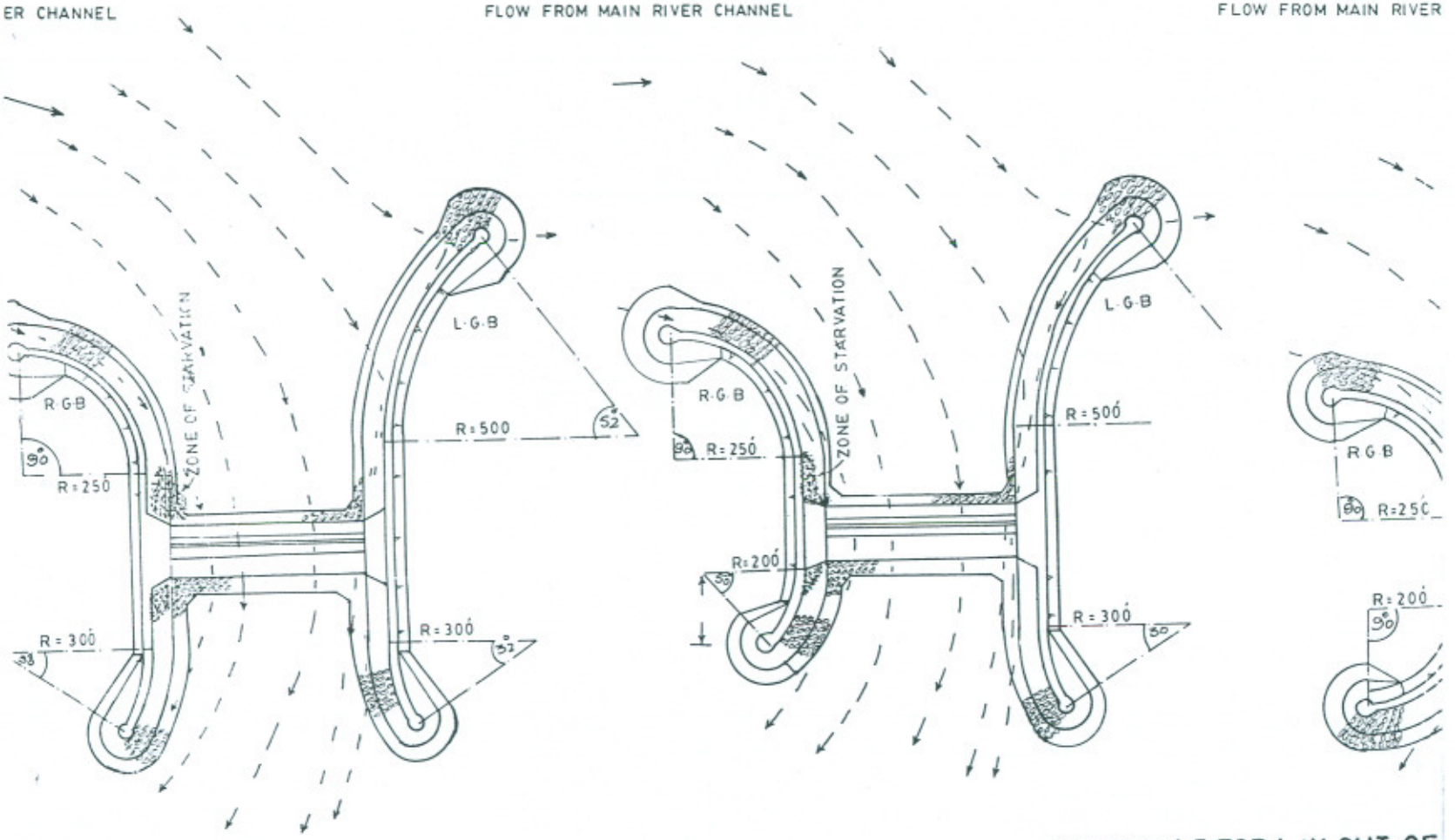
MODIFICATION NO II

FINAL MO

ER CHANNEL

FLOW FROM MAIN RIVER CHANNEL

FLOW FROM MAIN RIVER



PROPOSALS FOR LAY OUT OF

LOCATION U/S SIDE OF

(PL

ORIGINAL DESIGN

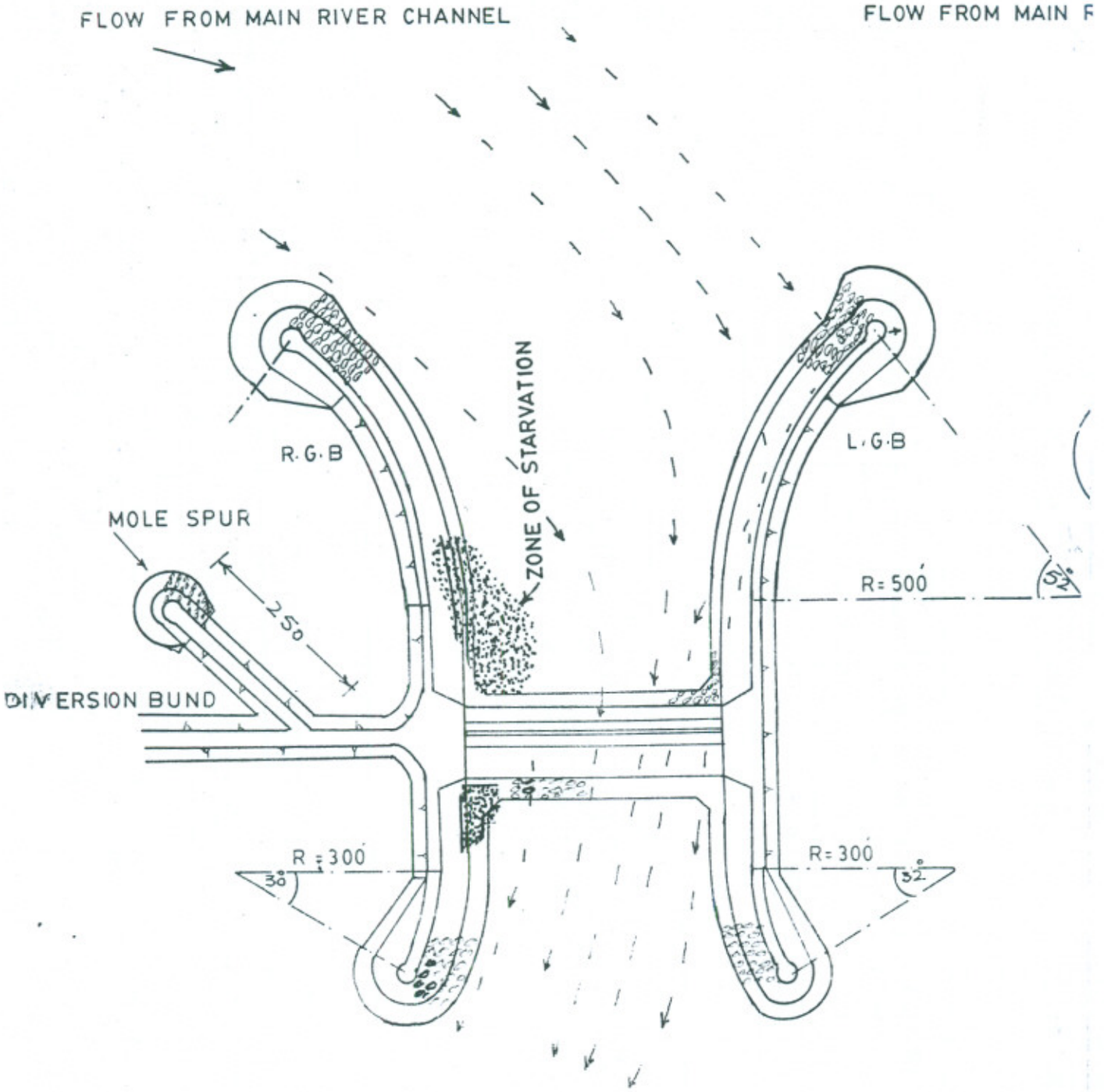
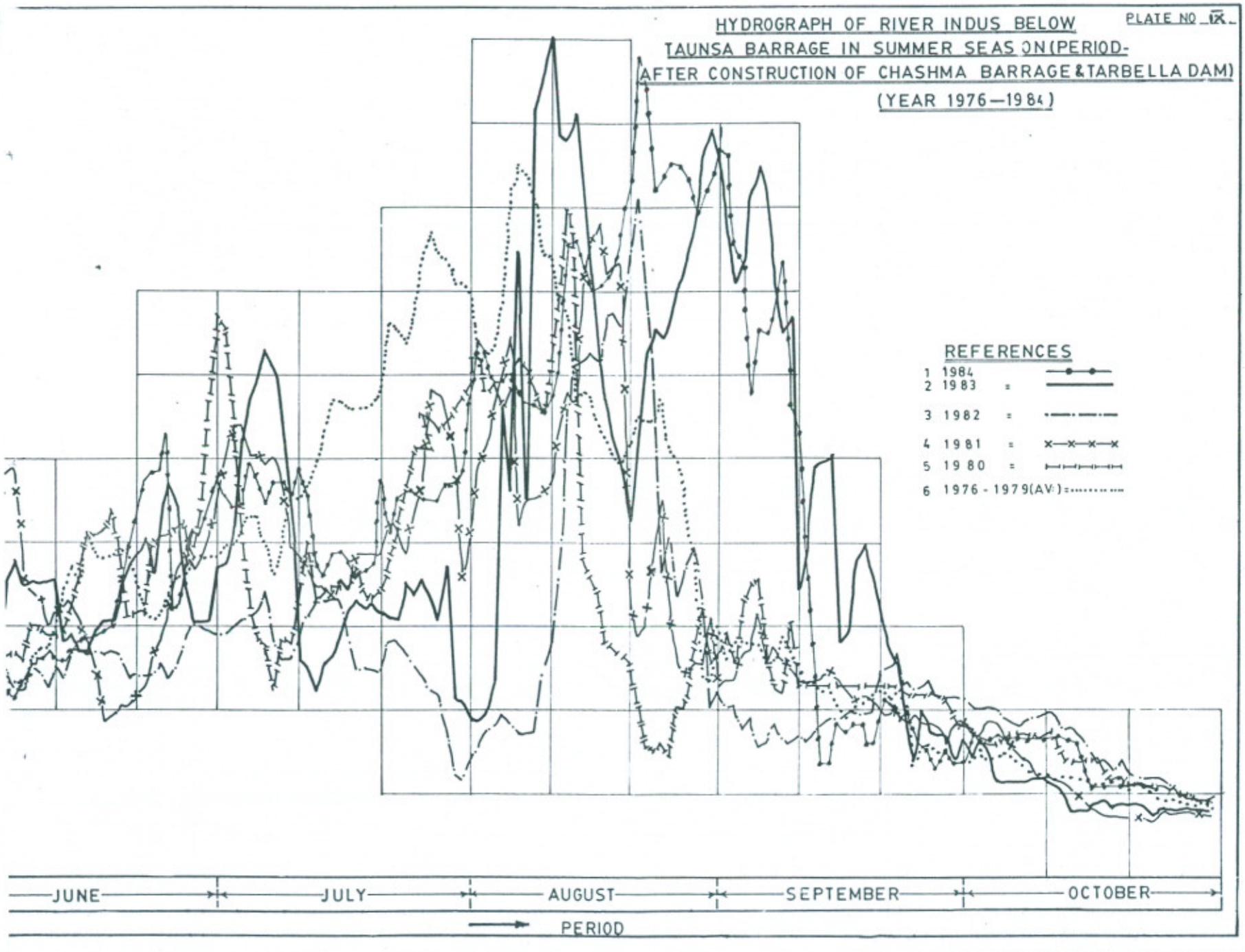
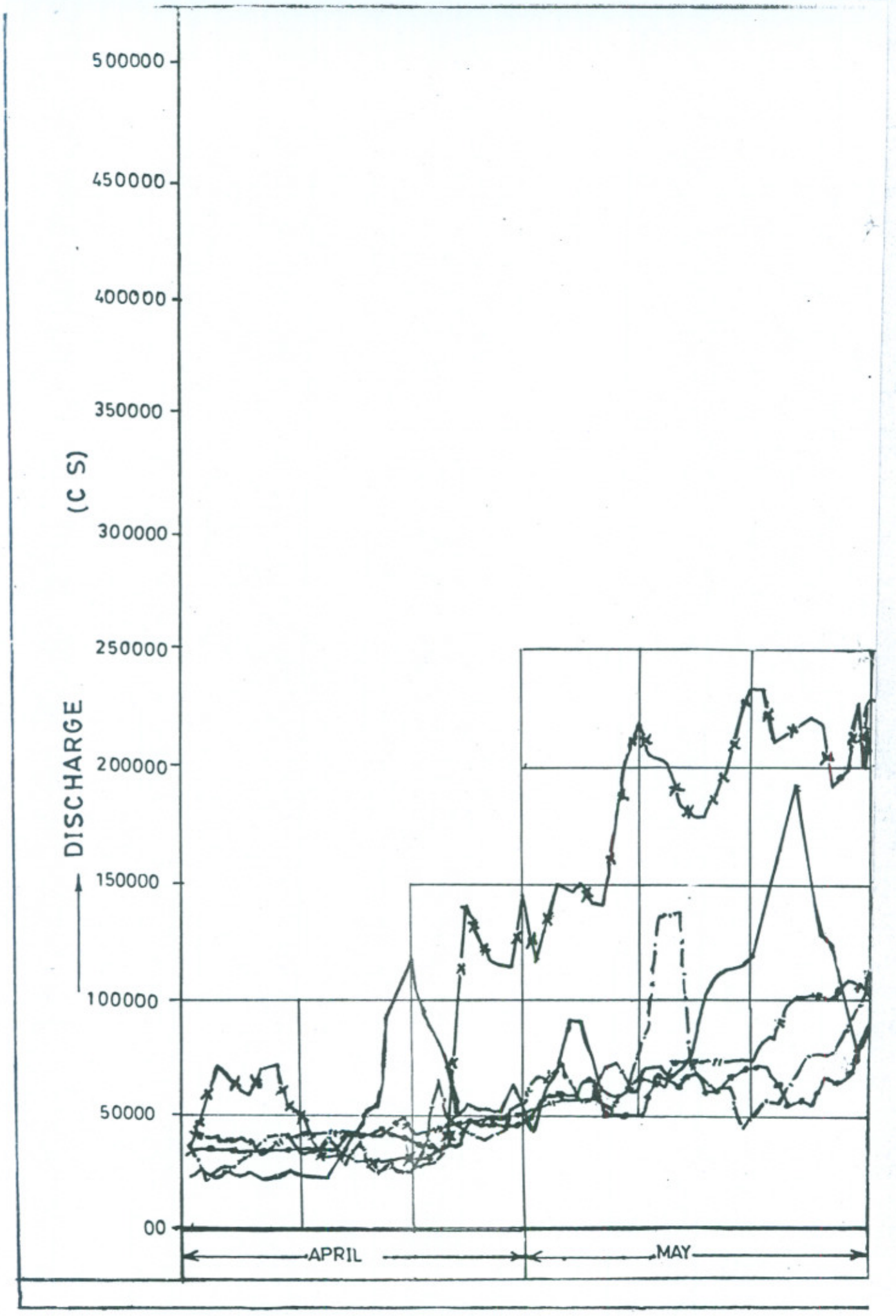
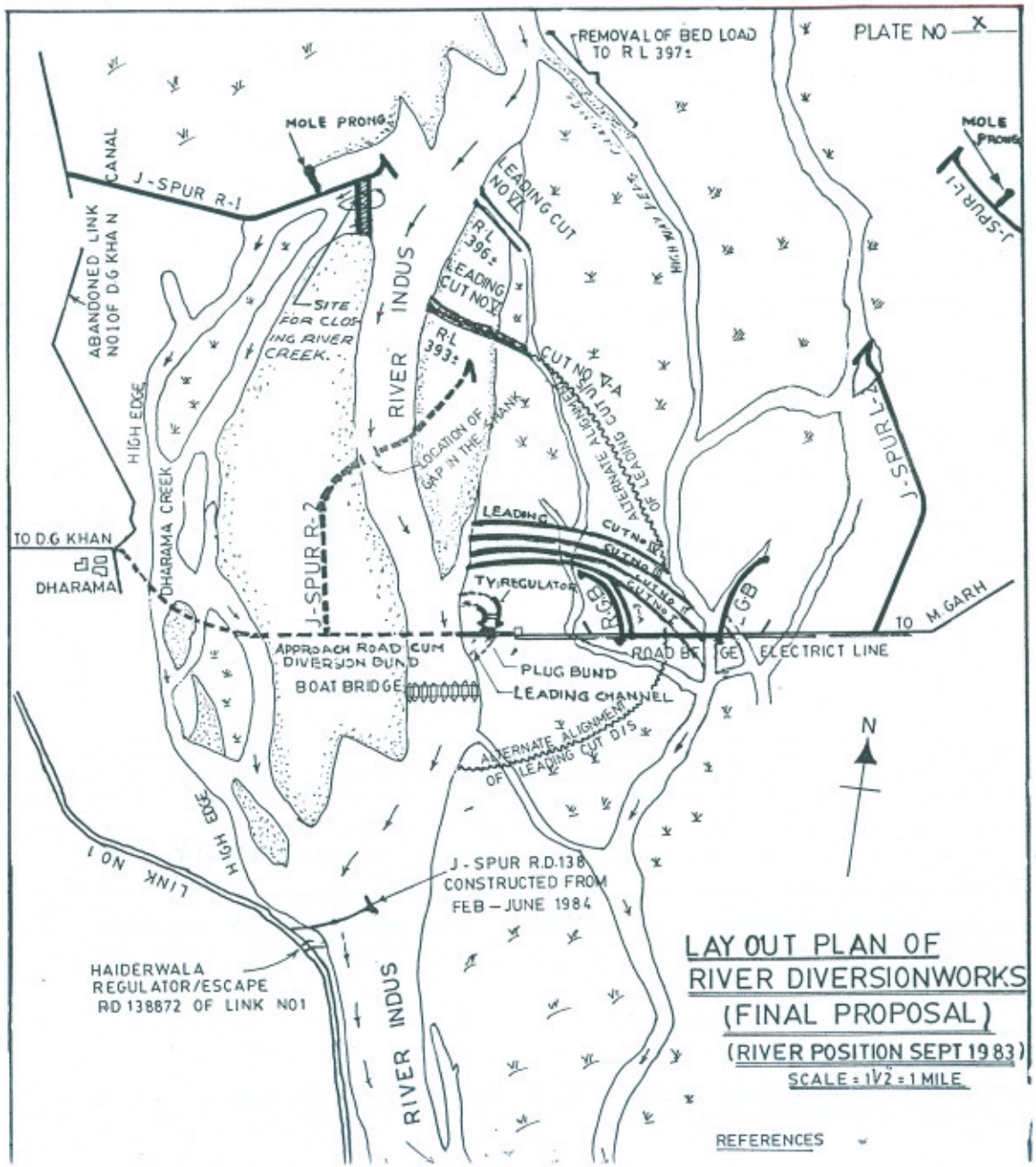


