PAPER NO. 444

CONSTRUCTION AND WORKING OF SPURS FOR PROTECTION OF BRBD LINK CANAL

BY

AHMAD TARIQ,

Chief Engineer, Irrigation and Power Department,

KHURSHEED MAHMUD,

Executive Engineer, Irrigation and Power Department

&

RIAZ AHMAD,

Executive Engineer, Irrigation and Power Department

CONSTRUCTION AND WORKING OF SPURS FOR PROTECTION OF BRBD LINK CANAL

By

AHMAD TARIQ[*], *KHURSHEED MAHMUD*[**], *& RIAZ AHMAD*[**]

1.0 BRIEF HISTORY OF B.R.B.D. LINK CANAL

With partition of the Punjab in the year 1947, stoppage of Canal Water supplies to areas of Upper Bari Doab and epalpur Canal System falling in Pakistan, was threatened by India as the sources of the channels irrigating these areas before Independence had remained with India and regular Canal water supply could not be ensured. Out of the gross area of 15,64,135 Acres irrigated by Upper Bari Doab Canal, 8,85,007 Acres situated in Lahore District remained with Pakistan. Actual irrigation in Lahore District in the years before partition, was in the order of 8,35,000 Acres which was about 61% of the total area irrigated by Upper Bari Doab Canal earning a revenue of nearly Rs.77.00 lacs. This shows the importance of Upper Bari Doab Canal.

The Branches, distributaries and Minors of Upper Bari Doab Canal which irrigated areas in Lahore District (C.B.D.C. System) cross the Indo-Pakistan Border at 15 different points. The total discharge of CBDC system at the points of crossing the Indo-Pakistan border was 2,659 Cusecs. Supplies from India since partition were unsatisfactory and even totally cut off at one time. Heavy amounts were paid for maintenance charges of Modhopur and Ferozepur Headworks and carrier channels in India. Bombanwala Ravi Bedian Depalpur Link Canal commonly known as B.R.B.D. Link was therefore constructed in the year 1949-52 to replace supplies to areas on C.B.D.C. and Deepalpur Canal. Break-up of CC.A on C.B.D.C. and Upper

---

**Chief Engineer, Irrigation and Power Department*

***Executive Engineers, Irrigation and Power Department*

Deepalpur Canal is as under :-

C.B.D.C.	=	6,37,536 Acres
Upper Depalpur Canal	=	2,81,823 Acres
Total	=	9,19,359 Acres

The BRBD Link Canal which has a capacity of 5,140 Cs. at its head, takes off at R.D. 1,33,000/L of Upper Chenab Canal near village Bombanwala in Sialkot District and delivers about 2,300 Cusecs to Upper Depalpur Canal near Ganda Singhwala in Kasur District. The Link Canal having a total length of about 107 Miles follows alignment of old Raya Branch of Upper Chenab Canal in its head reach R.D. 0 to 1,77,000. About 23 miles of the Canal in reach R.D. 2,60,000 to 3,73,000 is lined while the remaining length is unlined. It delivers supplies of about 1,600 Cs. to channels of old Raya Branch in reach 0-1,77,000 and leaves about 3,507 Cusecs for areas below R.D. 1,77,000. About 2,000 cusecs is augmented from M.R. Link Canal through a Sub Link outfalling at R.D. 1,88,500. After feeding, Chakrali Minor, Shahdara Minor, Gujran Minor, Kala Khatai, Pakhiala, and Shahdara Distys: of old Raya Branch in reach R.D. 1,77,000 to 2,82,760, the Link Canal delivers about 5,000 Cs. for feeding areas on C.B.D.C. and Depalpur Canal System across Ravi Syphon. These areas are situated in Lahore, Kasur and Sahiwal Districts and can be compared with regard to fertility and population, with best areas of the Punjab.

The Canal though located near the Indo-Pakistan Border, could not command the entire area fed by C.B.D.C. System. About 48,000 acres lying in Lahore District on the east has been left out and is served by tubewells. The area falling to the West of the B.R.B.D. Link Canal is mostly served by gravity flow except small areas on Rai, Pull, Shalamar, Tehra, Gohawa and Kasur Minors which is served with Lift pumps water from the Canal. The Link Canal in its reach R.D. 189 to 3,00,000 passes through riverean tract and runs in high filling shown in Figure-1.

The B.R.B.D. Link Canal from its very construction has been suffering from revages of floods in Ravi River. Being aligned in North South direction against local natural country slope which runs in North East to South West, it cuts across natural drainages all along its route. Flood and Rain water heads up on the upstream and causes

disposal problems at various places.

The Canal from R.D. 0-434 i.e. point of confluence with Main Branch lower of Upper Bari Doab Canal (near Bedian Village) was completed in the year 1952. Depalpur Canal having authorised full supply capacity of 6,950 cusecs used to take off from Ferozepur Head Works which remained with India. It was therefore proposed to extend B.R.B.D. Link Canal to Depalpur Canal for delivering about 2,300 Cs. to its upper portion. Accordingly the reach R.D. 434 to its tail (R.D. 5,37,546) was constructed in the years 1955-1957. Areas in the lower reaches of Depalpur Canal were put on supplies from B.S. Link, which was taken up for construction in the year 1953-54. The Canal was first opened in the year 1961 although supplies from India were received intermittantly upto the year 1967.

The B.R.B.D. Link Canal had to face floods of unprecedented nature in the year 1955. Flood discharge received at B.R.B.D. near Ravi Syphon was of the order of 6,59,000 cusecs. The Syphon under Ravi River (R.D. 2,82,760-2,84,623 of B.R.B.D.) which had designed capacity of only 2,50,000 cusecs, was badly damaged. The canal breached at several places, the major breach being between R.Ds 258-260 which passed about 50,000 cusecs.

On account of total importance of B.R.B.D. Link being life line for large irrigated areas of Lahore, Kasur and Sahiwal Districts and economy of the country which is basically agricultural, breaches on this Canal like the one in year 1955 cannot be afforded in future. Any breach on this Canal would amount to a national disaster and stoppage of Canal supplies to about one Million acres.

The Canal Syphon with its allied works was repaired during the year 1955-57 and strengthened to pass flood discharge of 4,50,000 cusecs. Banks were restored and breach at R.D. 259, closed in the form of a ring bund.

The B.R.B.D. Link Canal again suffered heavy losses during the year 1958 on account of un-precedented rainfall. Downpour on 2nd and 4th of September was in the order of 5". The Link Canal obstructed the sheet flow of water accumulating due to rains and flooding in natural Nullahs crossed by it, causing severe damages to banks and masonry works. Water level in the Canal is much higher than the highest Flood level of river Ravi within the river Khadir. Canal banks are not consolidated adequately. The action at the left toe of the Canal which is at a low elevation with respect to the bank level resulted in

slip circles. Repairs and remodelling of B.R.B.D. Link Canal was taken up under Indus Basin Replacement Plan during the year 1961, at an estimated cost of Rs.52.70 Millions. The project relating to B.R.B.D. aimed to repair and remodel the canal in its entire length so as to make it fit for taking up supplies, to make it safe against damage by floods in natural Nullahs with remodelling and provision of more and adequate number of cross Drainage works in reaches R.D. 0-1,77,000 and below Ravi Syphon. The Canal was for the first time opened in April 1961 and raised gradually to full supply capacity with strenuous efforts. Regrading of the canal in the upper reach was done in order to increase the slope and bring down silt for creating berms with killa spurs in high filling reach R.D. 205-260.

2.0 SPURS ALONG B.R.B.D. LINK

B.R.B.D. Link runs parallel and very close to the River Ravi in reach R.D. 205 to Ravi Syphon - Figure-2. The distance between the Ravi River and the canal ranges between half to two miles. Land adjacent to B.R.B.D. Link in this reach is low and flood spills on the right bank of the River are attracted towards the low land and start flowing parallel to left bank of the Canal till it outfalls again into the river, upstream of Ravi Syphon. Usual slope of this flow is in the order of 2.0' per mile which develops tremendous velocities.

During early sixtees due to steep water slope available along B.R.B.D. Link Canal from R.D. 189 to Ravi Syphon, retrogression started from R.D. 276 and travelled upwards from year to year. The parallel flow through depression along the canal developed into a well defined creek having a depth varying from 20'-40' in reach R.D. 276 to 256 during early seventees. This creek became active when river discharge rose above 40,000 cusecs at Jassar.

The change in the hydrology and the course of the river and as a result of construction of flood banks and other training works on left bank in India necessitated comprehensive flood protection on the right bank to save the canal and areas in the riverean belt from erosion.

