Silt Trap Efficiency of Reservoirs with Special Reference to Tarbela and Mangla Dams.

By

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SYNOPSIS

Tarbela and Mangla Dams compare very well with the big dams of the world constructed on high sediment transporting rivers. It is presumed that their trap efficiency will be as high as the other dams of the world. The yearly sediment transport of the river separated into sand, silt and clay is given in the note together with life expectancy of the storages. A study of the temperature, sediment content, shape of the storage, inflowing water and the existence of low elevation conduits point out to the fact that there exists a hopeful possibility of the development of density currents in the Tarbela Dam storage and a certain portion of the silt and clay may be excluded due to the high withdrawals from the conduits. As for Mangla Dam the same conditions do not hold primarily due to higher rise of temperature as a result of the existence of four prongs of the storage in Khad, Poonch, Kanshi and Jhelum rivers, withdrawal from which will have a disturbing effects on the density currents, so that silt exclusion through the five low level tunnels, each of 30 ft. diameter, will not be much effective.

General.

It is only during the last few years that Pakistan has under-taken the construction of Dams. The first concrete Dam in this country was completed two years back. It is the Warsak Dam constructed on the Kabul. There are three more dams under construction, these being the Nari Bolan Dam in Quetta, the Kurrum Garhi Dam in Bannu and the Karnafuli Dam in East Pakistan. Construction of two more Dams, the Tarbela Dam on the Indus and the Mangla Dam on the Jhelum is to be undertaken shortly. All these dams; both under construction or proposed to be constructed, are to be either earthern or earth and rock filled.

An estimation about the rate of sedimentation in a storage can to some extent, be based upon the sediment transport characteristics and sediment intensity of rivers but very often the flow characteristics after the construction of a dam are so complicated, that this estimate is far from accuracy. Sometimes predictions can be made on the basis of behaviour of

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dam constructed under similar conditions to the one which is being planned. There are a dozen cases known to the world when dams have lived only for an unexpected short periods, one example is that of Osborne Dam built on Solomon [1] river in the Kanas State of U.S.A. at a cost of $ 150,000. The dam having 2100 sq. miles of drainage area and having 300 Aft. capacity hardly last for one year. There are several such cases in which the useful life has been considerably reduced.

On the other hand example of Aswan Dam on the Nile in Egypt is often quoted which has no silt trouble at all although the river itself carries excessive silt. In this case flow characteristics have an important influence on the deposition of the sediment. Sedimentation of the dam already constructed in different parts of the world can be a good example to draw conclusions about the probable behaviour of the Tarbela and the Mangla Dams.

Sedimentation of the Existing Dams.

In America hundreds of Dams are in existence and data of sediment deposition in these for a number of years is available. Several attempts have been made by various workers to analyse this information and put these under some order, so that the conclusions could be used on dams being planned.

Brown [2] in 1939 collected the data of the amount of sediment entrapped in different existing storages and expressed it as percentage of the total of inflow sediment. He called this factor, E, as trap efficiency of the dam. It was plotted against a non dimensional number being the ratio of the capacity of the storage, C, to the drainage area, W, both factors expressed in acre feet. Brown found that an Envelope curve (Figure 1) enclosing the data could be expressed by an equation of the type

$$E = 100 \left(1 - \frac{1}{1 + K\frac{C}{W}}\right)$$

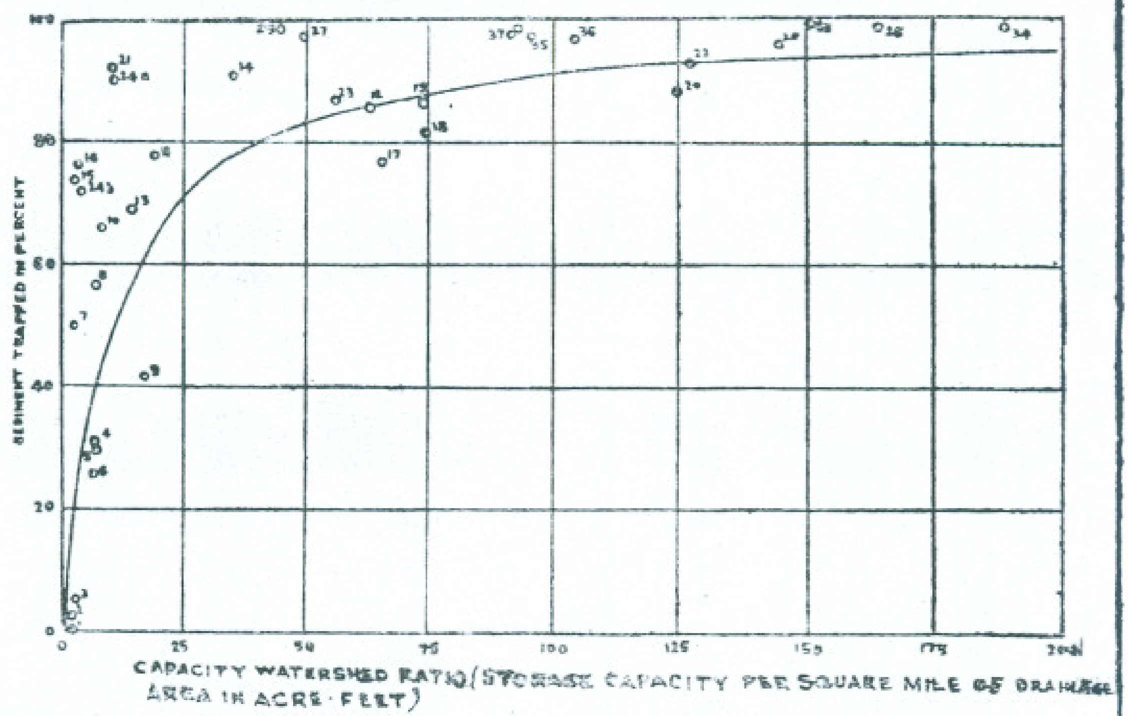
where K was a constant equal to 0.1

In fact this type of plot is not an index of sedimentation of a new reservoir as it ignores the sediment character and the intensity of a stream both of which are important factors.