PLATE NO IX

HYDROGRAPH OF RIVER INDUS BELOW TAUNSA BARRAGE IN SUMMER SEASON (PERIOD- AFTER CONSTRUCTION OF CHASHMA BARRAGE & TARBELLA DAM) (YEAR 1976—1984)




500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
00
DISCHARGE
(C S)
APRIL
MAY


PLATE NO X
REMOVAL OF BED LOAD TO R L 397±
MOLE PRONG
J-SPUR L-1
CANAL
J-SPUR R-1
ABANDONED LINK NO1 OF D G KHAN
SITE FOR CLOSING RIVER CREEK.
RIVER INDUS
LEADING CUT NO VI
R.L 396±
LEADING CUT NO V
R.L 393±
CUT NO IV
ALTERNATE ALIGNMENT OF LEADING CUT NO IV
LOCATION OF GAP IN THE SPUR
HIGH EDGE
DHARAMA CREEK
TO D.G KHAN
DHARAMA
J-SPUR R-2
J-SPUR L-2
LEADING CUT No III
LEADING CUT No II
LEADING CUT No I
TY. REGULATOR
ROAD BR
GE
GB
TO M GARH
ELECTRICT LINE
APPROACH ROAD CUM DIVERSION BUND
BOAT BRIDGE
PLUG BUND
LEADING CHANNEL
ALTERNATE ALIGNMENT OF LEADING CUT DIS
N
LINK NO I
HIGH EDGE
J-SPUR R.D.138 CONSTRUCTED FROM FEB – JUNE 1984
HAIDERWALA REGULATOR/ESCAPE RD 138872 OF LINK NO1
RIVER INDUS
LAY OUT PLAN OF RIVER DIVERSIONWORKS (FINAL PROPOSAL)
(RIVER POSITION SEPT 1983)
SCALE = 1½ = 1 MILE
REFERENCES

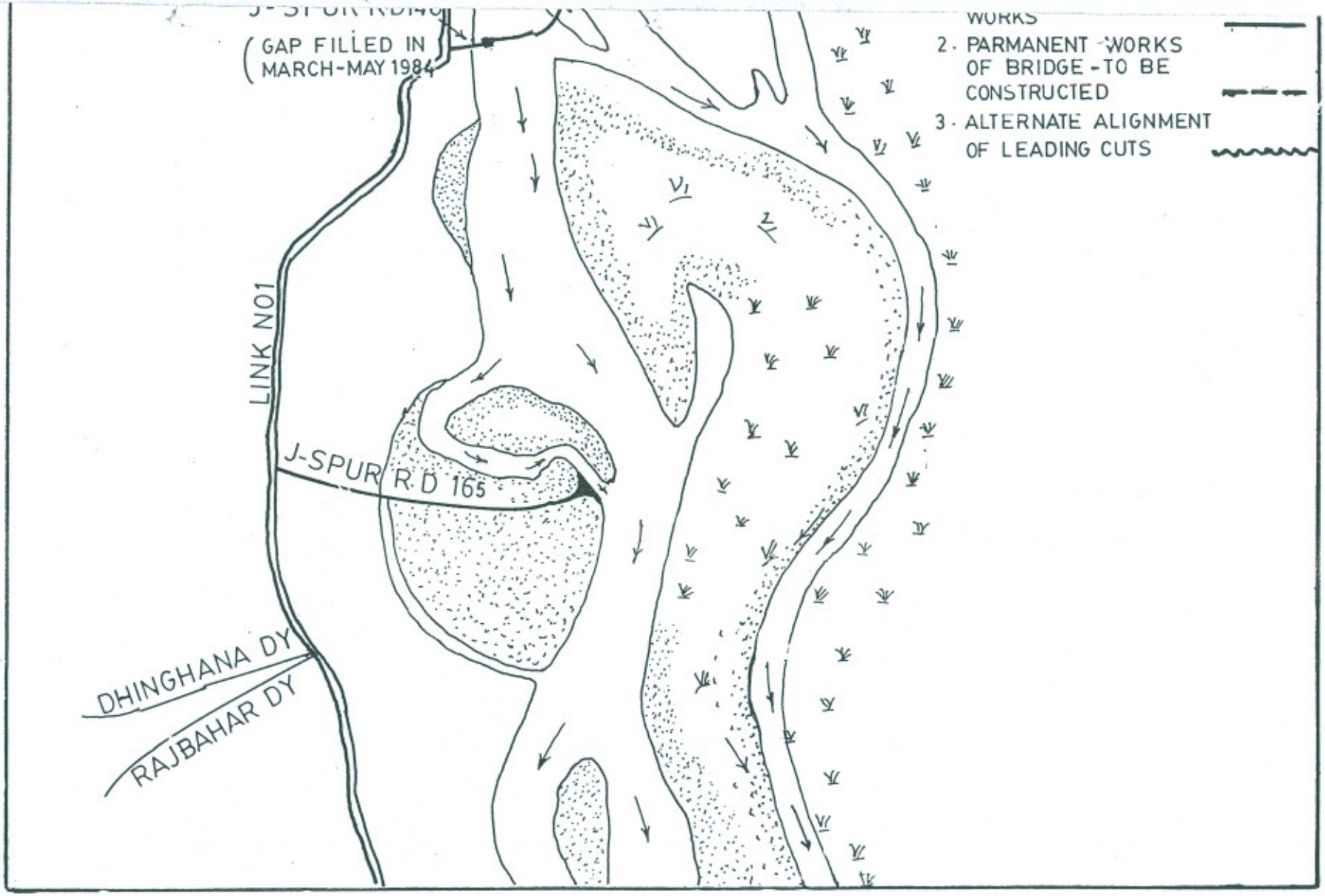

WORKS
2. PARMANENT WORKS OF BRIDGE - TO BE CONSTRUCTED
3. ALTERNATE ALIGNMENT OF LEADING CUTS
GAP FILLED IN MARCH-MAY 1984
LINK NO1
J-SPUR R.D 165
DHINGHANA DY
RAJBAHAR DY

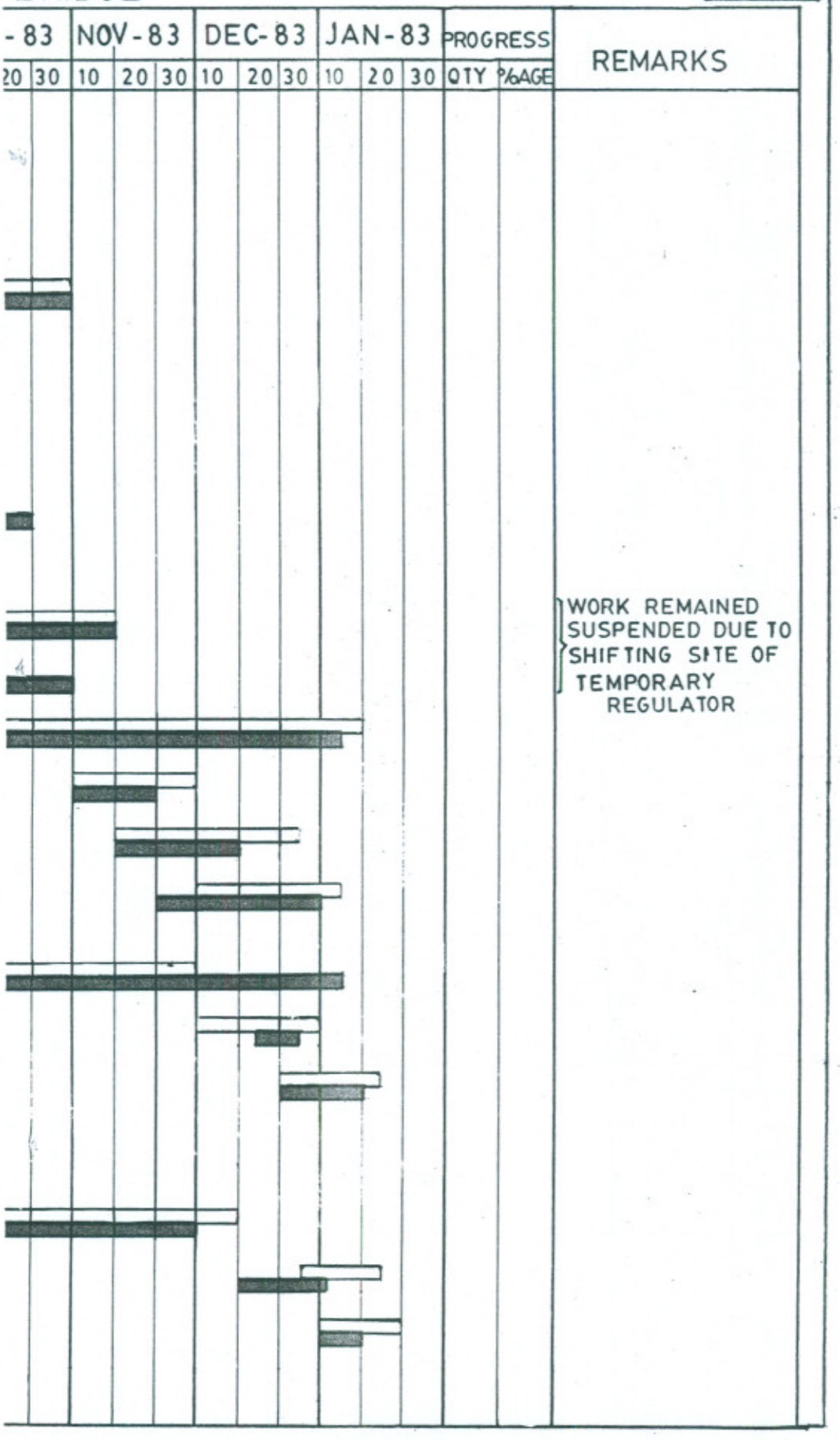
PLATE NO — A1 —

PROGRESS REPORT PERIOD ENDING 31.1.84.

;ULATOR FOR BRIDGE

SCHEDULE

PROGRESS



SCHEDULE FOR THE CONSTRUCTION OF TEMPORARY F
DIVERTING RIVER INDUS THROUGH GHAZI GHAT RO

S. NO.	DESCRIPTION OF ITEMS	ESTIMATED Q TY.
1	RIVER SURVEYS (PHASE I).	
2	" " (PHASE II).	
3	MODEL STUDIES (PRELIMINARY).	
4	// // (REFINEMENT).	
5	MACHINERY & MATERIALS.	
6	APPROACH ROAD.	4000 LFT
7	ERECTION OF TRANSMISSION LINE.	7 MILES
8	STAND BY GENERATION.	
9	DESIGN PLANNING & OTHER PRELIMINARIES.	
10	EXCAVATION OF PIT.	9.2 MCF
11	BORING & T/WELL INSTALLATION.	40-50 NOS
12	DEWATERING.	
13	SHEET PILING.	11000 SFT
14	CONCRETING.	0.19 MCF
15	BRICK MASONARY.	0.10 MCF
16	STONE WORK.	
	a. GUIDE BANKS.	0.71 MCF
	b. REGULATOR.	0.08 MCF
17	BRIDGE DECKING.	6000 SFT
18	FABRICATION OF IRON GATES.	30 NOS
	a. DESIGN DRAWINGS.	
	b. FABRICATION.	
	C. ERECTION.	
19	SITE CLEARING.	