The problem of protection of B.R.B.D. between R.D. 205 to Ravi Syphon is part of the overall flood protection plan on the

right bank of river Ravi starting from the Ujh river and extending upto Ravi Syphon. These flood protection and river training works need thorough and thought provoking investigations for any permanent solution.

River Ravi starts spilling over right bank as soon as discharge exceeds 40,000 cusecs at Jasser and when a discharge of 1.0 Lac cusecs in the River is reached, the discharge from the over spill ranges between 25,000 to 30,000 cusecs. These over spills directly hit the left bank B.R.B.D. Link and result into regular flow in the toe of the bank in the form of a defined channel. Thus the left bank of B.R.B.D. Link is subjected to erosion due to parallel flow and safety of the canal is exposed to great danger.

While taking up remodelling of B.R.B.D. Link under Indus Basin Replacement Plan in the year 1961, it was visualised that reach R.D.205 to Ravi Syphon needed protection against spill of river by means of spurs having armoured heads.

The depressions along the Canal caused by removal of earth for construction of the Canal is responsible for initiating parallel flow along the Canal. This lesson needs to be brought home to all responsible for execution of flood protection schemes along the banks of rivers. Borrowing of earth along the bunds in a regular chain must be discouraged. These depressions with raising of beds and lips of the river attract the flood spills continuously developing into dangerous and active channels with passage of time.

To check the development of the right channel along the left bank of the canal by cataract action during different stages of the river in different years, three earthen low level spurs, were constructed in the reach R.D. 276 - 279. These spurs and the earthen shank bund with stone spurs at R.D. 1,900, 2,500 and 3,200 (of the shank bund) already constructed to stop embayment on the back of right Guide Bund of Ravi Syphon, proved effective. Flow of flood spills along the toe of left bank of the Canal in the vicinity of Ravi Syphon, was checked. The tenency, however, developed subsequently further upstream of R.D. 276. In the year 1970 and 1971, the creek in reach R.D. 269-275, hit the toe of bank and appreciably damaged it. Damage was protected temporarily by launching trees tied with steel wire ropes. This clearly indicated the necessity of effective measures in the shape of chain of spurs to check the process of cataract action during different stages of the river in order to save the Canal.

3.0 BATTERY OF ELEVEN SPURS & THEIR FAILURE:

Earlier in the year 1962-63, Eleven Nos. short spurs were constructed between R.D. 246-275 under Indus Basin Replacement Plan to check parallel flow of flood spills along the canal in this reach. These spurs estimated to cost Rs. 1.0 Million were designed to have 300.0' length 15 feet top width 2:1 side slopes, and 3.0' free-board above H.F.L. of the year 1955. Noses of these spurs were protected with light armour consisting of 1.0' stone pitching over 0.50' spaul and loose stone aprons having 45.0 cft per foot run of stone. These spurs were located at 2,000 ft apart between R.D. 246-256 & 4,000' apart between R.Ds 256-2,79,500. One spur was proposed in the centre of old ring bund opposite R.D. 2,59,000 Figure-2. It was intended that these spurs would keep the flow away from the toe of the canal and catered for sheet flow only and not the concentrated flood spill flows. It is incidently note-worthy that floods remained dormant for 14 years i.e. from 1959-73. It was, however, experienced that during these years severe retrogression had started from Ravi Syphon which continued to develop upwards in the form of a well defined creek. The creek meandered between the spurs hitting the left bank of the Link Canal from place to place. As a result of retrogression in the creek, earthen shanks of spurs R.D. 259, 263, 2,67,500 were cut through leaving the small nose portion as isolated dunes. Under the conditions prevailing before the year 1973 there was no protection of B.R.B.D. Link Canal against the flood spill flows which had assumed the form of concentrated flow at the toe of left bank of the Canal. At several places embayment by the creek towards toe of the bank was severe.

4.0 DAMAGES DURING FLOOD OF 1973:

On 11.8.1973 high flood was received in River Ravi. Flood water spilling on the right bank of the Ravi started flowing along B.R.B.D. Link in the reach R.D. 205-276. A creek along B.R.B.D. Link already existed from R.D. 2,60,100 to 2,76,000/left. When discharge in the River rose to 2,16,000 cusecs at Ravi Syphon discharge in the creek went upto 40,000 cusecs. Reaches R.D. 260-2,62,500, 263-264, 275-276 came under direct action of the flood water and erosion started at the toe of the left bank. Hanging spurs of trees tied with steel ropes and weighted with stone filled in trangers were launched to arrest erosive tendency of flood flow concentrated at the toe. On 16.8.1973 when flood was falling, the erosion was alarming and left bank started falling rapidly specially in the reaches R.D. 260-261 and 263-264/Left. Half of the left bank in these reaches was eroded away by 25.0' deep creek at the toe. At several points the entire left bank

leaving no back-fill behind the lining was eroded away and cracked the lining. Flood fighting was rigorously continued till 20.8.73. The damaged reaches of left bank of the Canal between R.D. 2,60,400-2,60,700-2,63,150-2,63,660 and 2,74,985 to 2,75,600 were restored with great difficulty and at an expense of about Rs. 8.0 Lacs to run the Canal.

Experience of damage during floods of 8/1973 gave the signal of danger and need for adequate protection of B.R.B.D. Link Canal against damage by floods in River Ravi.

Different alternative proposals were suggested as solution to the problem which were :-

a) Construction of a weir on the right creek along the left bank of the Canal to stop further development of the channel upstream.

b) Short spurs 500' along (already tried)

c) Short spurs 2000' long.

d) Long spurs as constructed at site.

e) A bund in the river Khadir at safe distance from the Canal adequately protected by spurs.

5.0 REFERENCE TO MODEL EXPERIMENT OF 1963 AND CONSTRUCTION OF TWO SPURS AT R.D. 250 AND 265/ LEFT B.R.B.D. LINK.

The problem was earlier entrusted to Irrigation Research Institute, Lahore, in the year 1963 who conducted a series of model experiments. The Institute had published the results in their report No. 408/Hyd/1963 and recommended :-

1. Restoration of the right bank of Escape Channel at R.D. 2,04,805/ Left B.R.B.D. to act as a spur.

2. Construction of following four long spurs:

i) Spur at R.D. 225 with a length of 6,275 Ft.
ii) Spur at R.D. 237 with a length of 5,000 Ft.
iii) Spur at R.D. 250 with a length of 4,200 Ft.
iv) Spur at R.D. 265 with a length of 7,500 Ft.

Two spurs at R.D. 250 and 265 were constructed and completed

before June, 1975, at an estimated cost of Rs.37.46 Lacs, while construction of the other two spurs at R.D. 225 and 237 was deferred so that behaviour of the River after the construction of spurs at R.D. 250 and 265/Left B.R.B.D. is studied by Irrigation Research Institute on fresh Model based on detailed survey of the area. The spurs constructed at R.D. 250 and 265 had 20.0' width at the top of shanks; 2:1 side slopes and 5.0' free boards over H.F.Ls of 8/1973. Noses of spurs which were designed as Mole Head four spur R.D. 250, Figure-3, and Hockey cum-T-Head shape for the spur at R.D. 265, Figure-4, were protected with stone pitching 1.30' thick over 0.70' thick spawl. Apron of Mole Head was provided with stone 90 Cft per foot while apron of Hockey cum-T-Head had stone @ 126 Cft per foot on the upstream nose reducing to 90 Cft per foot run on the Downstream pose. Slopes of shanks were protected with pilchi sarkanda pitching. In the depressions traversed by the shanks, flatter side slope protected by stone pitching was provided.

6.0 DESIGN OF APRONS FOR MOLE HEAD AND T. HEAD OF THE SPURS

6.1 For Mole Head of Spur R.D. 2,50,000/ Left B.R.B.D.

Max: discharge in Ravi River during floods of 1955.

= 6,27,000 cusecs (as per Tech: Report No.488/Hyd/1963 page 4).

Width of water way = 6,000 Ft.

Discharge per foot run: q $= \frac{6,27,000}{6,000} = 105$ cusecs.

Regime flow depth, with laceys' Formula:

$$R = 0.90 \times \left(\frac{q^2}{f}\right)^{1/3}$$

$$= 0.90 \times \left(\frac{105^2}{1.0}\right)^{1/3}$$

$$= 20.0 \text{ Ft.}$$

Scour depth, due to class-A straight reach with Lacey's scour Factor, D = 1.27 x R.
= 1.27 x 20.0
= 25.40'

Scour depth below H.F.L. of 727.60
= 25.40(-) (727.60-722.26)
= 25.40 - 5.34
20.06 Say 20.10'

Quantity of stone per foot as per Manual of Irrigation Practice - Art: 6.37 - Page 13
= 2.25 x 2.0 x 20.10
= 90.45 Say 90.0 Cft

Width of apron = 1.50 D
= 1.50 x 20.0
= 30.0 Ft.