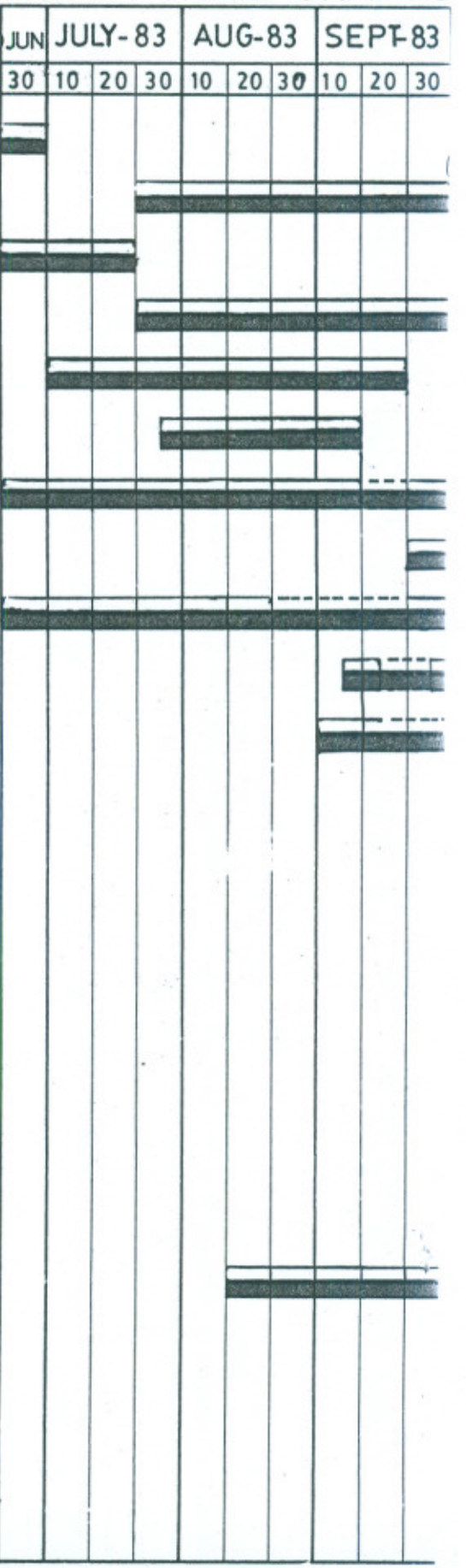


PLATE NO 2

SCHEDULE FOR THE CONSTRUCTION OF RIVER DIVERSION WORKS AT GHAZI GHAT

PROGRESS REPORT PERIOD ENDING 31-3-84
SCHEDULE
PROGRESS

S NO	DESCRIPTION OF WORKS	ESTIMATED QTY.	PROGRESS QTY	PROGRESS %AGE	REMARKS
1	RIVER SURVEYS (PHASE I).	—		100	
2	" " (PHASE II).	—		100	
3	MODEL STUDIES (PRELIMINARY).	—		100	
4	" " (FINAL).	—		100	
5	MACHINERY & EQUIPMENT.	—		100	
6	TRANSMISSION LINE.	7 MILES		100	
7	APPROACH ROAD.	4000 FT		100	
8	TEMPORARY REGULATOR.	380 FT		100	
9	PLUGGING & DIVERSION OF RIVER CREEKS.	3 NOS		100	
10	LEADING CUTS (6 NOS).	8·7 MILES (60 MCF)		100	Plugs of I to IV leading cuts near the river edge removed from 21. to 26.1.84
11	APPROACH ROAD CUM DIVESION BUND. (INCLUDING PUSHTA)	2·3 MILES (44 MCF)	50	91	Pushta work in progress
12	DIVERSION CHANNEL.	0·4 MILES (19 MCF)		100	
13	CLOSURE OF MAIN RIVER COURSE. (INCLUDING PUSHTA)	0.20 MILES (22 MCF)	25	100	Gap plugged on 29-1-84 strengthening work continued
14	PLUG BUND BELOW REGULATOR. (INCLUDING PUSHTA)	400 FT (7 MCF)	12	100	Delayed for constructing shank of spur R-2 in the river portion - Gap plugged on 12-2-84. strengthening work continued
15	STRENGTHENING/STAUNCHING & WATCHING OF BUNDS.	—			Staunching work commenced from 16-2-84.
16	HAND OVER TO HIGHWAYS DEPARTMENT/ CLEARANCE.	—			No handing over done. Watch & ward kept with the Irrigation department

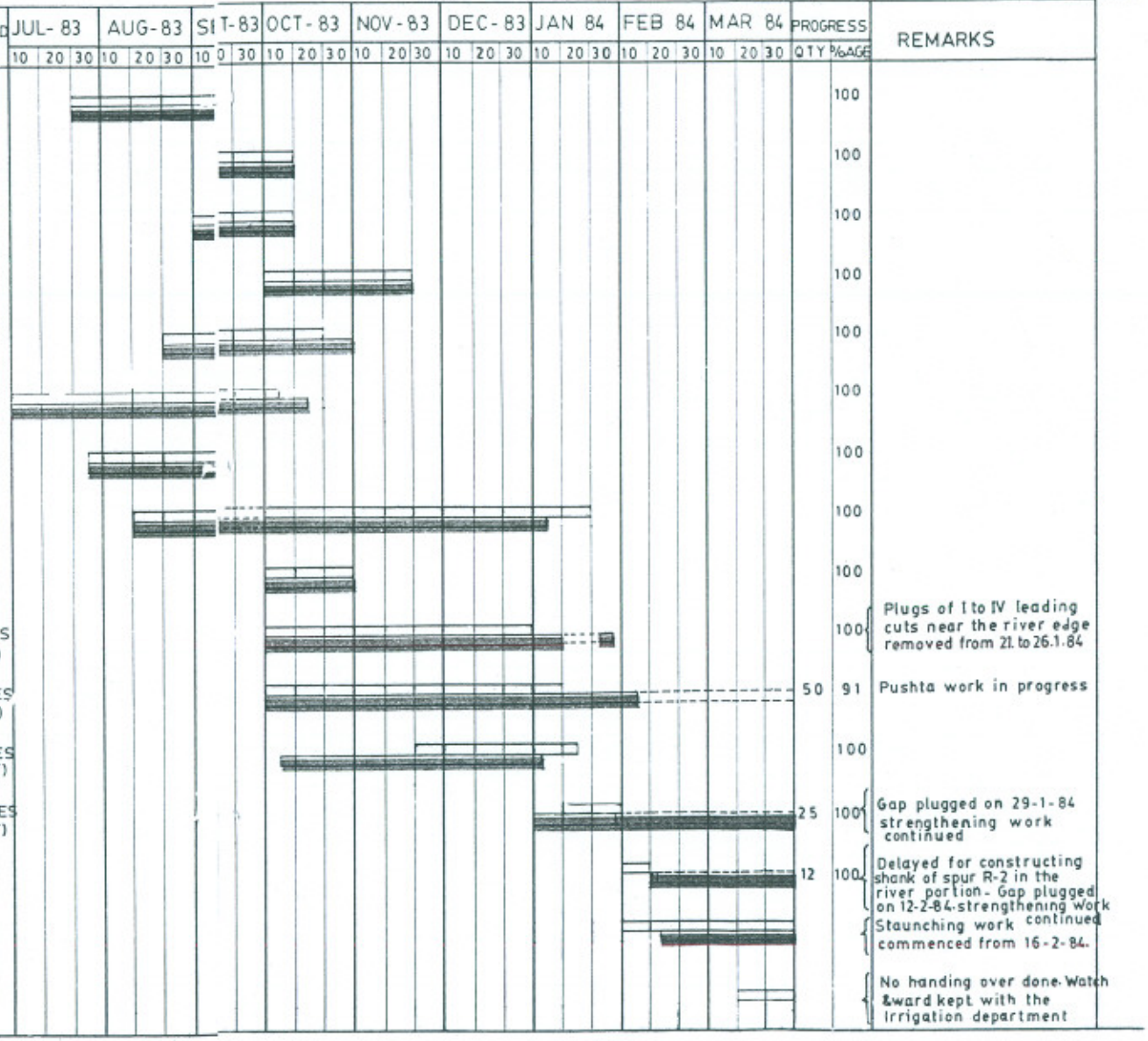
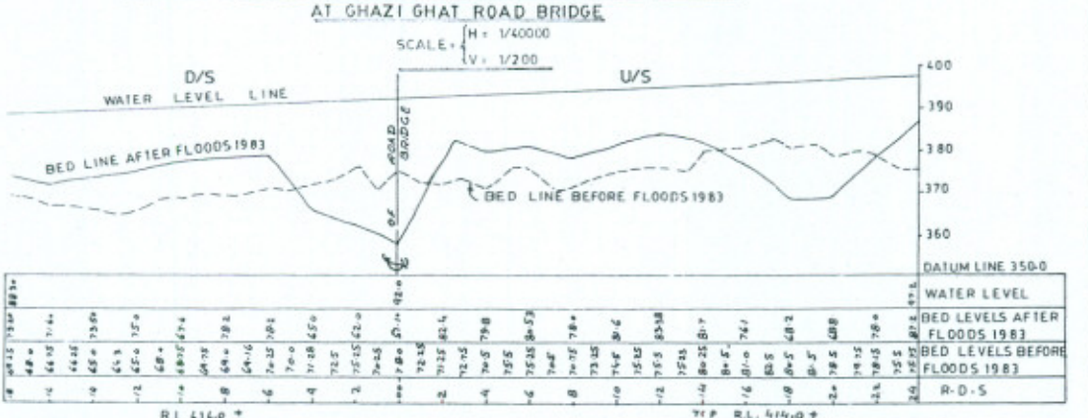
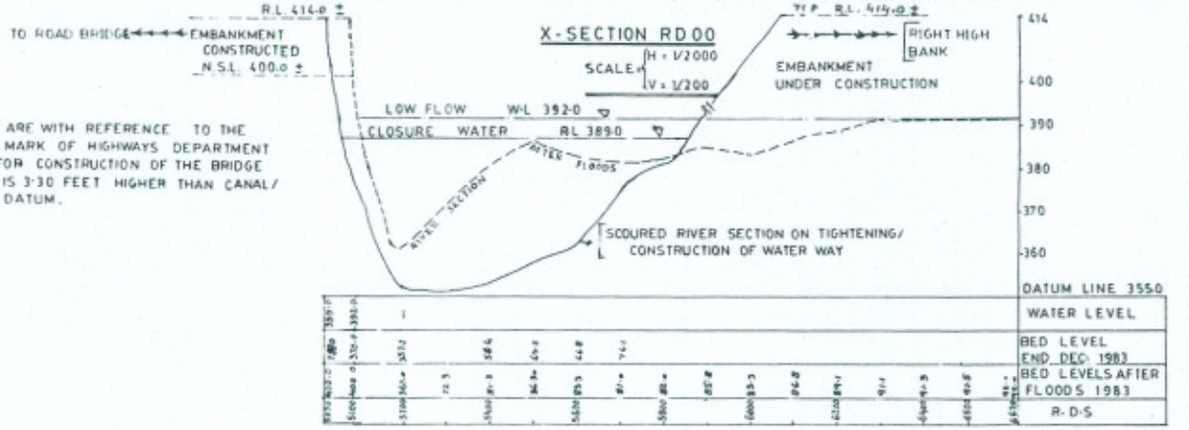


PLATE NO XIII

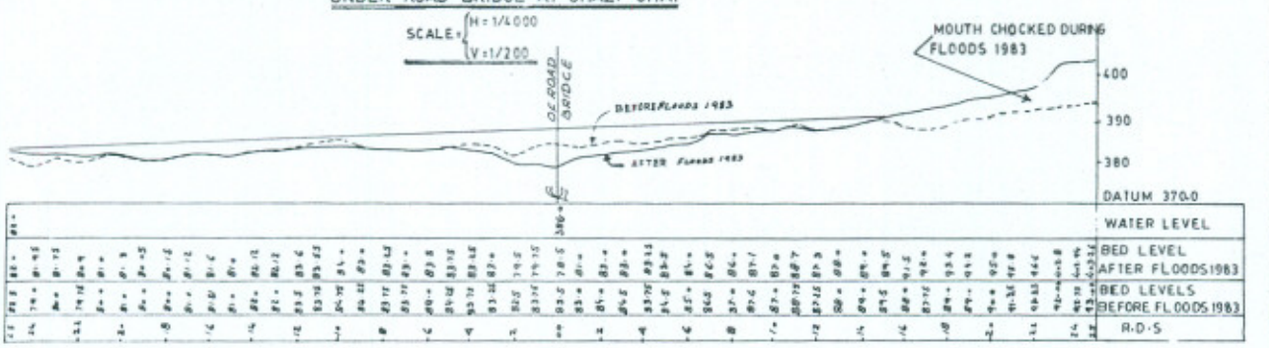
L-SECTION OF MAIN CHANNEL OF RIVER INDUS (DEEPEST BED) AT GHAZI GHAT ROAD BRIDGE



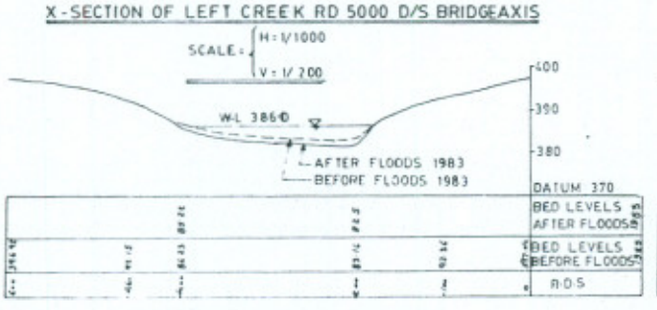


NOTE:- LEVELS ARE WITH REFERENCE TO THE BENCH MARK OF HIGHWAYS DEPARTMENT USED FOR CONSTRUCTION OF THE BRIDGE WHICH IS 3·30 FEET HIGHER THAN CANAL/ G.T.S DATUM.

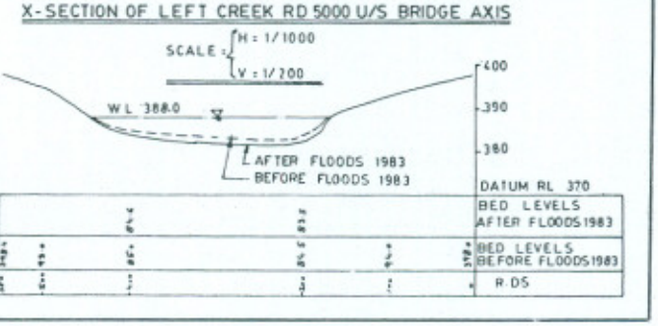
L-SECTION OF LEFT CREEK OF RIVER INDUS UNDER ROAD BRIDGE AT GHAZI GHAT



X-SECTION OF LEFT CREEK RD 5000 D/S BRIDGE AXIS



X-SECTION OF LEFT CREEK RD 5000 U/S BRIDGE AXIS



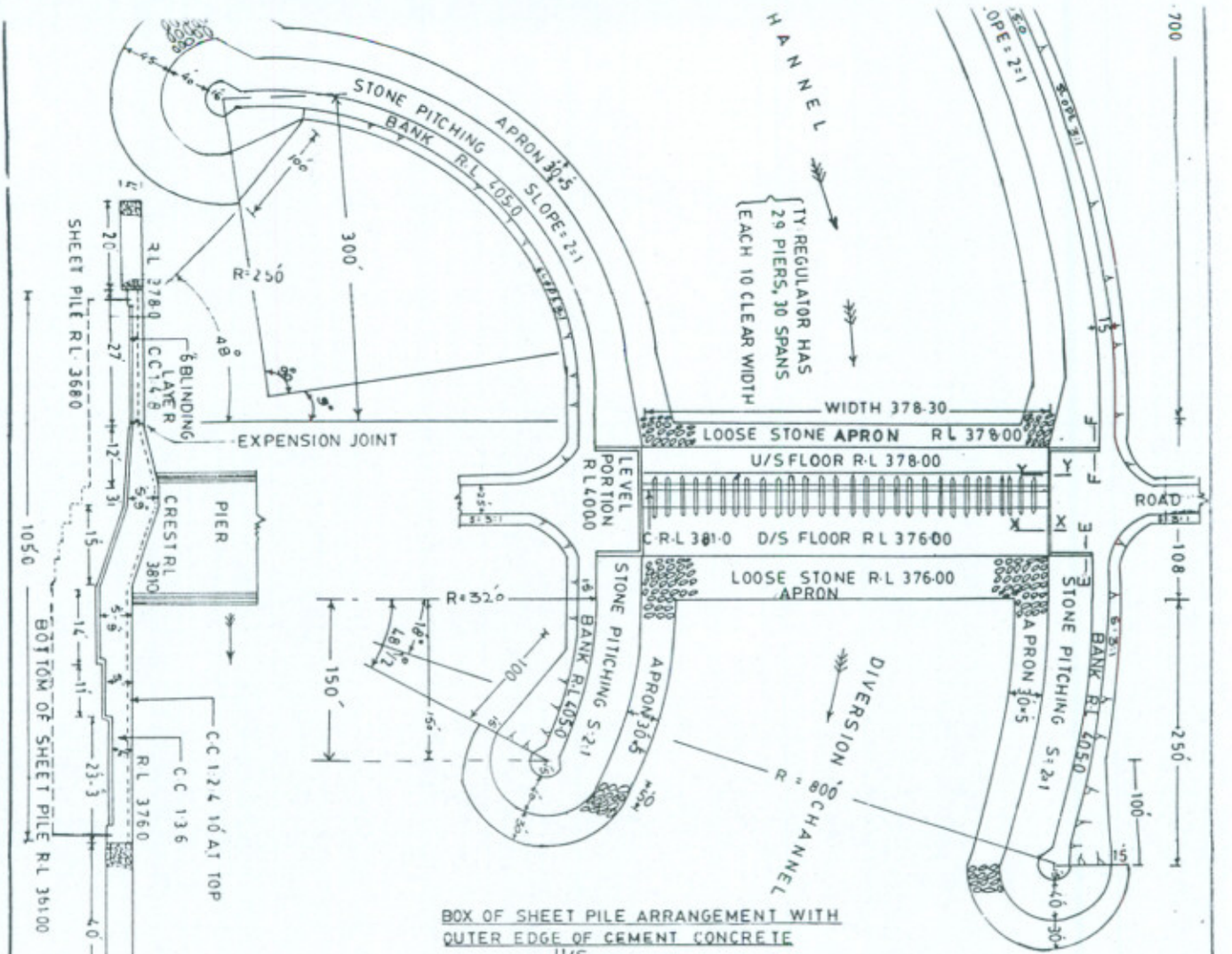
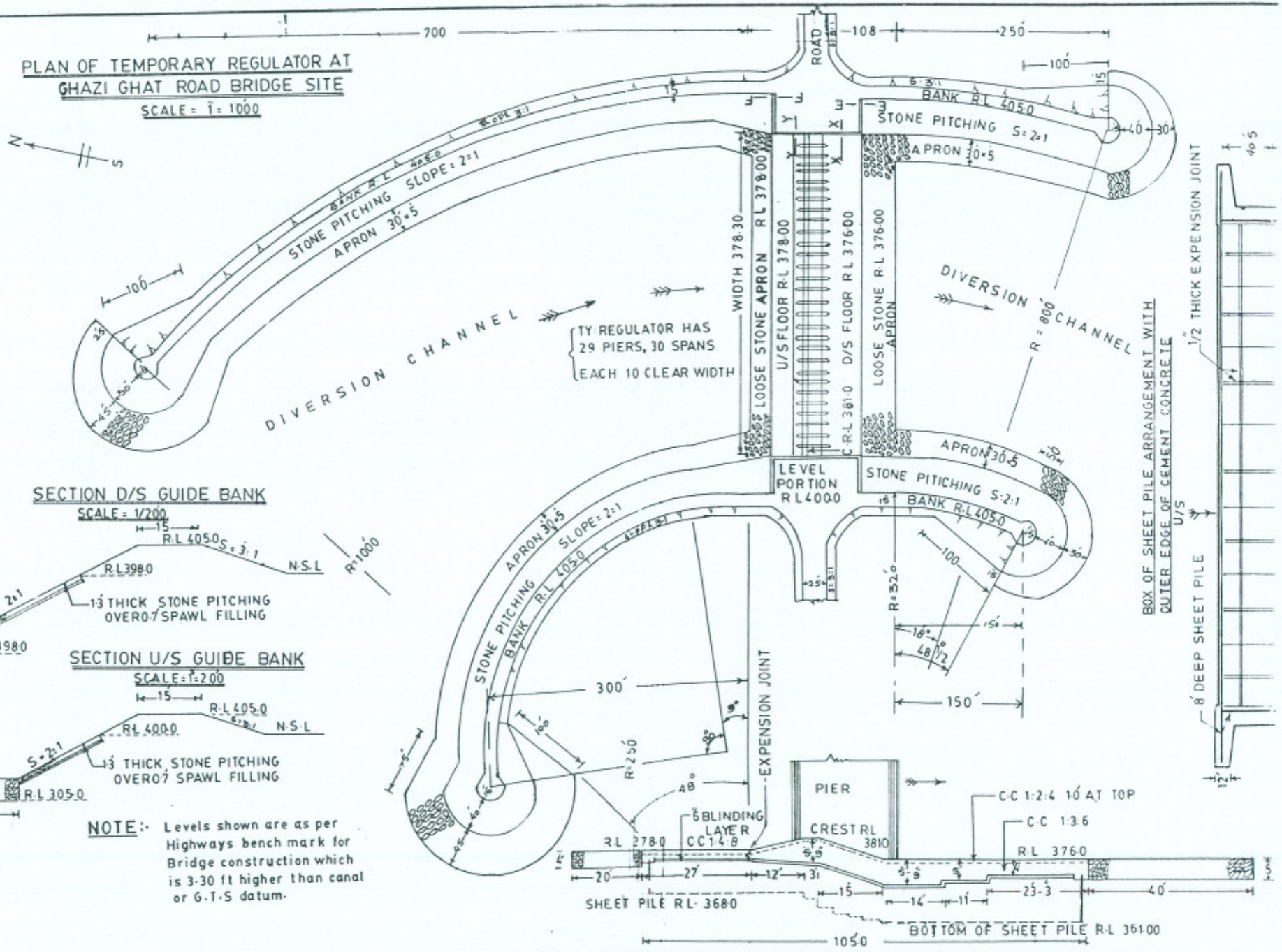

STONE PITCHING
BANK R.L 4050
APRON 30'-5
SLOPE 2:1
300'
R=250'
48°
EXPENSION JOINT
SHEET PILE R.L 3680
6" BLINDING LAYER
CC 1:4:8
CREST R.L 3810
PIER
CC 1:2:4 10' AT TOP
CC 1:3:6
R.L 3760
BOTTOM OF SHEET PILE R.L 3510
1050
LEVEL PORTION R.L 4000
HANNEL
TY REGULATOR HAS
29 PIERS, 30 SPANS
EACH 10 CLEAR WIDTH
WIDTH 378-30
LOOSE STONE APRON R.L 378-00
U/S FLOOR R.L 378-00
C R.L 381-0 D/S FLOOR R.L 376-00
LOOSE STONE R.L 376-00
APRON
R=320'
150'
STONE PITCHING S:2:1
BANK R.L 4050
APRON 30'-5
DIVERSION
R=800' CHANNEL
SLOPE 2:1
ROAD
700
108
250'
100'
BOX OF SHEET PILE ARRANGEMENT WITH
OUTER EDGE OF CEMENT CONCRETE
U/S
8' DEEP SHEET PILE
1/2 THICK EXPENSION JOINT
40'-5
61'-50
40
OUTER EDGE OF C.C
10-8' DEEP SHEET PILE
D/S
CONSTRUCTION JOINT
SECTION OF CONSTRUCTION JOINT
SCALE = 1/10 = 1'
CEMENT CONCRETE 1:2:4
9" P.V.C
WATER STOPPER
CEMENT CONCRETE 1:3:6
6" THICK BLINDING LAYER
1:4:8
SECTION OF EXPANSION JOINT
SCALE = 1/10 = 1'
CEMENT CONCRETE 1:2:4
9" P.V.C
WATER STOPPER
1/2 THICK
THERMOPORE
CEMENT CONCRETE
1:3:6
6" THICK
BLINDING LAYER
1:4:8

PLATE NO. XIV

PLAN OF TEMPORARY REGULATOR AT GHAZI GHAT ROAD BRIDGE SITE

SCALE = 1" = 1000



SECTION D/S GUIDE BANK

SCALE = 1/200

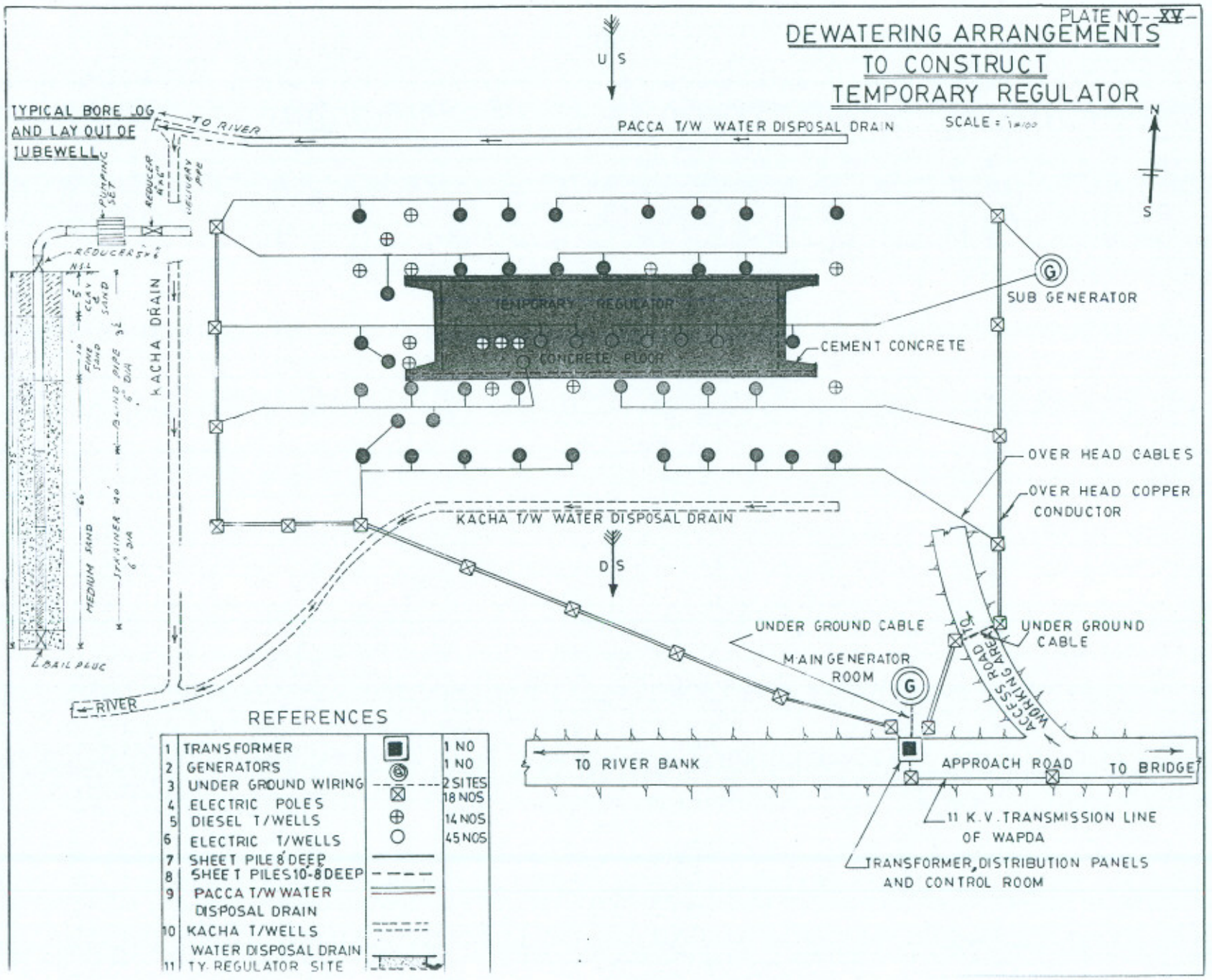
SECTION U/S GUIDE BANK

SCALE = 1=200

NOTE:- Levels shown are as per Highways bench mark for Bridge construction which is 3.30 ft higher than canal or G.T.S datum.