Av: depth of stone in apron = $\frac{90}{30}$ = 3.0'

6.2 For T-Head of Spur R.D. 265/L.B.R.B.D.

Regime scour depth
R as per above calculations = 20.0'

Scour with Laceys' factor of 1.75 for class-C severe bend on the U/S Nose.

D = 1.75 R.
= 1.75 x 20.0' = 35.0'

Scour depth below apron = 35.0' - (722.80 - 716.00)
= 35.0 - 6.80'
= 28.20'

Quantity of stone = 2.25 x 28.20 x 2.0 = 126.90 Cft

Width of apron = 1.25 D
= 1.50 x 28.20
= 42.30 Say 42.0'

Av: depth of stone in apron on the U/S Nose

$$= \frac{126.90}{42.0} = 3.02' \quad \text{Say } 3.0'$$

On the D/S Nose; Scour is reduced to 1.27 R= 25.40' as in the case of spur R.D. 250/L.

Width of apron = 30.0'

Av: depth of stone = 3.0'

7.0 DAMAGE IN FLOODS OF 1975:

There was no serious flood in the year 1974 and the spurs which were under construction did not come into action.

During 1975, the very first high flood received in 3rd week of July was of the magnitude of 2.06 Lacs cusecs at Jasser. Flood water spilling on the right bank of Ravi River headed up against the spurs. The rise of river water was so sudden that the spurs R.D. 250 and 265 could not stand against the on slought, the head across caused by afflux and due to weak sections.

The shanks of the spurs had been protected with pilchi pitching 5.0' deep on the upstream and D/S slopes, thus leaving a core of 10.0' only. E/Work of bunds was carried out through manual labour and not compacted at optimum moisture content. The earthen bunds did not offer strong defence against the flood water and breached at 19 different places. Thus the intention of checking a regular flow in the creek at the toe of the bank was defeated and the discharge in the creek rose to 40,000 cusecs. The calculations for scour in the creek given below support the scour depth of 30.0' to 40.0' actually prevailing at site during high floods in the river:

Q = 40,000 cusecs.
width of creek = 250.0'
q i.e. discharge per foot $= \frac{40,000}{250} = 160$ Cs.

Regime depth with Lacey's formula

$$R = 0.90 \left(\frac{q^2}{f}\right)^{1/3}$$

$$= 0.90 \times \left(\frac{160 \times 160}{1.0}\right)^{1/3}$$

$$= 26.50'$$

Scour with Lacey's factor

= 1.27 R for St. reach

= 1.27 x 26.50

= 33.66 Say 34.0'

8.0 STATEMENT SHOWING FLOODS AT JASSER DURING 1975:

Later on series of Medium, High, Very High and exceptionally high floods kept on instantly arriving. In the period from 16.7.75 to 24.8.75 there were ten floods in all out of which five were high to exceptionally high floods and five medium floods. In other words there had been on the average one flood every fourth day which had given no time to remedy the situation.

The floods are enumerated date-wise below:-

S.No.	Dated	Discharge (Cusecs)	Classification of Flood
1.	16.7.75	92,400	Medium
2.	17.7.75	2,06,300	Exceptionally high
3.	18.7.75	1,12,250	High
4.	20.7.75	76,630	Medium
5.	22.7.75	75,200	Medium
6.	23.7.75	88,070	Medium
7.	24.7.75	1,80,750	Very High
8.	25.7.75	80,920	Medium
9.	21.8.75	1,15,550	High
10.	24.8.75	1,25,900	High

These floods gradually damaged the bank in an aggregate length of about 5,000' between R.D. 257 to 276. During the floods great effort was made to arrest further erosion by launching of trees, construction of temporary spurs to keep the canal flowing by protecting and repairing the bank by deployment of heavy earth moving machinery which was pooled up from all resources and a fleet of trucks arranged by local agencies. The equipment dumped about 10.0 Million Cft of earth alongwith huge quantity of trees weighted with stones. At that time the erosion was so serious that at places only the lined slope of bank remained standing without any earth fill on the back and at places even half of the lining fell down or cracked. The damage was huge and the canal had to remain closed for about 2 months while

repairs and restoration of the bank was in progress. The whole operation of checking erosion, protecting and restoring left bank during floods and thereafter was carried out at an estimated cost of nearby Rs.100.00 Lacs. Although a complete collapse was averted, yet the whole situation was highly unsatisfactory and demanded action to match the gravity of problem. It may be mentioned here that the model experiments conducted in the Irrigation Research Institute were again held valid on the basis of river conditions observed in the year 1975. These recommendations it may be remembered, included construction of 4 Nos. long spurs at R.D. 226, 237, 250, 265/Left B.R.B.D. to check parallel flow along the left bank of the Canal.

It was therefore decided to restore and strengthen the old spurs constructed at R.D. 205, 250 and 265/Left B.R.B.D. with an additional spur at R.D. 259 so as to make them fit and safe against anticipated head across and afflux.

In view of magnitude of earth involved the restoration and strengthening of the spur R.D. 265/Left B.R.B.D. was taken up through earth-moving machinery of Mechanical Circle, Lahore, in the month of February, 1976. Work on spur R.D. 250/Left B.R.B.D. being of lesser magnitude was entrusted to local contractors. It was proposed to provide 30.0' width of shank; 3:1 side slopes and top level of the shanks in their entire length 1.0' below designed top level of left bank of B.R.B.D. Link Canal, Figure-5 & 6. The top level was adopted to provide for about 5.0' afflux and make the spurs safe for future floods. Stone armouring of the Noses of the spurs was also considered inadequate. It was proposed to provide stone in apron at 225 Cft per foot run in view of anticipated scour at the nose due to converging flow.

9.0 CALCULATIONS FOR DESIGN OF APRONS OF SPURS R.D. 250 AND 265/LEFT B.R.B.D. LINK BASED ON FLOODS OF 1975

Flood discharge, Q at Ravi Syphon during the year 1975 = 1,61,500 cusecs

Add for absorption in flood plain between R.D. 250-285 @ 10% of 1,61,500 = 16,150

Total = 1,77,650

Say = 1,78,000 cusecs.

H.F.L. at spur 265/L (1975) = 724.65

with Lacey's regime flow, depth:

$$R = 0.75 \left(\frac{Q}{4xf}\right)^{1/3}$$

as per article 6.13 of Manual of Irrigation Practice

$$R = 0.75 \times \left(\frac{1,78,000}{4x1.10}\right)^{1/3}$$

$$= 0.75 \times 34.30 = 25.72 \text{ Say } 26.0$$

Scour depth with Lacey's factor 1.75 R

Scour depth = 1.75 x 26.0 = 45.50

Scour level below H.F.L. of 724.65

= 724.65 - 45.50 = 679.15

Bottom R.L. of apron = 710.00

Depth of scour below bottom of apron

= 710.00 - 679.15

= 30.85 Say 31.0'

Quantity of stone per foot of apron @ 7-D as per Golden Jubilee publications of Engineering

= 7 x 31.0
= 217 Cft/per foot.

Width of apron
= 1.50 D
= 1.50 x 31.0
= 46.50 Kept at site 45.0'

Av: depth of stone in apron $= \frac{217}{45.0} = 4.86$ Say 5.0'

Quantity of stone/foot actually adopted

= 45.0 x 5.0
= 225 Cft.

Design of shank of the spur R.D. 250/L B.R.B.D. was also kept the same as that of spur R.D. 265.Nose of the spur R.D. 250/L B.R.B.D. was originally constructed of the shape of Mole Head was converted into Hockey cum T-Head of the design constructed at spur R.D. 265 - Figure-7.

10.0 RESTORATION AND STRENGTHENING OF SPURS DAMAGED DURING FLOODS OF 1975:

The project estimated to cost Rs.93.46 Lacs involved a little over 20 Million cubic feet of earth work and half a Million cubic feet of stone work. In view of experience gained from the colloŝal damage suffered by B.R.B.D. Link during floods of 1975, it was aimed to complete work on these spurs before floods of 1976 at all costs. The work remained in progress through machinery on spur R.D. 265 and through donkey labour on spur R.D. 250 till end of May, 1976, when bulk of earth work on spur R.D. 265 was complated. In the meantime Irrigation Research Institute results of new Model experiments conducted in January 1976 as reported upon vide their letter No.425-C/1568/BRBD dated 6.4.1976, were received recommending construction of eight number spurs along BRBD as a permanent solution for its protection against damage by floods in Ravi River in order of their priorities:

Priority No.1	J-spur at R.D. 250/L BRBD	Length 4,200'
	J-spur at R.D. 265/L BRBD	Length 7,500'
	Mole Head spur R.D. 259/L	Length 3,700'
Priority No.2	J-spur at R.D. 215/L	Length 3,150'
	J-spur at R.D. 224500/L	Length 6,450'
	Mole Head spur R.D.205/L	Length 3,000'
Priority No.3	Mole Head spur R.D.232/L	Length 2,800'
	Mole Head spur R.D.241/L	Length 3,550'

Right bank of escape channel at R.D. 204805/L B.R.B.D. was proposed to act as a spur and be provided with a Mole Head at R.D.3000. The recommendations are appended as Annexure-A.