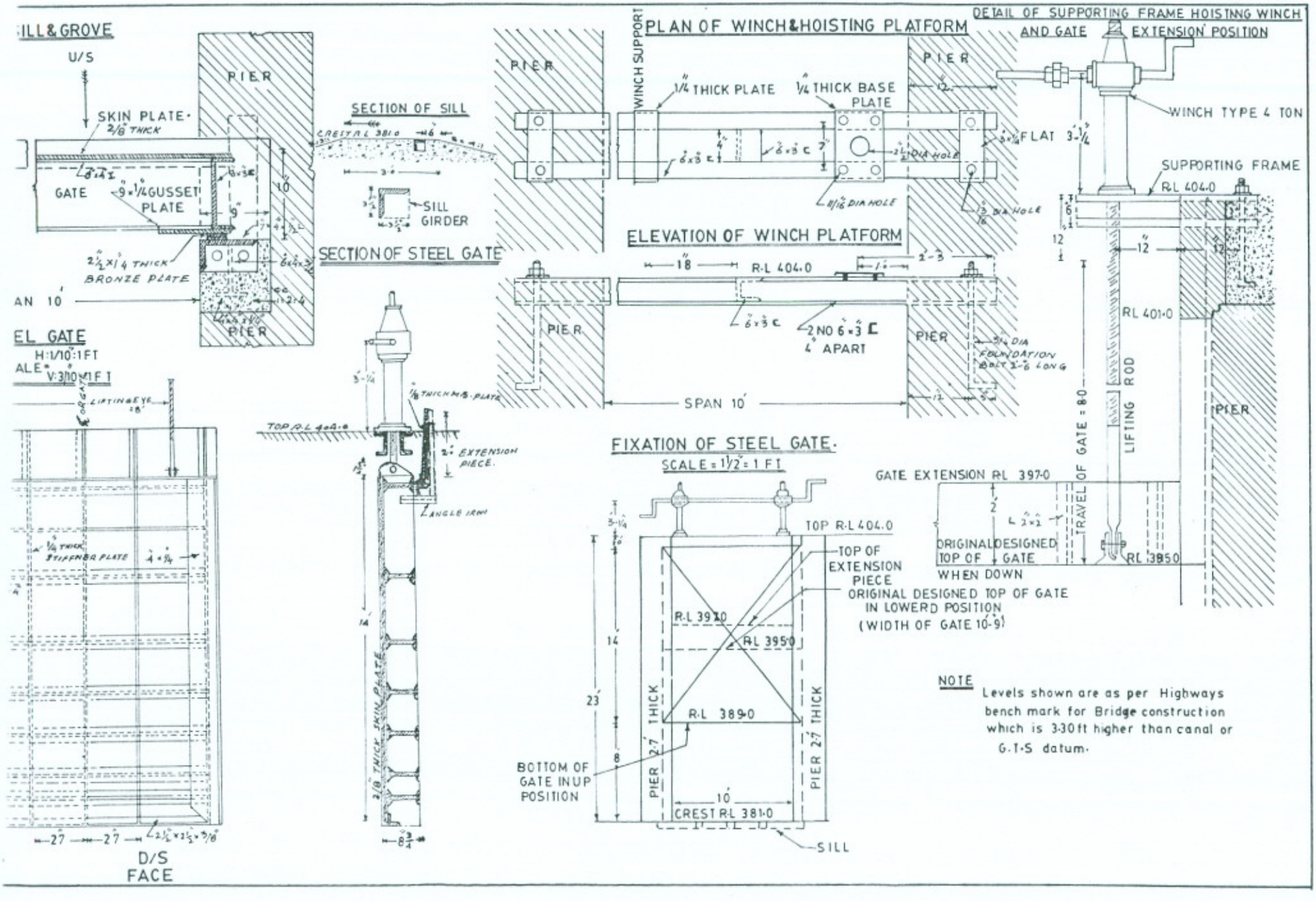
PLATE NO- XV -

DEWATERING ARRANGEMENTS TO CONSTRUCT TEMPORARY REGULATOR



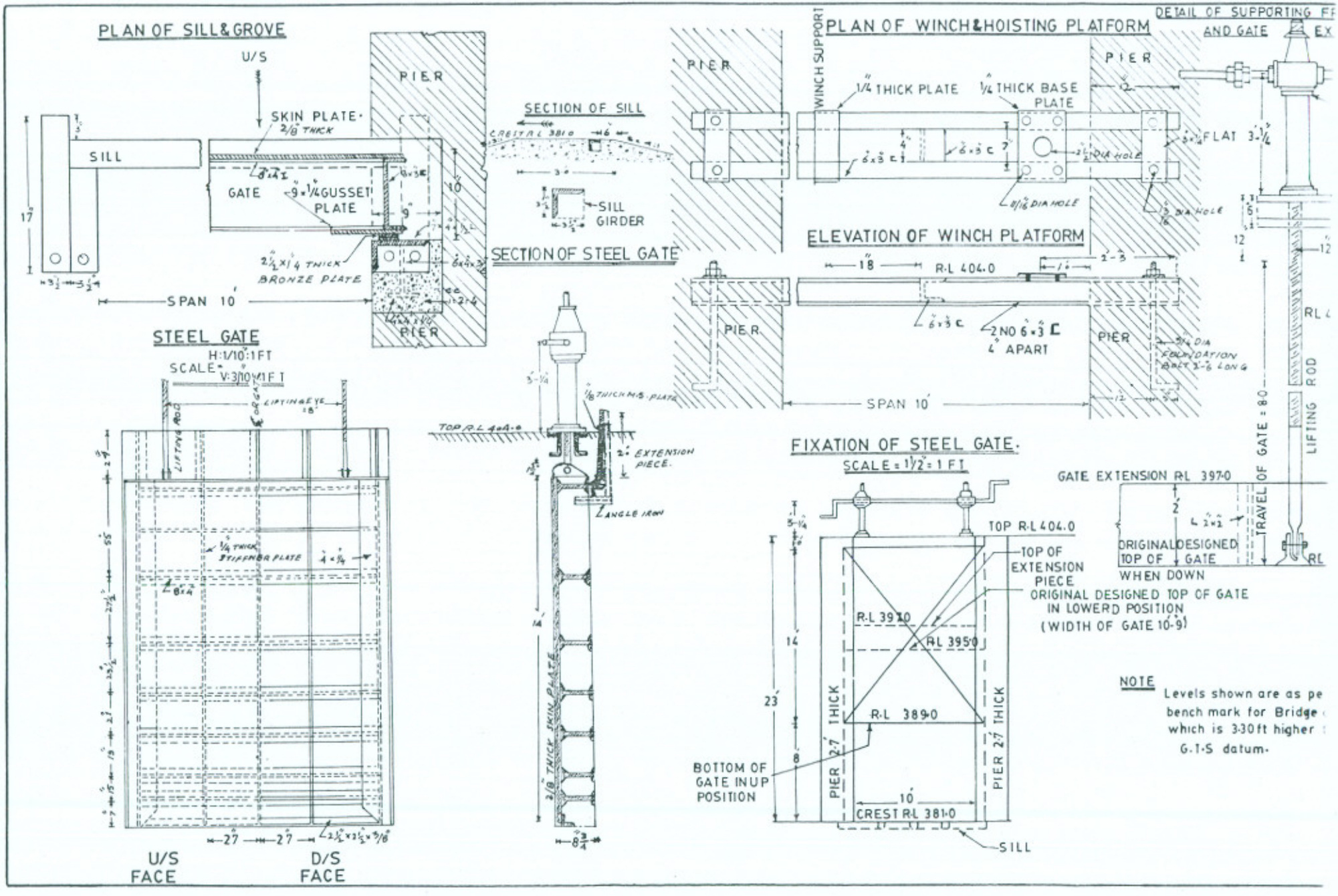
REFERENCES

1	TRANSFORMER	1 NO
2	GENERATORS	1 NO
3	UNDER GROUND WIRING	2 SITES
4	ELECTRIC POLES	18 NOS
5	DIESEL T/WELLS	14 NOS
6	ELECTRIC T/WELLS	45 NOS
7	SHEET PILE 8' DEEP	
8	SHEET PILES 10-8 DEEP	
9	PACCA T/W WATER DISPOSAL DRAIN	
10	KACHA T/WELLS WATER DISPOSAL DRAIN	
11	TY. REGULATOR SITE	



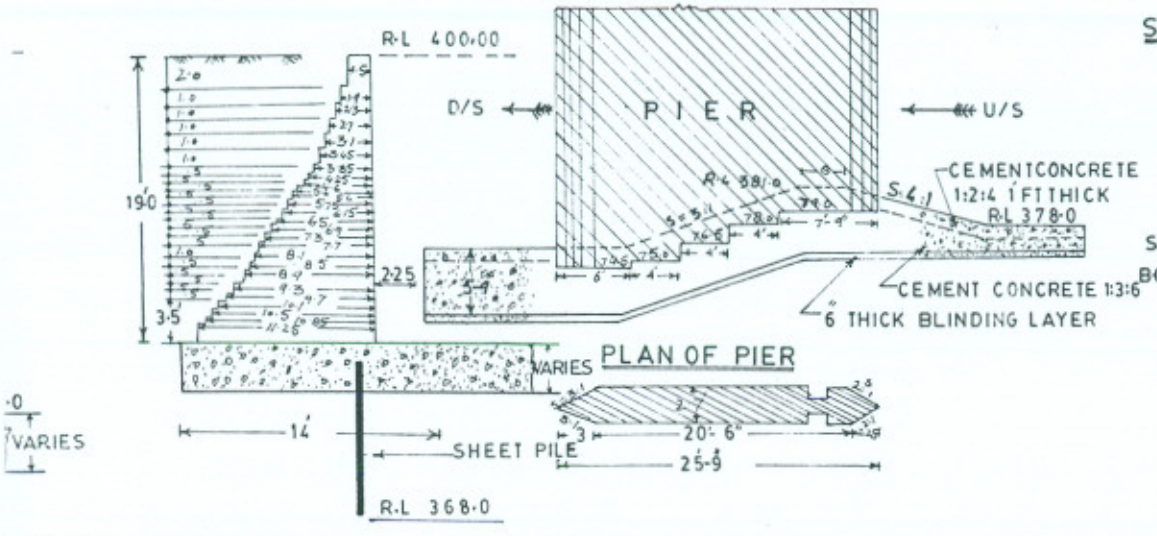
NOTE

Levels shown are as per Highways bench mark for Bridge construction which is 3.30 ft higher than canal or G.T.S datum.

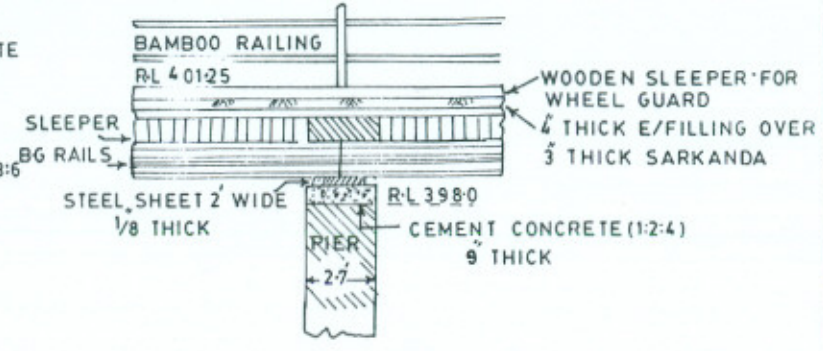

PLAN OF SILL & GROVE
U/S
PIER
SKIN PLATE
2/8" THICK
SILL
GATE
9"×1/4 GUSSET PLATE
2½"×1/4 THICK BRONZE PLATE
SPAN 10'
SECTION OF SILL
CREST RL 381.0
SILL GIRDER
SECTION OF STEEL GATE
PLAN OF WINCH & HOISTING PLATFORM
WINCH SUPPORT
1/4 THICK PLATE
1/4 THICK BASE PLATE
2½" DIA HOLE
FLAT 3-1/4
ELEVATION OF WINCH PLATFORM
R.L 404.0
2 NO 6×3 C
4" APART
SPAN 10'
DETAIL OF SUPPORTING FR AND GATE EX
RL
LIFTING ROD
TRAVEL OF GATE = 8·0
GATE EXTENSION RL 397·0
ORIGINAL DESIGNED TOP OF GATE WHEN DOWN
STEEL GATE
H: 1/10" : 1 FT
SCALE
V: 3/10" : 1 FT
LIFTING EYE
LIFTING ROD
1/8" THICK STIFFNER PLATE
U/S FACE
D/S FACE
1/8" THICK M.S. PLATE
TOP R.L 404·0
2" EXTENSION PIECE.
ANGLE IRON
2/8" THICK SKIN PLATE
FIXATION OF STEEL GATE.
SCALE = 1½" = 1 FT
TOP R.L 404.0
TOP OF EXTENSION PIECE
ORIGINAL DESIGNED TOP OF GATE IN LOWERD POSITION (WIDTH OF GATE 10'-9")
R.L 397.0
RL 395·0
R.L 389·0
BOTTOM OF GATE IN UP POSITION
PIER 2·7' THICK
CREST R.L 381·0
SILL
NOTE
Levels shown are as pe
bench mark for Bridge
which is 3·30 ft higher
G.T.S datum.

SECTION AT Y-Y
SCALE = 1/100

SECTION OF PIER FOUNDATION
SCALE = 1/100

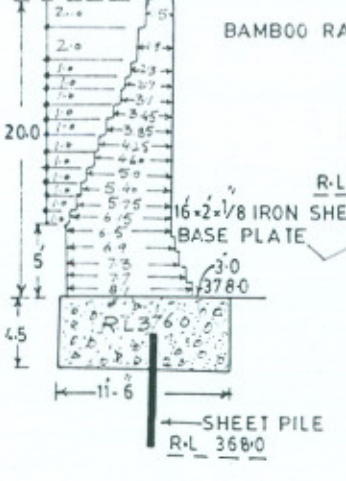


SECTION OF ROAD WAY THROUGH PIER
SCALE = 1/50

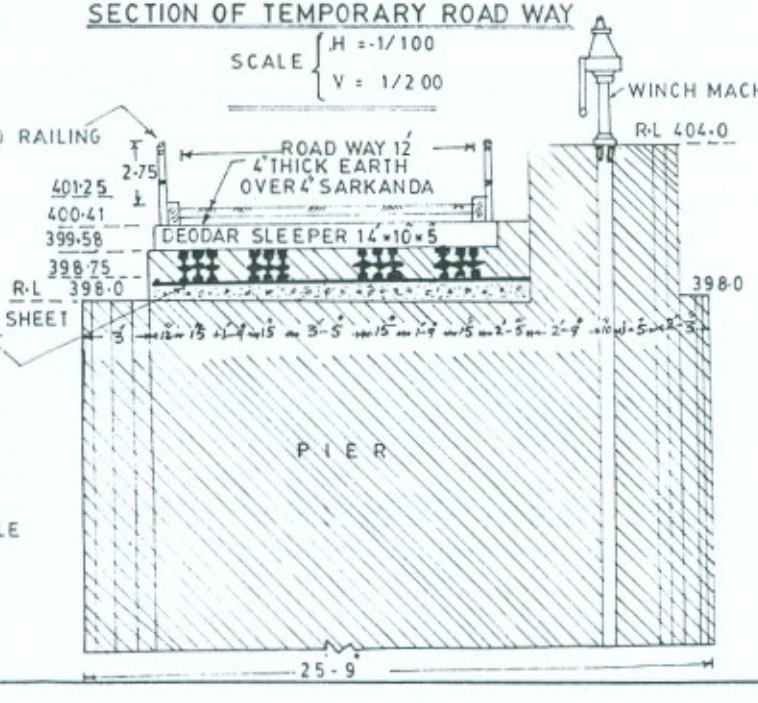


·0
VARIES
T PILE

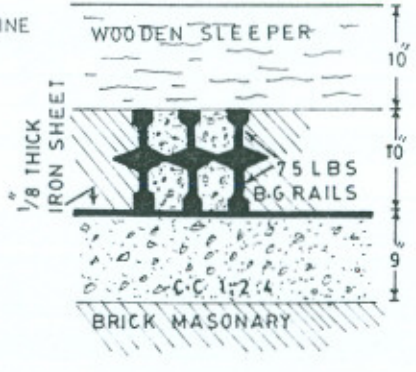
SECTION OF U/S WING WALL AT F-F



SECTION OF TEMPORARY ROAD WAY
SCALE { H = 1/100 ; V = 1/200



DETAIL OF DECKING

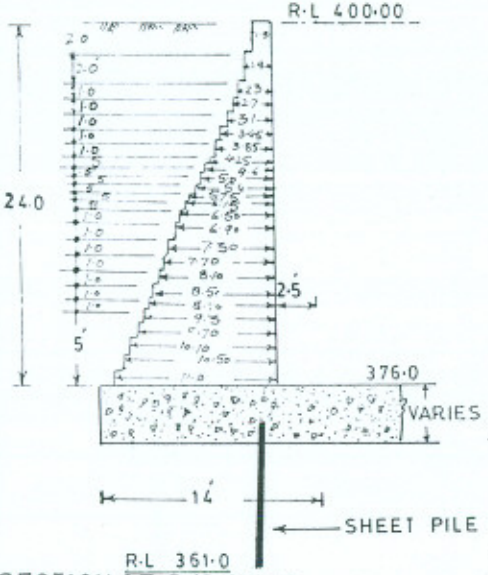


NOTE Levels shown are as per Highways bench mark for Bridge construction which is 330 ft higher than canal or G·T·S datum.

NOTE The location of x-sections is as per plate no.