11.0 STAY ORDER BY THE HIGH COURT

According to recommendations of priorities as described above construction of spur R.D. 259/L B.R.B.D. was taken up in the last week of May, 1976, by shifting machinery from spur R.D. 265, which was almost completed to safe limits. The work however remained in progress for a couple of days only when it was suspended as the land owners, affected with the construction of the spur managed a stay order from Lahore High Court. Work on restoring and strengthening of spur R.D. 250/L and spur R.D. 205/L which was progressing at a slow pace through local contractors was now speeded up through machinery falling

spare from the work stayed by the High Court in the first week of June, 1976, and both these spurs were completed by the end of Financial Year 1975-76.

12.0 COMPLETION OF FOUR SPURS:

Construction of the spur R.D. 259/L B.R.B.D. Link involved about 75 Lacs Cft earth and 2.0 Lacs Cft of stone work. Work was resumed in the first week of July, 1976, and continued upto 3rd week when a flood of high intensity was received and all the area U/S and D/S of the spur was submerged under water. About 50% of earth work had been completed before flood when further work was suspended. Earth on shank of the spur had to be protected against damage by temporary spurs and gunny bags for holding earthen nose. Luckily the shank was not over topped by flood water. After the flood season, the work was taken up again in November, 1976, when working conditions were restored and finished before June, 1977. This marked the completion of four spurs at R.D. 205,250,259 and 265 B.R.B.D.

13.0 CONSTRUCTION OF TWO PRONGS

The spurs at R.D. 250 and 265 had to face flood of same magnitude in 1976 as in the year 1975. High flood levels during the year 1976 were almost equal to that of the year 1975. Model studies conducted in the year 1976 indicated parallel flow along the downstream face upto a distance of 2,000' from the nose of the spur R.D. 250/L B.R.B.D.During rising and falling stages of floods in 1976 it was experienced, that the parallel flow was of a severe and damaging nature. Downstream slope in reach R.D. 100-3,500 was eroded away by parallel flow passing round the nose of the spur following depression along B.R.B.D. Link. Flow however left the D/S face during peak stages. This proved necessity of a prong at R.D. 2000 to save parallel flow along D/S face of the spur. The prong 1000' long has now been constructed and served the purpose during floods of 1977.

During floods of 1976 parallel flow was also experienced along D/S face of spur R.D. 265/L B.R.B.D. The flow was smooth along the shank in the reach R.D. 4000 to 7000 of the spur but concentrated through old creeks and hit the spur at R.D. 3,500 and caused damage to D/S slope, Shank of the spur was saved by putting a small temporary earthen bund in the route of flow towards depression along the canal and diverting the flow to an old Nullah Shoru on the Plan at Figure-2. Necessity of a prong on the D/S face of this spur as well was evident.

A prong 1,250' long at R.D. 6,200/Right of the spur at an angle of about 60 with the main spur has been added during the year 1976-77. The prong through not totally completed before floods in July, 1977, served well to protect D/S face of the spur against parallel flow.

14.0 CONSTRUCTION OF REMAINING FOUR NUMBER SPURS:

Construction of remaining four Spurs at R.D. 215, 224500, 232 and 241/L B.R.B.D. Link was deferred for the time being in 1976 as:-

i) Little time had been left for completion of the entire work before floods of 1976.

ii) Land owners posed some resistance requesting that alignment of spur at R.D. 215 be reconsidered.

It was therefore decided to watch the behaviour of already completed four spurs at R.D. 205, 250, 259 and 265/L B.R.B.D. Link during floods of 1976 and obtain fresh opinion from Irrigation Research Institute regarding the remaining four spurs.

Planetable and contour survey of the Riverean area between R.D. 205 - 265 was done after floods of 1976 and was examined afresh.

On the other hand the Irrigation Research Institute, Lahore, communicated firm opinion about completion of remaining spurs according to original design and locations.

Although floods of the years 1977 and 1978 were not of high intensity River continued eroding on its right bank opposite the proposed locations of spurs R.D. 215 and 224500/Left/B.R.B.D. Right handed loop opposite R.D. 212-213/L extended itself and eroded away a big village named Passianwala during 1976-77.

The loop opposite R.D. 224500/L/B.R.B.D. Link continued to extend considerably towards right even after floods of 1978 and endangered safety of village Jandiala Kalsan located on the back of proposed spur R.D. 224500 about half mile from the head of the spur.

Construction of the Spurs at R.D. 215, 224500, 232 and 241/Left/B.R.B.D. Link was taken up during 1978-79. By the end of June, 1979, shanks and armoured noses of spurs, R.D. 215, 224500 (with a prong 500' long at its R.D. 4450/R) and Mole Head spur RD 241/Left had almost

been completed. Earth work of shank of spur 232/Left was only done through machinery before 30.6.1979 and construction of its Mole Head was taken up during the financial year 1979-80 so as to meet the resources available over the years.

15.0 BENEFICIAL RESULTS

Thus spurs constructed and completed before flood 1977 at R.D. 205, 250, 259 and 265 of B.R.B.D. Link Canal have proved very useful and had saved the Link Canal from the recurring damages to the Canal irrigating over a million acres of fertile areas in the most thickly populated part of the province. The benefit of saving village abadies and large cultivated area between the Canal and right bank of the River from erosion is in addition. The River has now developed a defined channel far away from the Link in the vulnerable reach. In addition to all these benefits the approach of the River Ravi to the Ravi Syphon at R.D. 282 has been improved considerably. The bela masking the water way across the syphon is showing signs of being eroded.

Floods of the year 1976 were of the order of 2.0 Lac cusecs. The four spurs at R.D. 205, 250, 259 and 265 B.R.B.D. stood well and proved effective. Flood water was headed up against these spurs to H.F.L. almost equal to the floods, of the year 1975. The creek along the left bank stood closed by the spur shanks at four places. At the noses, due to converging sheet flow scour in the order of 40.0' occurred. The spur heads which were adequately armoured with stone, faced the attack effectively and damages were not abnormal. Due to heading up against the spurs, velocities in the pockets

i) Near upstream of spur R.D. 205;
ii) Between spur R.D. 250 and 259;
iii) Between spur R.D. 259 and 265;

had the silting tendency in the depressions along the canal. Marked silting in the pockets was observed after floods water had dried up. With the construction of spur R.D. 224500 further development of loop of the River has been effectively checked thus obviating threat to Village Jandiala and the B.R.B.D. Link itself. Consequently, the loop on the upstream of nose of this spur is developing on the right side in order to adjust with the deviation of flow at the head of the spur.

At spur R.D. 215/Left loop is also extending towards the right gradually even during low river stages. The spur head is likely to come

in action after one or two floods in future.

Heads of spurs R.D. 232 and 241/Left are located comparatively in retired position and are designed to cater for the flood spills in the existing position of River.

With the construction of spurs as envisaged in Model studies erosion of Ravi River on its right bank will be effectively checked thus protecting B.R.B.D. Link adequately. Apart from this numerous Village Abadies located in the riverean tract and fertile culturable lands have been protected from erosion.

The unique alignment and orientation of the spurs were found most suitable. Parallel flow along the upstream of the shanks in the head reaches were nominal. Even near the spur heads where parallel flow was noticeable, it did not cause appreciable damage. Head across at the spurs conformed to remarkable accuracy with those observed in the Model. In the rising and falling stages however sheet flood flows passing round the noses were attracted towards the depression along the canal causing parallel flow along the D/S faces of spurs at R.D. 250 and 265. Obstructions caused by old banks of abandoned Shahdara disty. etc. and creeks existing in the area were also responsible for causing parallel flow. As a result of construction of spurs at R.D. 250, 259 and 265/Left B.R.B.D. Link, the main river has shifted well away from these spur heads. However, the river has shifted further towards the canal in between R.D. 215-225. The survey plan prepared after floods of 1977 has shown the utility and benefits of the spurs already constructed at R.D. 205, 250 and 265/Left B.R.B.D.