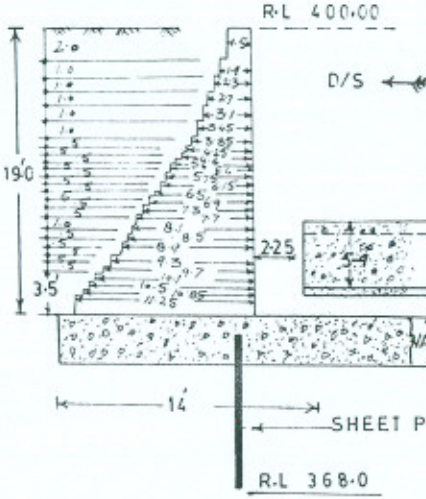
SECTION AT X-X

SCALE = 1/100



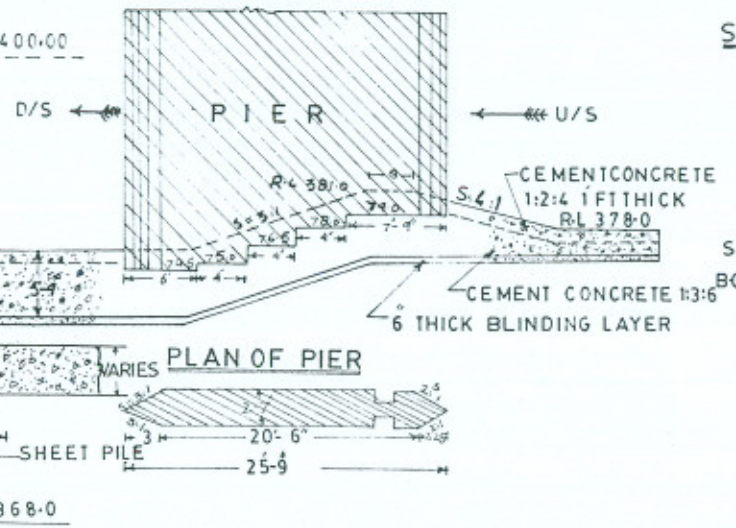
SECTION AT Y-Y

SCALE = 1/100



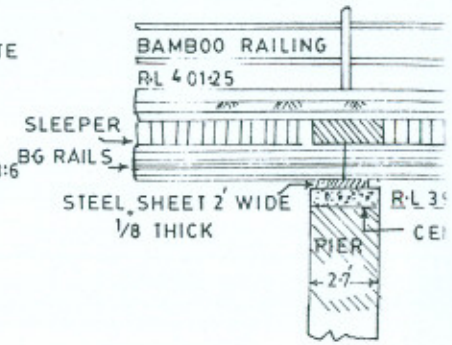
SECTION OF PIER FOUNDATION

SCALE = 1/100

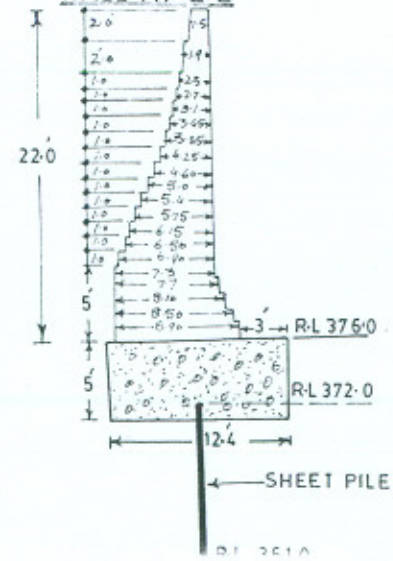


SECTION OF ROAD WAY THROU

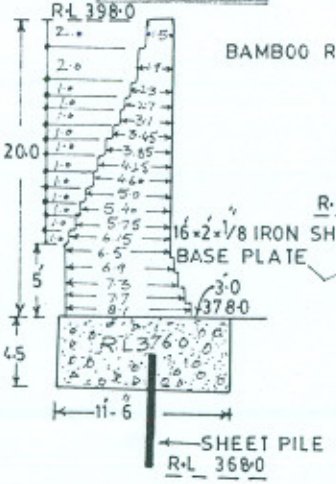
SCALE = 1/50



SECTION OF D/S WING WALL AT E-E

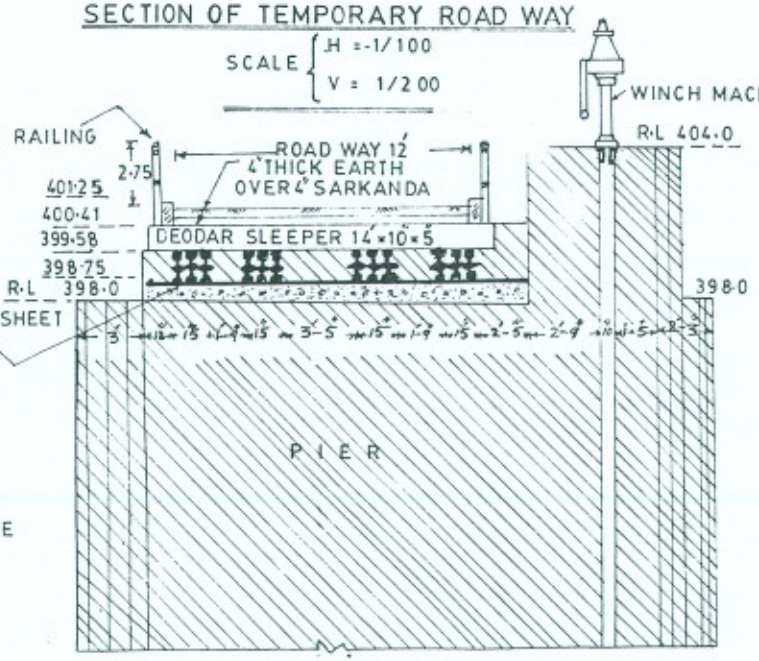


SECTION OF U/S WING WALL AT F-F

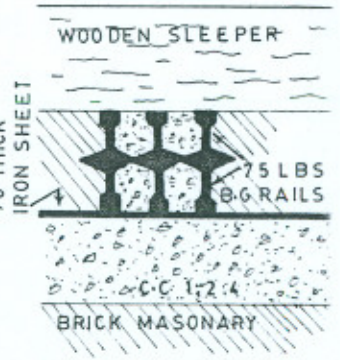


SECTION OF TEMPORARY ROAD WAY

SCALE { H = 1/100, V = 1/200 }



DETAIL OF DECKING



NOTE Levels sho
mark for f
3·30 ft high

NOTE The locatio
plate n

PLATE NO. ~~XIII~~

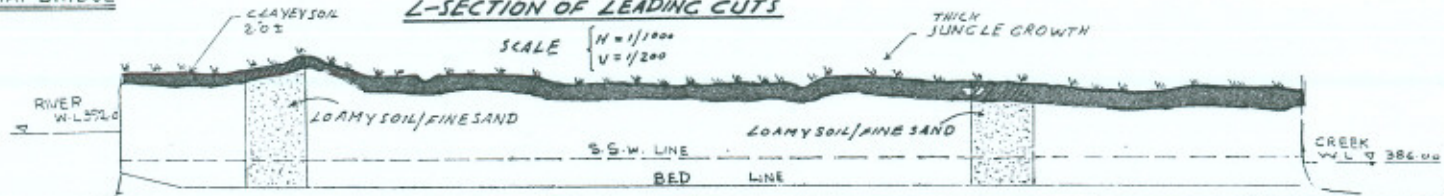
DIVERSION OF RIVER INDUS AT GHAZI GHAT BRIDGE

LEADING CUTS DETAILS



L-SECTION OF LEADING CUTS

SCALE { H = 1/1000, V = 1/200



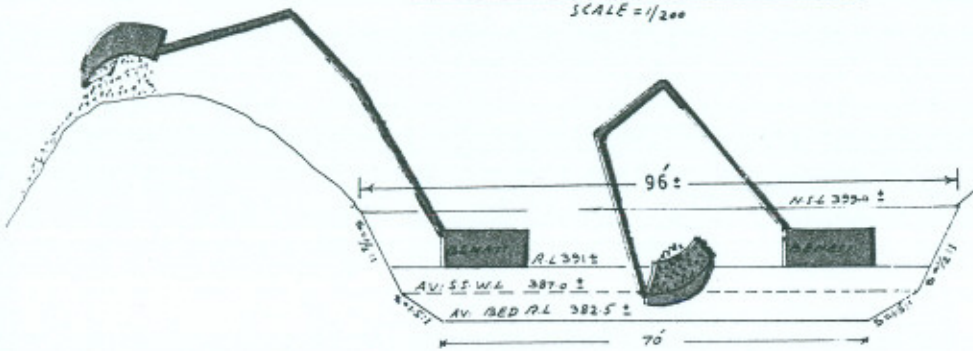
| | | |

DIVERSION OF RIVER INDUS AT GHAZI GHAT BRIDGE

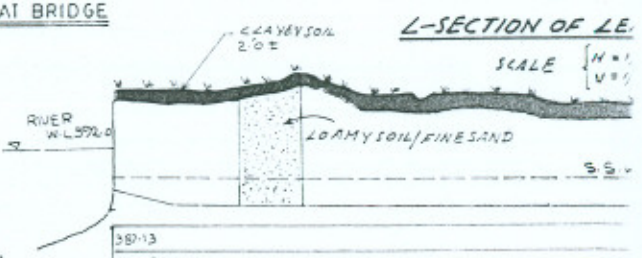
LEADING CUTS DETAILS

AV: X-SECTION OF LEADING CUT NO I, II, III & IV

SCALE = 1/200

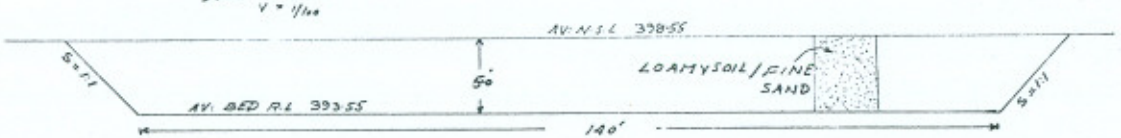


L-SECTION OF LE...

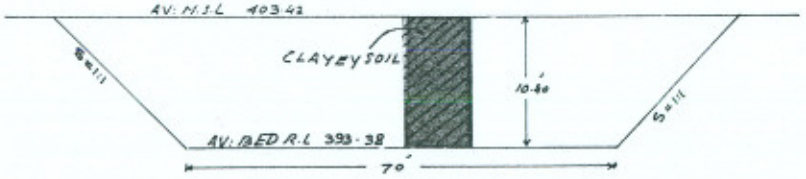


AV: X-SECTION OF LEADING CUT NO V

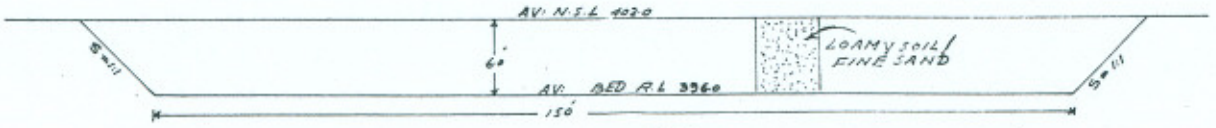
SCALE H = 1/200
V = 1/100



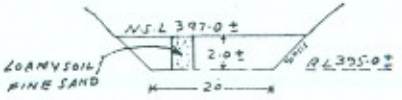
AV: X-SECTION OF LEADING CUT NO V-A



AV: X-SECTION OF LEADING CUT NO 6 (R.D 0-2000)



AV: X-SECTION OF LEADING CUT NO I-A



NOTE Levels shown are as per Highways bench mark for Bridge construction which is 3·30 ft higher than canal or G·T·S datum.

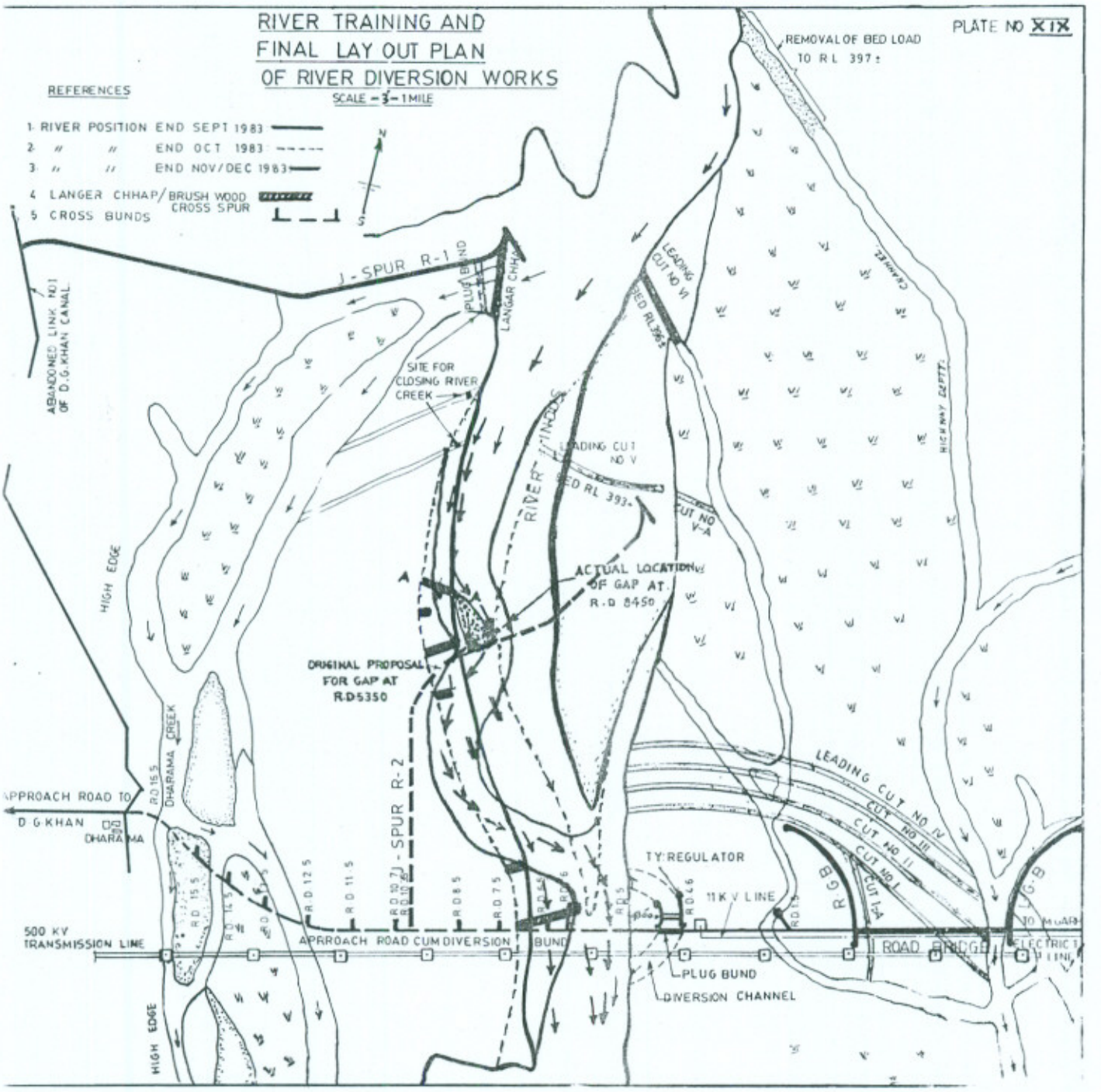
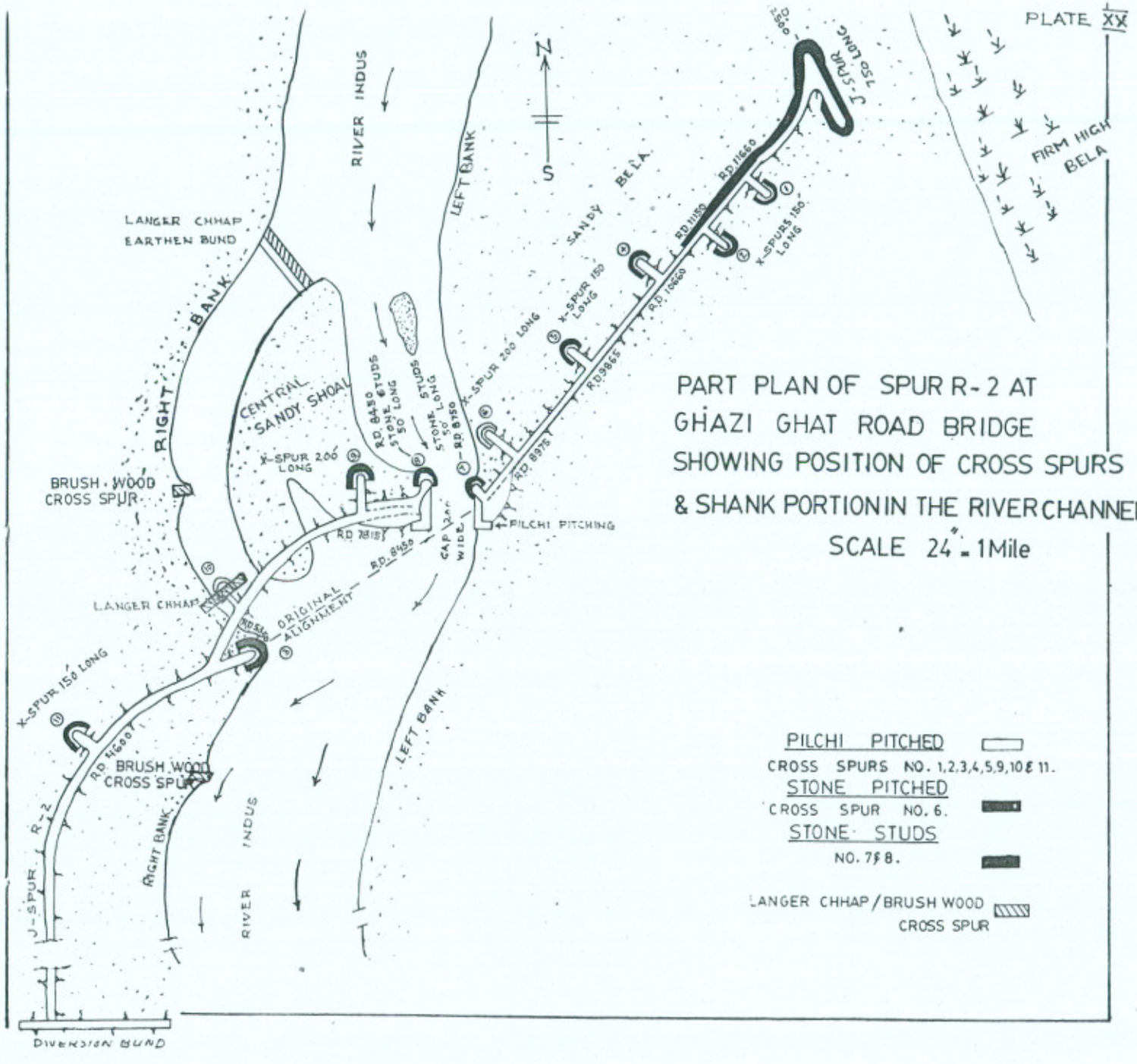