It is thus proved beyond doubt that effective flood protection of B.R.B.D. Link Canal in reach R.D. 205 to Ravi Syphon has been possible with construction of battery of 8 spurs recommended by Irrigation Research Institute as an efficient and permanent solution.

Experience at more than one place has shown that effective control of international rivers like Ravi can be achieved with construction of chain of long spurs projecting into the Khadir and tied with embankments located on high contours as far as possible for economy and safety.

Earth Work on the spurs was carried out through machinery of Mechanical Circle, Lahore, @ Rs.350%o Cft upto lead of 2,500'. This rate includes compaction of the required degree by machinery automatically. Rate of earth work by manual labour for the same lead works out

to Rs.228/- per o/oo cft including compaction. It is however experienced that compaction of the required degree is not easily obtained through contractors by manual labour. Earth work by machinery though costlier is therefore preferable on account of better quality. The earth work on the flood protection works should be carried out through heavy earth moving machinery.

ACKNOWLEDGEMENTS

The authors of this article are indebted to :-

1. The staff of the I.R.I. for the valuable help received through their Model Experiments.

2. Ch. Mohammad Ali for his numerous visits to site both during floods under trying conditions, after floods, for the valuable discussion and his advice.

ANNEXURE-A

Paper No. 444

EXTRACT FROM REPORT OF IRRIGATION RESEARCH INSTITUTE, LAHORE, REGARDING PERFORMANCE OF FINAL ARRANGEMENT OF SPURS BASED ON MODEL STUDIES CARRIED OUT IN THE YEAR 1976

The perusal of hydrograph from the year 1927 to 1975 shows that the peak of flood never exceeded 1.1 Lac cusecs upto 1947 but eight to nine floods peaking near about 2 Lacs cusecs occurred in the period 1947 to 1975. During the wet cycle 1948-58 a flood peak as high as 6.5 Lac cusecs visited Ravi Syphon in 1955. It was observed in the original cast on the model (which was run with a hydrograph peaking at 4.3 Lacs assuming the Mole headed spur at R.D. 250 and hockey-cum-sloping spur at R.D. 265 restored) that :-

a) The spill flow follows the depression 4 to 7 feet deep along B.R.B.D.

b) The velocities along B.R.B.D. at 2 Lacs cusecs from R.D. 205 to 242 exceeded 4 f.p.s. and varied between 4 to 11 f.p.s.

c) The entire spill flow in between the river and B.R.B.D. outfall in upper arm of old loop opposite R.D. 244 to 252 and then converges at the nose of existing spur head at R.D. 250 some parallel flow then follows along the D/S face of spur at R.D. 250 upto a length of 2,000 from the nose. The velocity along B.R.B.D. from R.D. 252 to 258 was of the order of 4 f.p.s.

d) The spur at R.D. 265 is correctly located as it is instrumental in deflecting the flow towards the main river D/S of it. A secondary channel develops D/S of this spur head which outfall into the main river opposite. R.D. 275 of B.R.B.D. There is no parallel flow along D/S face of shank of this spur or along B.R.B.D. D/S R.D. 265. There was some parallel flow along U/S face of this spur in a length of 1,000 feet near the head of spur.

RECOMMENDED SYSTEM OF SPURS:

As a result of number of trial tests on the model, the final arrangement of spurs shown in Figure-2 was evolved. The salient features of this system of spurs are:-

a) The existing mole head spur at R.D. 250 has been converted into a H.T.S. spur to cater for the maximum attack and to keep the current away from the two faces of the shank of the spur. A new mole head spur has been provided at R.D. 259 inclined U/S at an angle of 37 degrees from the line perpendicular to B.R.B.D. at R.D. 259.

The length of the spur is 2,700 feet. This mole spur results in early filling of pocket U/S of it and thus reducing the velocities along B.R.B.D. (below 0.75 f.p.s.) which are silt depositing velocities and it also reduces the maximum head across the spur at R.D. 265 from 8.5 to 7.5 feet and it also wards off the current from the U/S face of spur at R.D. 265.

b) Two H.T.S. spurs at R.D. 215 and 224.5 are essential to arrest erosion on the right bank of river Ravi and to deflect the currents towards left and away from B.R.B.D. These two spurs work in conjunction with each other and work as one unit to kick off the flow towards left. The shank of the two spurs are in three segments as shown in Fig. No.2. The heads of the two spurs are parallel. No prong spurs are required to protect the two faces of H.T.S. spurs at R.D. 215 and 265. The spur at R.D. 224.5 requires a mole branch spur with a shank of 400 to protect the D/S face of the spur against any parallel flow.

c) The mole head spur at R.D. 205, means that at least 3,000 feet length of one bank of escape channel is required to be maintained to function as a spur to check parallel flow along B.R.B.D. Link and U/S face of spur at R.D. 215.

d) Two mole head spurs each comprising two segments at R.D. 232 and 241 are essential to intercept and parallel flow along B.R.B.D. to create pockets U/S of the mole spurs resulting in reduction in head across the H.T.S. spurs at R.Ds 224.5 and 250.

e) The maximum head across the H.T.S. spurs at R.D. 215, 224.5 and 250 and 265 are 3.3, 4.3, 3.0 and 7.5 feet respectively. The maximum head across at mole head spurs at R.D. 205, 232, 241, 259 are 5.2, 1.2, 1.7 and 1.0 feet respectively. The shanks of spurs should be designed for these head across.

B I B L I O G R A P H Y

1. Indus Basin Project Report and estimate of Remodelling B.R.B.D. published by West Pakistan Irrigation Department, Lahore, in July, 1961.

2. Project Report and estimate of Armouring Spurs along left bank of B.R.B.D. Link from R.D. 246-275000 to protect from River floods carried out under Indus Basin Replacement Plan.

3. Technical Report No. 408/Hyd/1963 by Irrigation Research Institute, Lahore, on "Ravi River Flood Control and Protection of B.R.B.D."

4. Technical Report No.425/C/1568/BRBD dated 6.4.1976 by Irrigation Research Institute on Hydraulic Model Studies on spurs along B.R.B.D.

5. P.C-I Proforma of "Checking Erosion during high flood and protecting and restoring left bank of B.R.B.D. Link R.D. 260400 to 260700, 263150 to 263660 and 274985 to 275600 damaged by flood of 8/1973" approved by Secretary, I&P, Govt. of the Punjab, vide Memo No.3/149-S.O. (W&P)P&D/73 dated 6.3.1974.

6. P.C-I Proforma of "Constructing additional spurs for the protection of B.R.B.D. Link from floods in reach R.D. 246000 - 274500" approved vide Secretary to Govt. of the Punjab I&P Deptt: letter No. VI-22/LHR-S.P(Prog)/74 dated 16.7.74.

7. P.C-I Proforma for "Restoring and strengthening spurs R.D. 250 and 265/L B.R.B.D. damaged by floods of 1975"

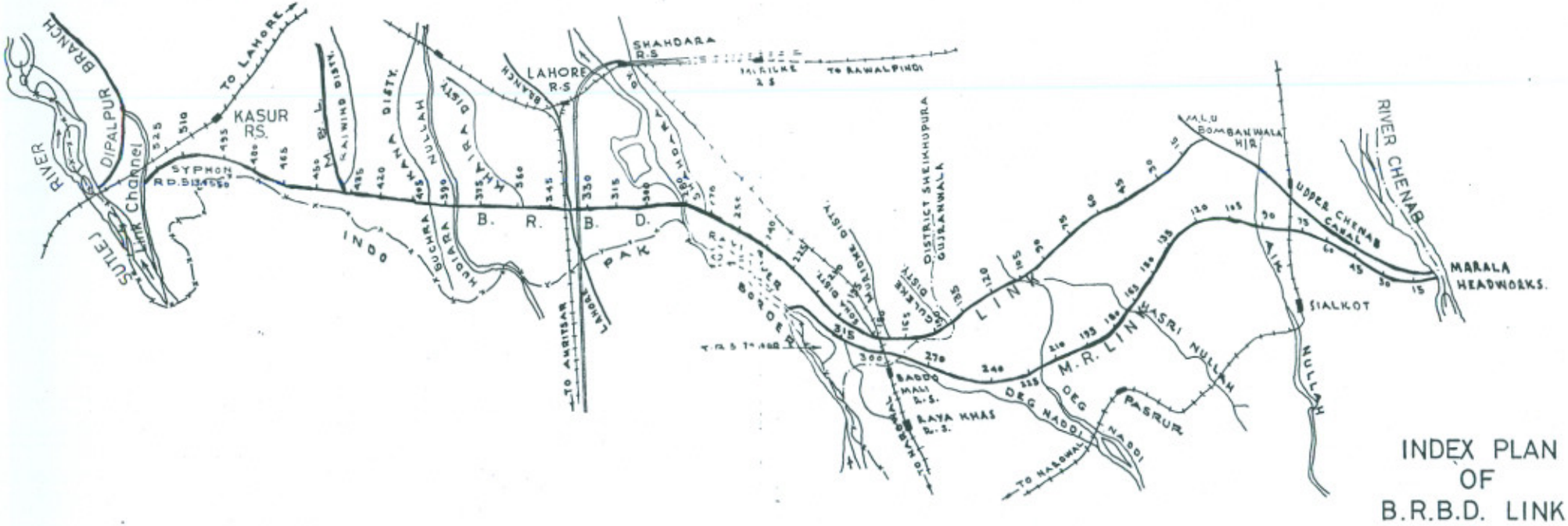
Paper No. 444

CONSTRUCTION & WORKING OF SPURS FOR PROTECTION OF B.R.B.D. LINK CANAL

(List of Figures)

Figure No.	T i t l e
FIG-1	Index Plan of B.R.B.D. Link
FIG-2	Planetable Survey of River Ravi from R.D. 205 to Ravi Syphon after Flood of 1975.
FIG-3	Mole Head Spur R.D. 250100/L B.R.B.D. Link (in 1975).
FIG-4	Plan of Hockey Cum Tee Spur Opposite R.D. 265000/L B.R.B.D. Link Canal (in 1975)
FIG-5	Cross Section for Raising and Strengthening Spur at R.D. 250100/L B.R.B.D. Link (0-4200) in 1976.
FIG-6	Cross Section at R.D. 2500 of Spur R.D. 265000/L B.R.B.D. Link (in 1976).
FIG-7	Plan of Hockey Cum Tee Spur Opposite R.D. 250100/L B.R.B.D. Link (in 1976)

FIGURE - I
PAPER No 44
BY
TARIQ & OTHER



INDEX PLAN
OF
B.R.B.D. LINK
SCALE 1.8 MILES

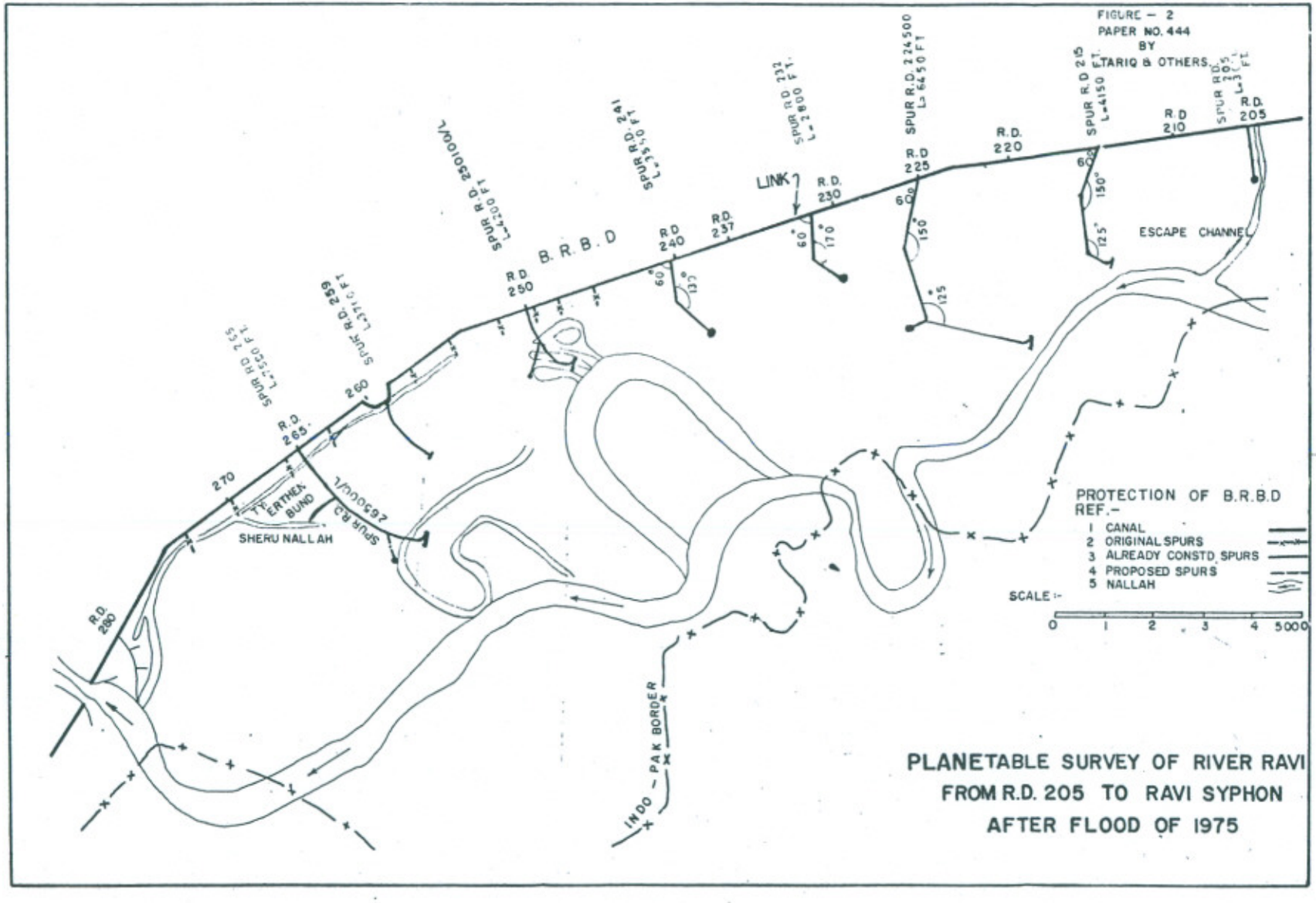

FIGURE – 2
PAPER NO. 444
BY
LTARIQ & OTHERS.
B.R.B.D
LINK
R.D. 205
R.D 210
R.D. 220
R.D 225
R.D. 230
R.D 240
R.D. 237
R.D. 250
R.D. 260
R.D. 265
R.D. 270
R.D. 280
SPUR R.D. 205 L=1350 FT.
SPUR R.D 215 L=4150 FT.
SPUR R.D. 224500 L=6450 FT
SPUR R.D 232 L=2800 FT.
SPUR R.D. 241 L=3500 FT
SPUR R.D. 250100 L=4200 FT
SPUR R.D. 259 L=3710 FT
SPUR R.D. 265 L=3520 FT.
SPUR R.D. 265000 L
ESCAPE CHANNEL
TERTIEK BUND
SHERU NALLAH
INDO – PAK BORDER
PROTECTION OF B.R.B.D
REF.–
1 CANAL
2 ORIGINAL SPURS
3 ALREADY CONSTD. SPURS
4 PROPOSED SPURS
5 NALLAH
SCALE :-
0 1 2 3 4 5000
PLANETABLE SURVEY OF RIVER RAVI
FROM R.D. 205 TO RAVI SYPHON
AFTER FLOOD OF 1975

FIGURE-3

PAPER NO. 444
BY
TARIQ & OTHERS.