RIVER TRAINING AND
FINAL LAY OUT PLAN
OF RIVER DIVERSION WORKS
SCALE - 1/2 - 1 MILE
PLATE NO XIX
REFERENCES
1. RIVER POSITION END SEPT 1983
2. " " END OCT 1983
3. " " END NOV/DEC 1983
4. LANGER CHHAP/ BRUSH WOOD CROSS SPUR
5. CROSS BUNDS
REMOVAL OF BED LOAD TO R L 397±
J - SPUR R-1
PLUG BUND
LANGAR CHHAP
LEADING CUT NO VI
BED RL 395±
ABANDONED LINK NO I OF D.G.KHAN CANAL
SITE FOR CLOSING RIVER CREEK
RIVER INDUS
LEADING CUT NO V
BED RL 393±
CUT NO V-A
HIGH WAY EMBTT.
HIGH EDGE
ACTUAL LOCATION OF GAP AT R.D 8450
ORIGINAL PROPOSAL FOR GAP AT R.D 5350
J - SPUR R-2
DHARAMA CREEK
APPROACH ROAD TO D G KHAN
DHARAMA
LEADING CUT NO IV
CUT NO III
CUT NO II
CUT NO I
CUT I-A
TY: REGULATOR
11 K.V LINE
R.G.B
L.G.B
500 KV TRANSMISSION LINE
APPROACH ROAD CUM DIVERSION BUND
ROAD BRIDGE
PLUG BUND
DIVERSION CHANNEL
HIGH EDGE

PLATE XX

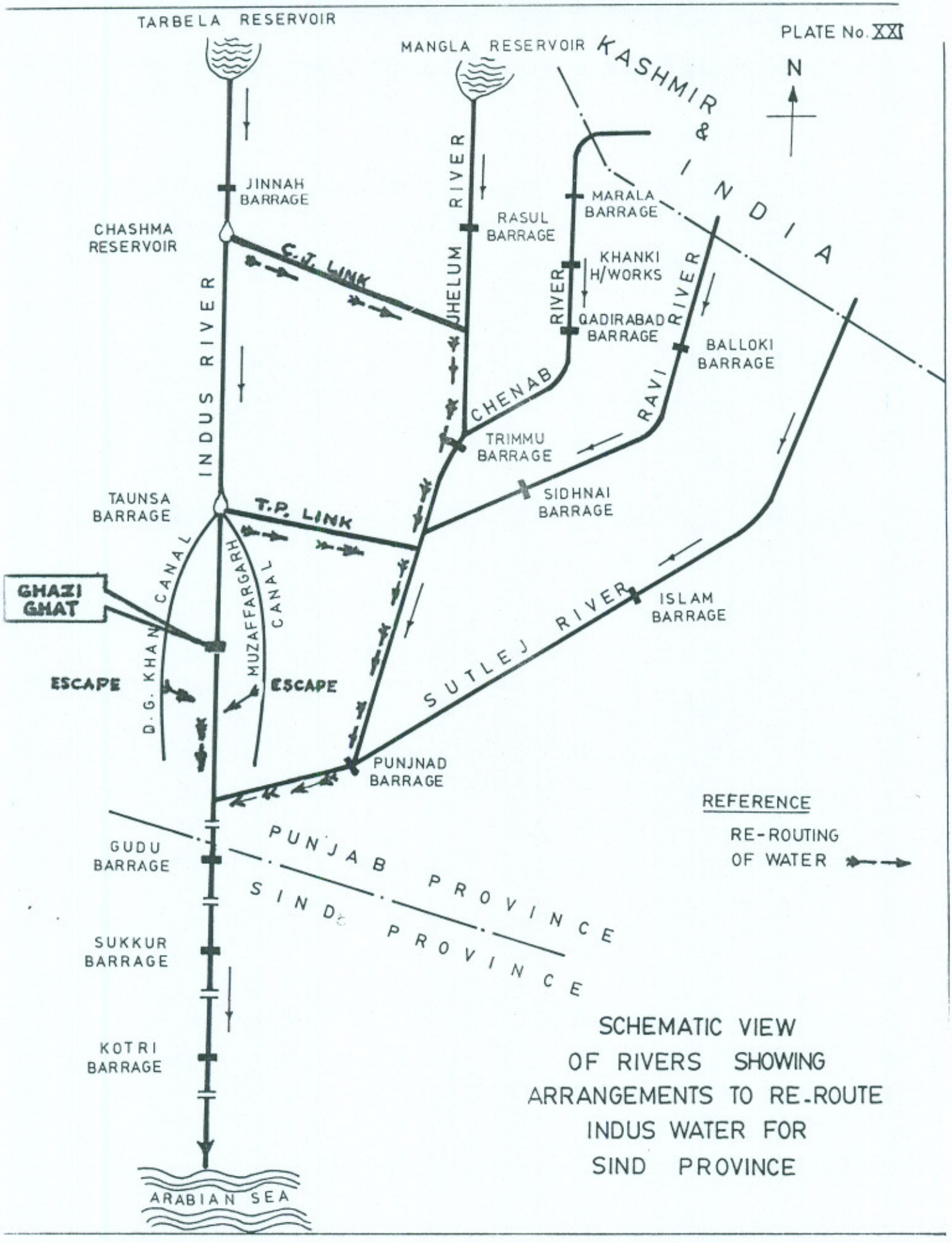


PART PLAN OF SPUR R-2 AT GHAZI GHAT ROAD BRIDGE SHOWING POSITION OF CROSS SPURS & SHANK PORTION IN THE RIVER CHANNEL

SCALE 24" = 1 Mile

PILCHI PITCHED
CROSS SPURS NO. 1, 2, 3, 4, 5, 9, 10 & 11.
STONE PITCHED
CROSS SPUR NO. 6.
STONE STUDS
NO. 7 & 8.
LANGER CHHAP / BRUSH WOOD CROSS SPUR

PLATE No. XXI



SCHEMATIC VIEW OF RIVERS SHOWING ARRANGEMENTS TO RE-ROUTE INDUS WATER FOR SIND PROVINCE

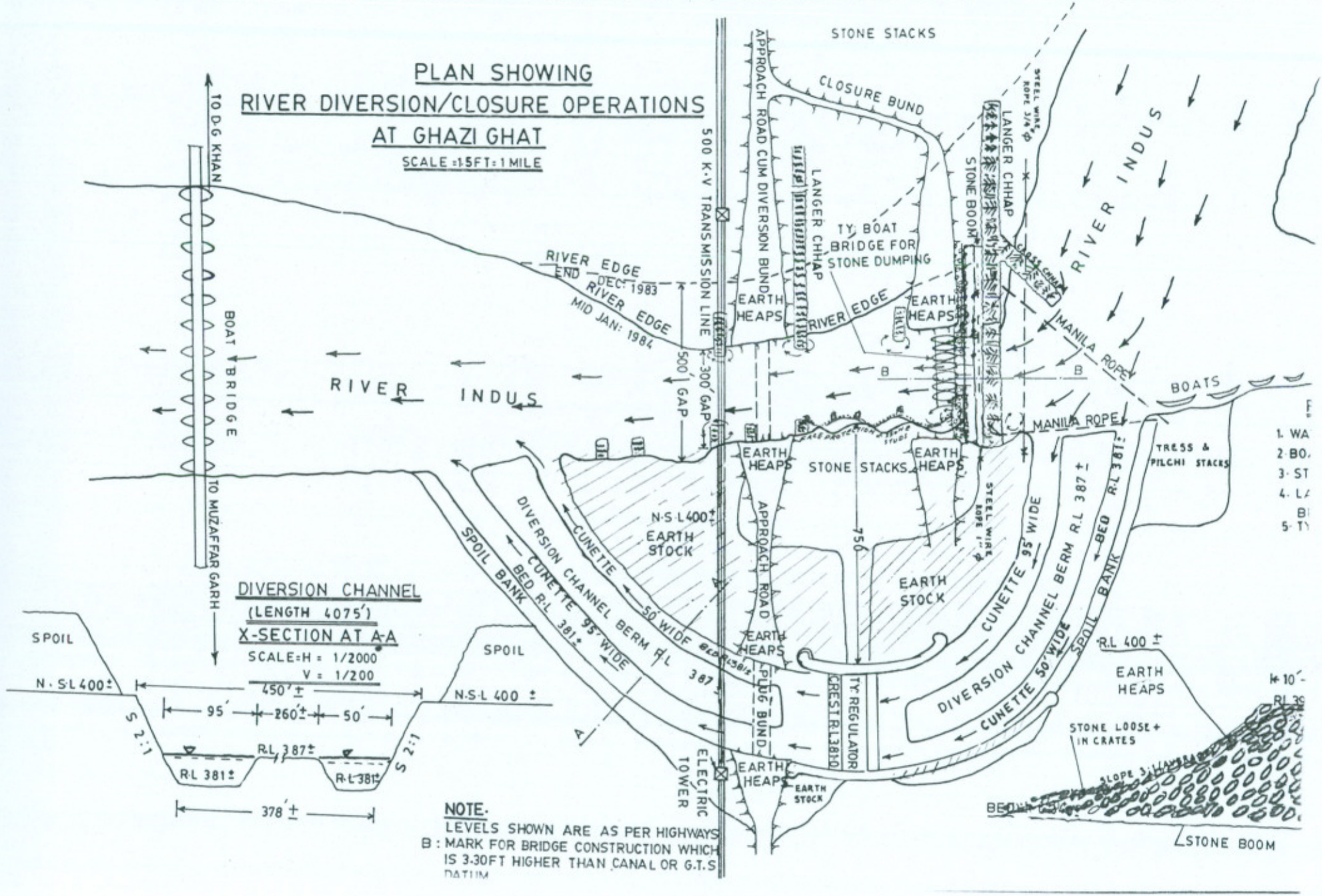
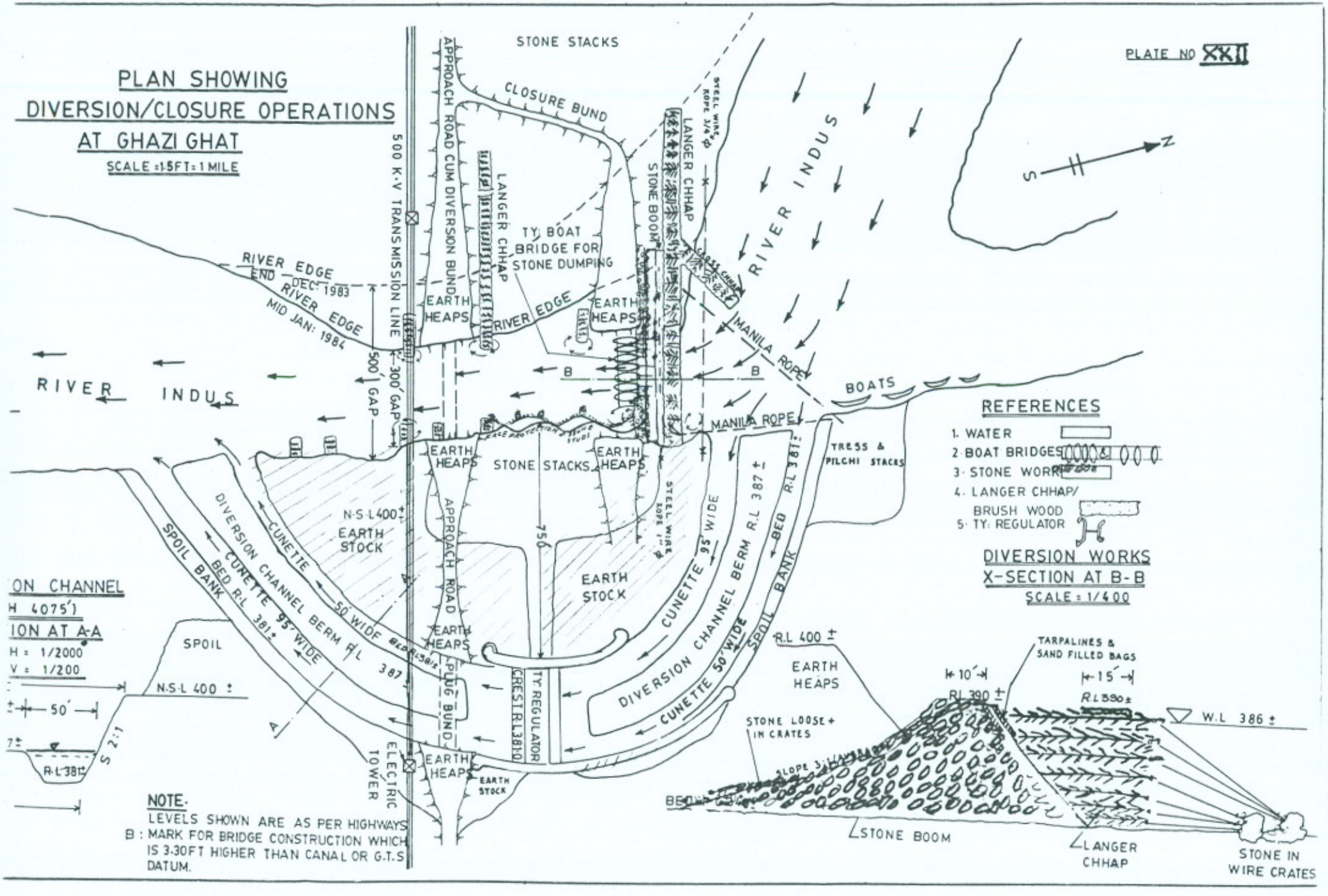

PLAN SHOWING
RIVER DIVERSION/CLOSURE OPERATIONS
AT GHAZI GHAT
SCALE :1.5FT: 1 MILE
TO D.G KHAN
TO MUZAFFAR GARH
BOAT BRIDGE
500 K.V TRANSMISSION LINE
RIVER EDGE END DEC: 1983
RIVER EDGE MID JAN: 1984
500' GAP
300' GAP
RIVER INDUS
STONE STACKS
CLOSURE BUND
APPROACH ROAD CUM DIVERSION BUND
LANGER CHHAP
STONE BOOM
TY: BOAT BRIDGE FOR STONE DUMPING
EARTH HEAPS
RIVER EDGE
MANILA ROPE
BOATS
TRESS & PILCHI STACKS
N.S.L 400±
EARTH STOCK
APPROACH ROAD
DIVERSION CHANNEL BERM R.L 387
CUNETTE 95' WIDE
CUNETTE 50' WIDE
BED R.L 381±
SPOIL BANK
PLUG BUND
TY: REGULATOR
CREST R.L 381.0
ELECTRIC TOWER
STEEL WIRE ROPE 1"
STEEL WIRE ROPE 3/4"
DIVERSION CHANNEL
(LENGTH 4075')
X-SECTION AT A-A
SCALE: H = 1/2000
V = 1/200
SPOIL
N.S.L 400±
450'±
95'
260'±
50'
S 2:1
R.L 387±
R.L 381±
378'±
STONE LOOSE + IN CRATES
SLOPE 3:1
STONE BOOM
NOTE.
LEVELS SHOWN ARE AS PER HIGHWAYS
B : MARK FOR BRIDGE CONSTRUCTION WHICH IS 3.30FT HIGHER THAN CANAL OR G.T.S DATUM

PLATE NO XXII

PLAN SHOWING DIVERSION/CLOSURE OPERATIONS AT GHAZI GHAT

SCALE :1·5FT: 1 MILE



REFERENCES

1. WATER
2. BOAT BRIDGES
3. STONE WORK
4. LANGER CHHAP/ BRUSH WOOD
5. TY: REGULATOR

DIVERSION WORKS X-SECTION AT B-B

SCALE = 1/400

ON CHANNEL

H 4075')

ION AT A-A

H = 1/2000

V = 1/200

NOTE.