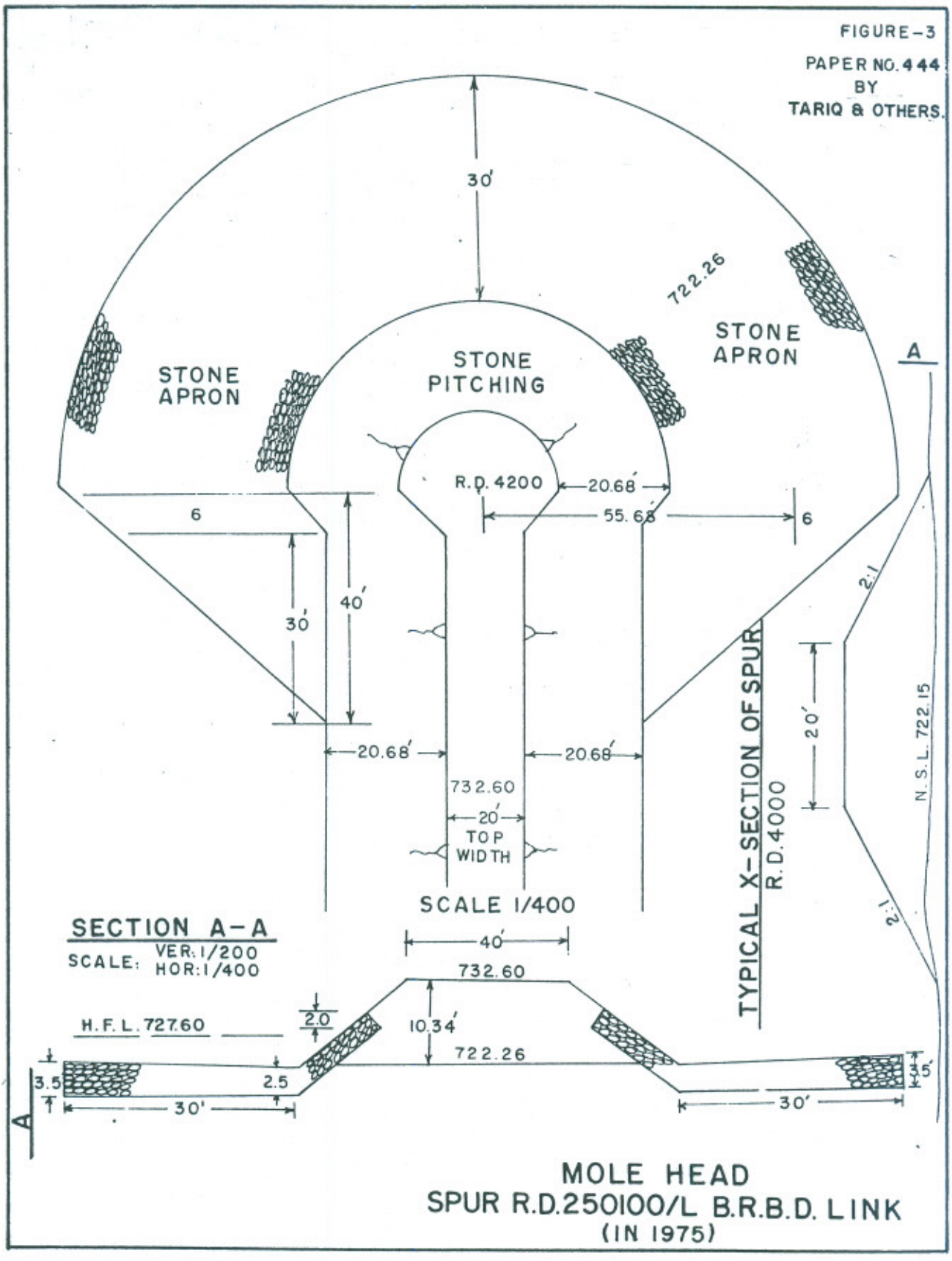
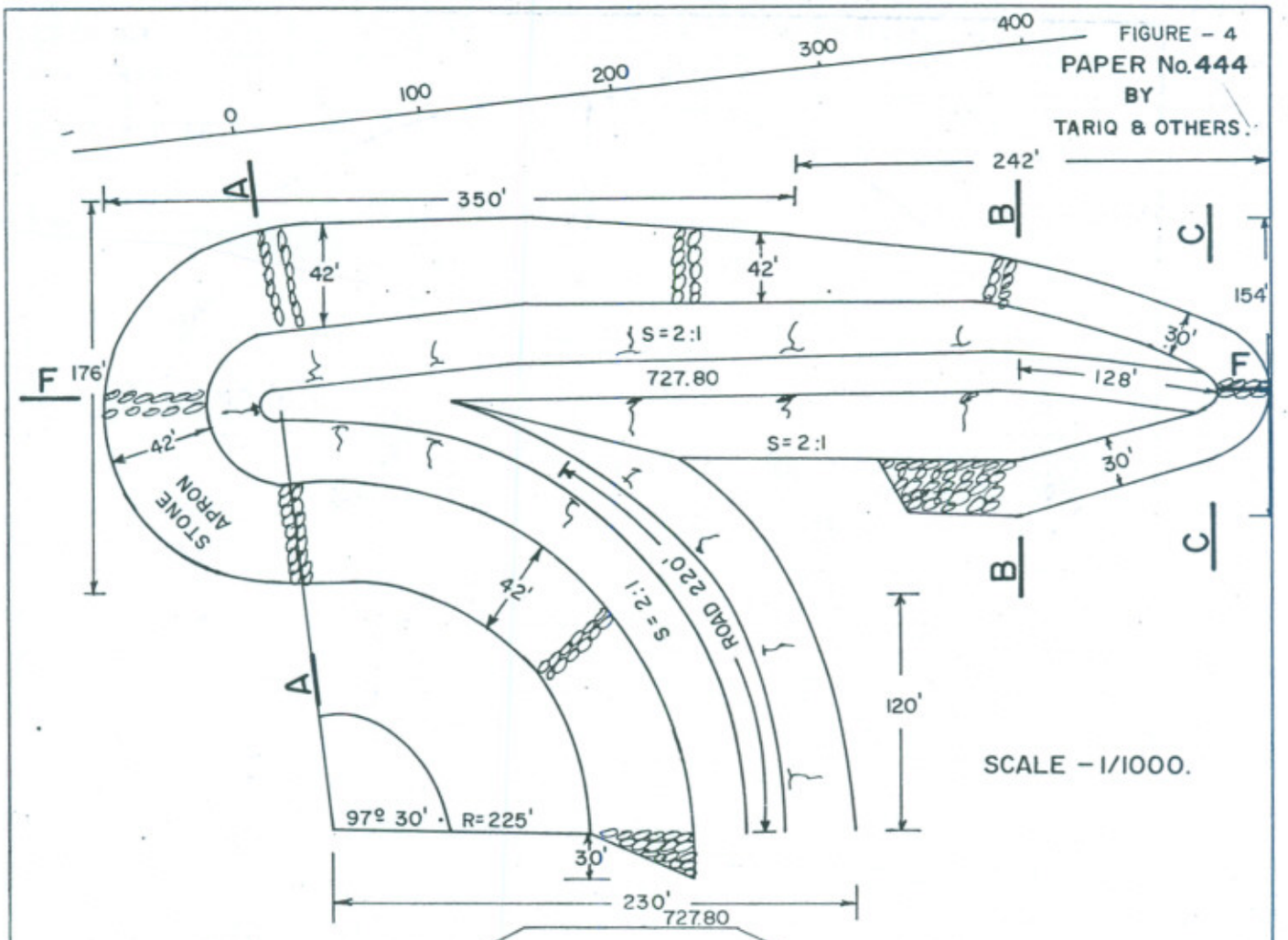
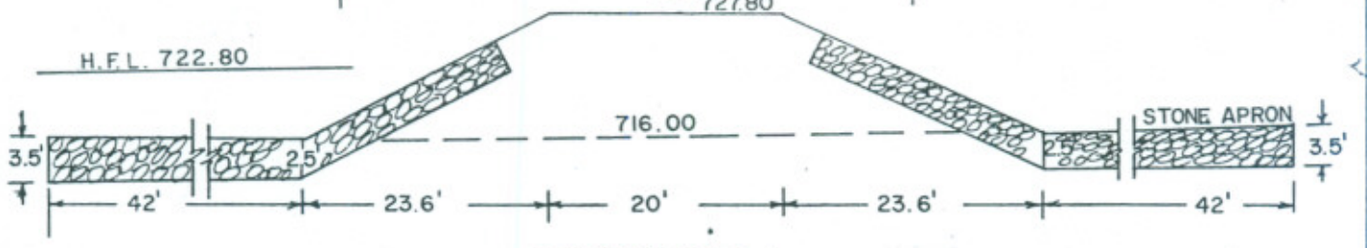


FIGURE – 4
PAPER No. 444
BY
TARIQ & OTHERS.

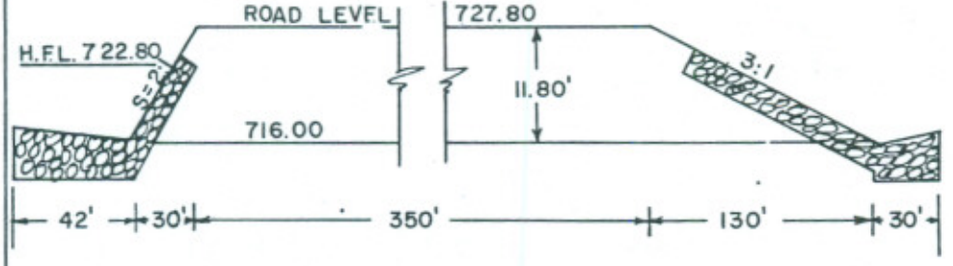


SCALE – 1/1000.



SECTION AT A. A.

SCALE :– 1/200



SECTION AT F. F.

SCALE :– H=1/1000
V=1/200

PLAN OF HOCKEY CUM TEE SPUR OPPOSITE R.D. 265000/L B.R.B.D. LINK CANAL (IN 1975)

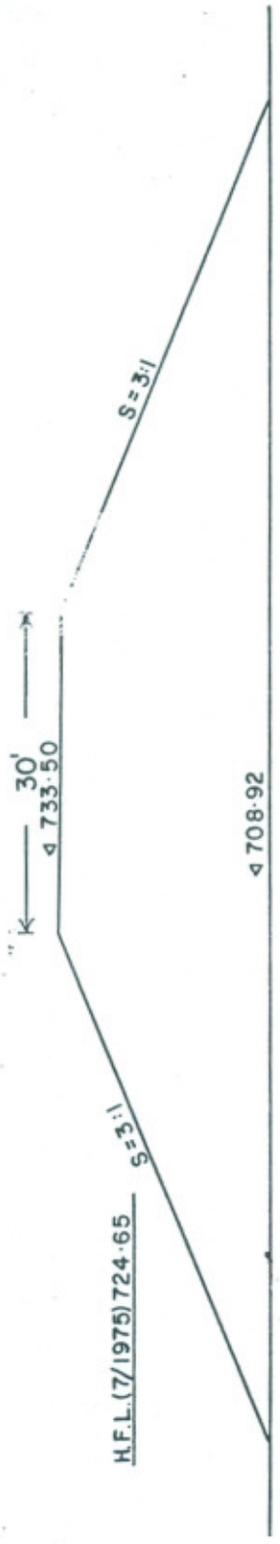
FIGURE – 5
PAPER NO. 444
BY
TARIQ & OTHERS.

X-SCTION AT R.D. 250 OF SPUR

SCALE :- 1/200

CROSS SECTION FOR
RAISING & STRENGTHENING
SPUR AT R.D. 250100/L B.R.B.D.LINK.
(0-4200)
IN 1976

FIGURE – 6
PAPER NO. 444
BY
TARIQ & OTHERS.

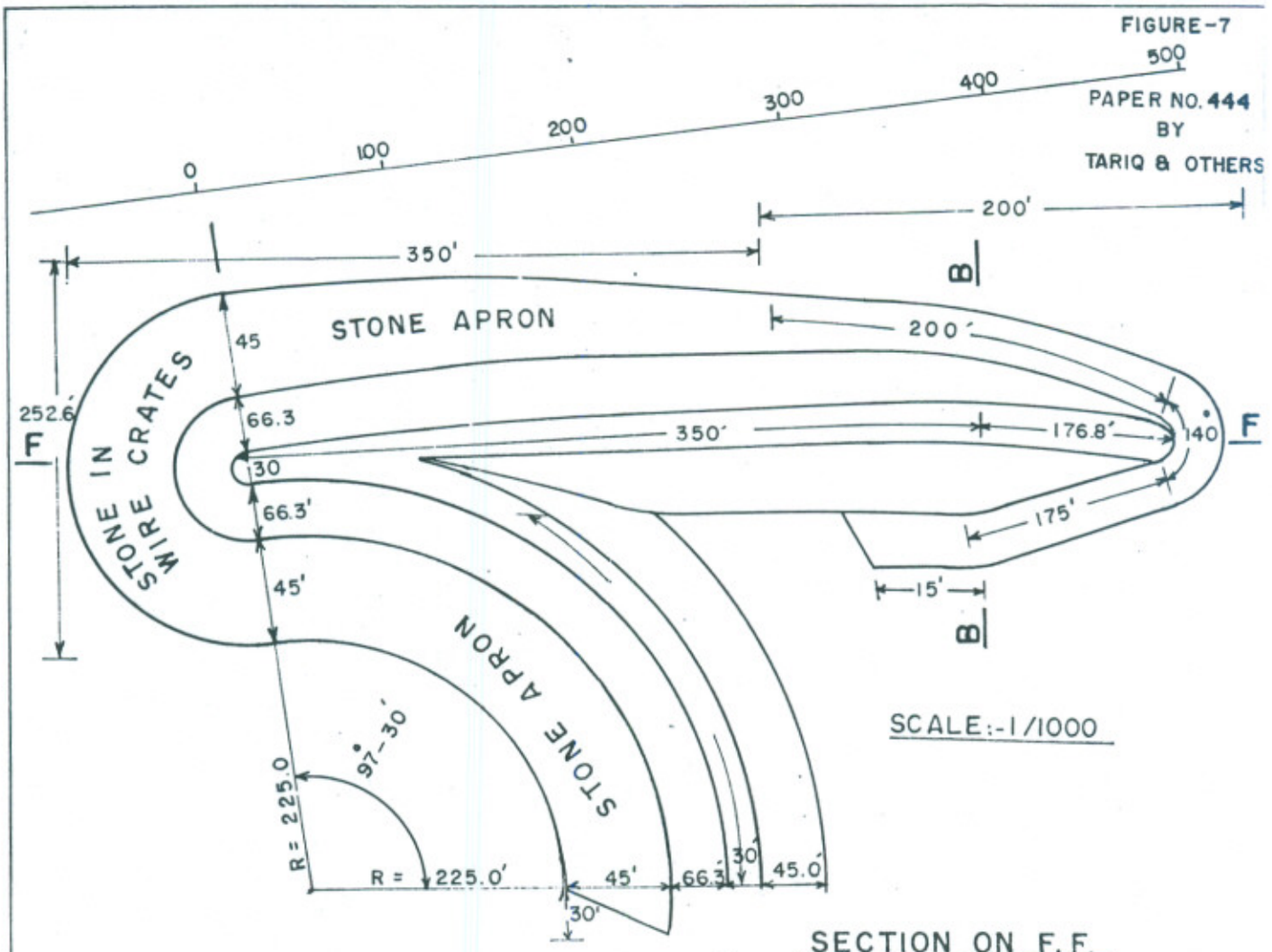


SCALE:– 1/200

CROSS SECTION
AT R.D. 2500 OF SPUR
R.D. 265000/L B.R.B.D.LINK
(IN 1976)

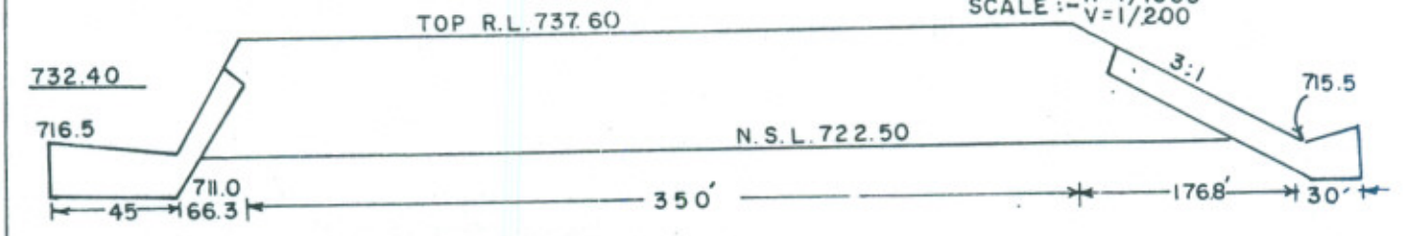
FIGURE-7

PAPER NO. 444
BY
TARIQ & OTHERS



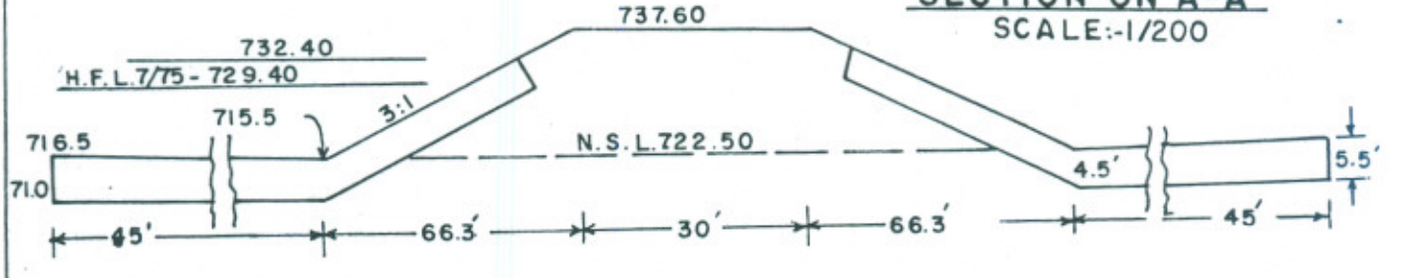
SECTION ON F.F.

SCALE :- H= 1/1000 V=1/200



SECTION ON A-A

SCALE:-1/200



PLAN OF HOCKEY CUM TEE SPUR
OPPOSITE R.D. 250100/L B.R.B.D LINK (IN 197