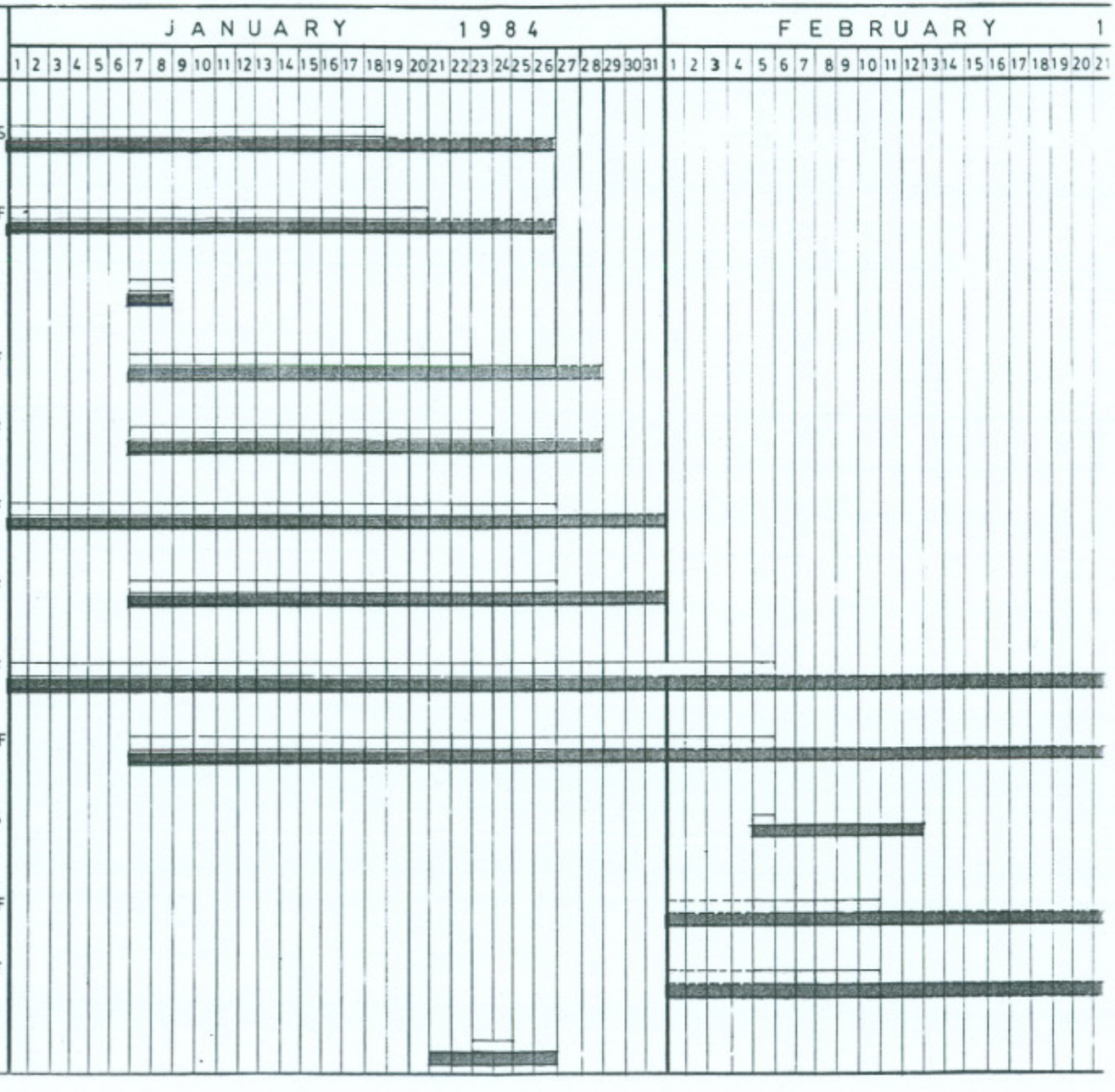
LEVELS SHOWN ARE AS PER HIGHWAYS

B : MARK FOR BRIDGE CONSTRUCTION WHICH IS 3·30FT HIGHER THAN CANAL OR G.T.S DATUM.

SCHEDULE FOR RIVER CLOSURE OPERATIONS

PROGRESS REPOR
SCHEDULE
PROGRESS

S.NO	OPERATION	DESCRIPTION OF MAJOR ITEMS	QTY
1	ERRECTION OF LANGER CHHAP	LAUNCHING AND ANCHORING OF TREES	4800 NOS
2	"	PILCHI/BRUSH WOOD PACKING	0·30 MCF
3	OPENING TEMPORARY REGULATOR	REMOVING PLUG BUNDS OF CUNETTES IN THE DIVERSION CHANNEL	4 NOS
4	CONSTRUCTION OF STONE BOOM	CARRIAGE OF STONE FROM YARD TO SITE OF WORK	1·10 MCF
5	" "	STONE DUMPING	1·10 MCF
6	CONSTRUCTION OF CLOSURE BUND IN THE MAIN RIVER CHANNEL	RIGHT BANK	4.0 MCF
7	" "	LEFT BANK	2·0 MCF
8	APPROACH ROAD (GAP IN THE MAIN RIVER CHANNEL)	RIGHT BANK	6·5 MCF
9	" "	LEFT BANK	6·5 MCF
10	LOWERING GATES OF TEMPORARY REGULATOR	—	30 NOS
11	PLUG BUND BELOW TEMPORARY REGULATOR	RIGHT BANK	3·5 MCF
	" "	LEFT BANK	3·5 MCF
12	OPENING OF LEADING CUTS	REMOVAL OF PLUG	4 NOS



:DULE FOR RIVER CLOSURE OPERATIONS

PROGRESS REPORT PERIOD ENDING 29-2-84 PLATE NO XXIII

SCHEDULE

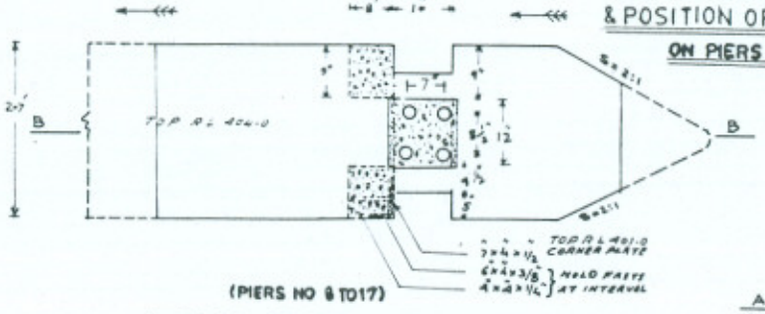
PROGRESS



PLAN SHOWING DETAILS OF HOISTING PLATFORM AT PIER & POSITION OF CRACK LINES ON PIERS NO 8 TO 17

PLATE NO EX 17

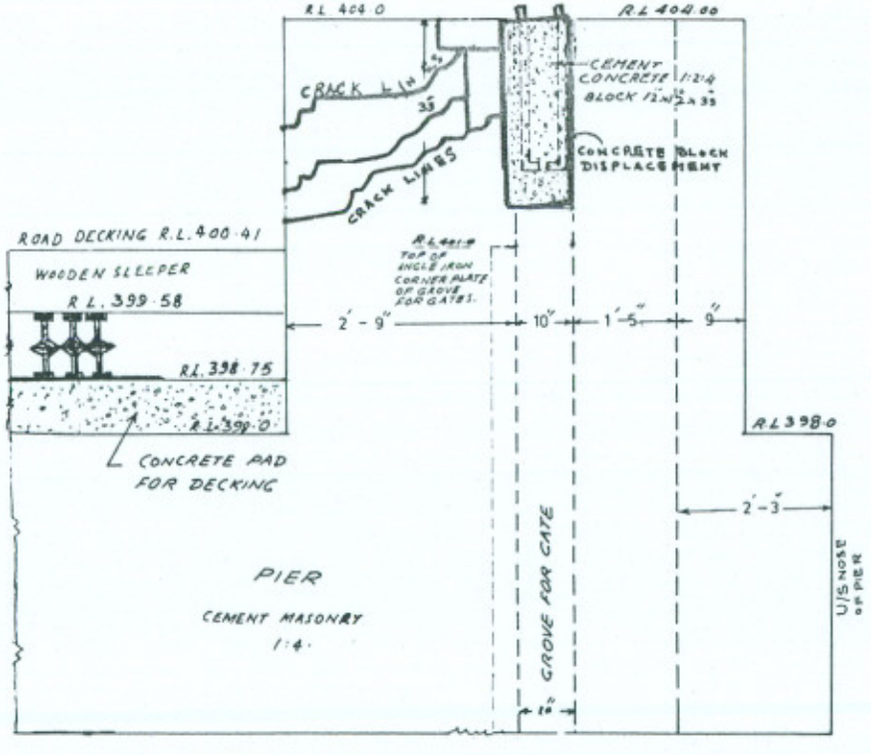
PLAN OF PIER

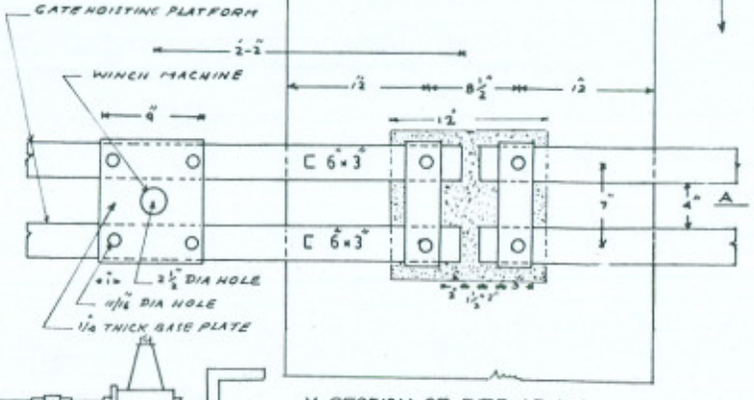


(PIERS NO 8 TO 17)

L-SECTION OF PIER AT B-B

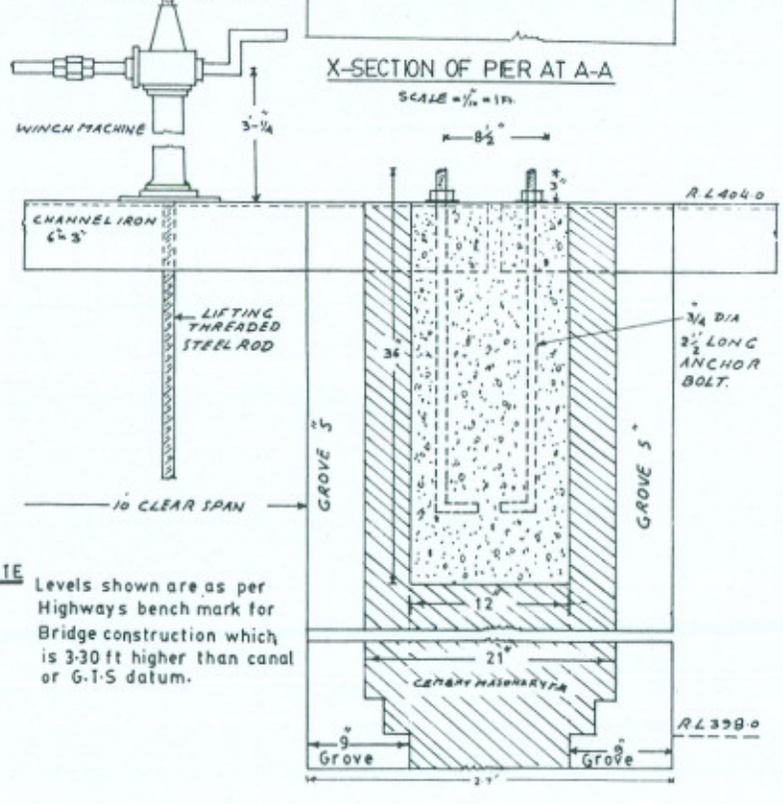
SCALE = 1/10 = 1'





X-SECTION OF PIER AT A-A

SCALE = 1/10 = 1'



NOTE Levels shown are as per Highways bench mark for Bridge construction which is 3.30 ft higher than canal or G.T.S datum.

GHAZI GHAT ROAD BRIDGE

TYPICAL CROSS SECTIONS OF APPROACH

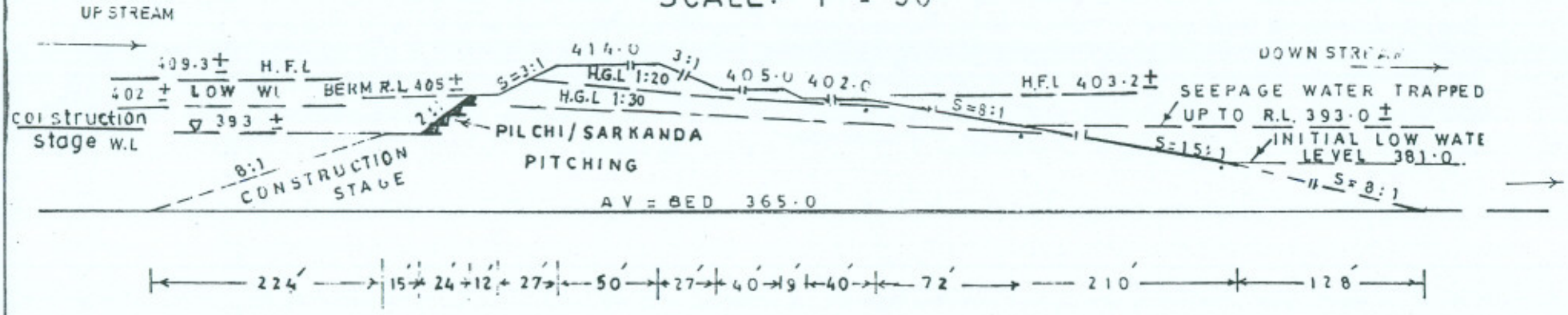
ROAD CUM DIVERSION BUND REACH MAIN

PLATE NO. XX V

RIVER PORTION

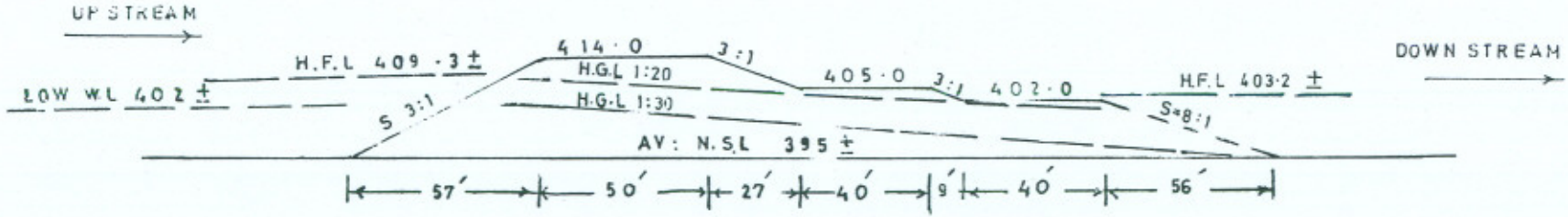
(R.D. 4200 – 4600 & 5030 – 6000)

SCALE:- 1" = 50'



NORMAL PORTION

REACH R.D. 4600 – 5030 & R.D. 6000 – 16500



NOTE:-(i) R.Ds start from right abutment of the bridge

(ii) Levels are with reference to the bench mark of High way Department used for construction of bridge which is 3.30 feet higher than canal / G.T.S. datum