Khosla [3] tried to interpret these results in a slightly different manner. He plotted the sediment deposited in a given reservoir in one year, against the catchment area of the storage. He found that the maximum sediment deposited in heavily silt laden streams was 75 acres feet per 100 sq. miles of the catchment area. The maximum order for a few streams, however, went upto 90 acre feet per 100 sq. miles of the catchment area.

FIG.1

TRAP EFFICIENCY AS RELATED TO CAPACITY-WATERSHED RATIO

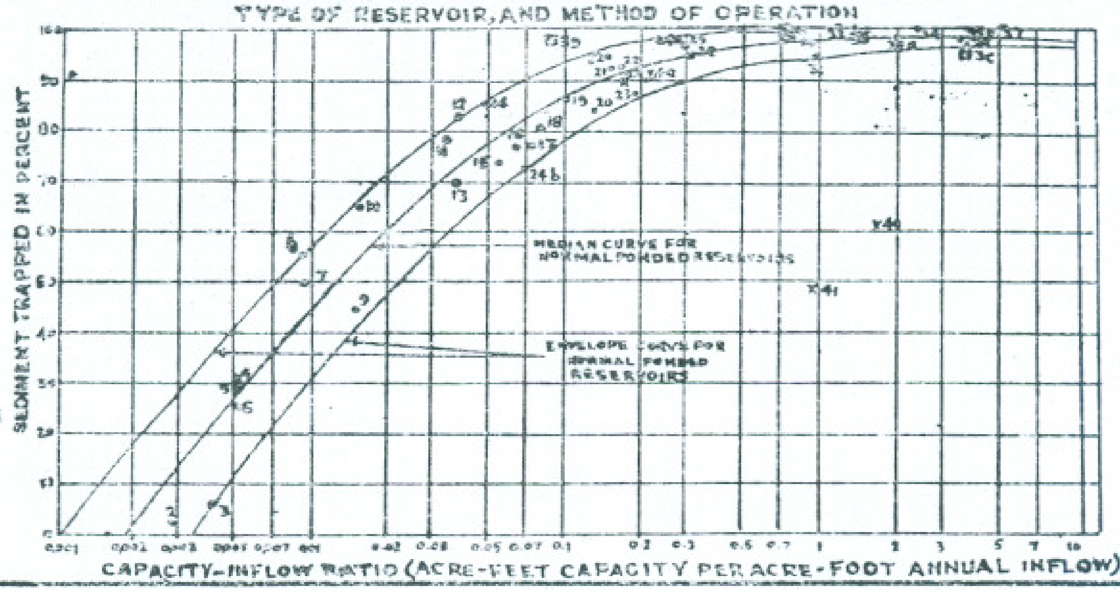


(4)

Recently Brune has tried to express the trap efficiency in terms of the ratio of the capacity of the storage to the inflow, both factors expressed in acre feet, the curve that he got is shown in Fig. 2.

FIG.2

TRAP EFFICIENCY AS RELATED TO CAPACITY-INFLOW RATIO, TYPE OF RESERVOIR, AND METHOD OF OPERATION



LEGEND FOR FIGS. 1 & 2.

Name of Reservoirs Data of which was used.

1. Williams Reservoir.
2. Lake Halbert (Rock Reservoir No. 1)
3. Lake Halbert (Rock Reservoir No. 3).
4. Hales Bar Reservoir (1935 and 1936).
5. Hales Bar Reservoir (1938).
6. Hales Bar Reservoir (1937).
7. Keokuk Reservoir.
8. Lake Taneycomo.
9. Wilson Lake.
10. Lake Marinuka.
11. Lake Decatur.
12. Bullards Bar Reservoir.
13. Lake Halbert (Earth Reservoir No. I).
14. Lake Rockwell.
15. Corpus Christi Reservoir (1942-1943).
16. Corpur Christi Reservoir (1934-1942).
17. Lexington Reservoir.
18. Lloyd Shoals Reservoir.
19. Lake Michie.
20. Lake Irsaqueena.
21. Guerasey Reersvoir.
22. Arrowrock Reservoir.
23. T and P Reservoir.
24. Hiwassee Reservoir.

24a. Imperial Dam Reservoir (1938-42).

24b. Imperial Dam Reservior (1943-1947).

25. Lake of the Oqarks.
26. Pardel Reservoir.
27. Possum Kingdon Lake.
28. White Rock Reservoir.
29. Buchanan Lake.
30. Norris Reservoir.
31. Senceavill Reservoir (1939-1943).
32. H. Lage Pond.
33. Denison Reservoir.
34. Lake Mead.
35. San Carlos Reservoir.
36. Conchanas Reservoir.
37. Elephant Butte Reservoir.

37a. Fort Peck Reservoir.

38. All American Canal Desilting Basin.
39. Hadley Creek New Desilting Basin.
40. John Martin Reservoir.
41. Senecaville Reservoi (1936-1939).

He utilized data of 41 reservoirs in which the percentage trap efficiency was estimated by various methods and in which the variation in drainage area was from 1.13 sq. miles to 185,600 sq. miles and annual inflow varied from a minimum of 27.2 to 1660 acre ft. per sq. mile of the catchment. This data for a few dams whieh have some similarity with the Tarbela and Mangla Dams is given in Table No. 1.

TABLE 1

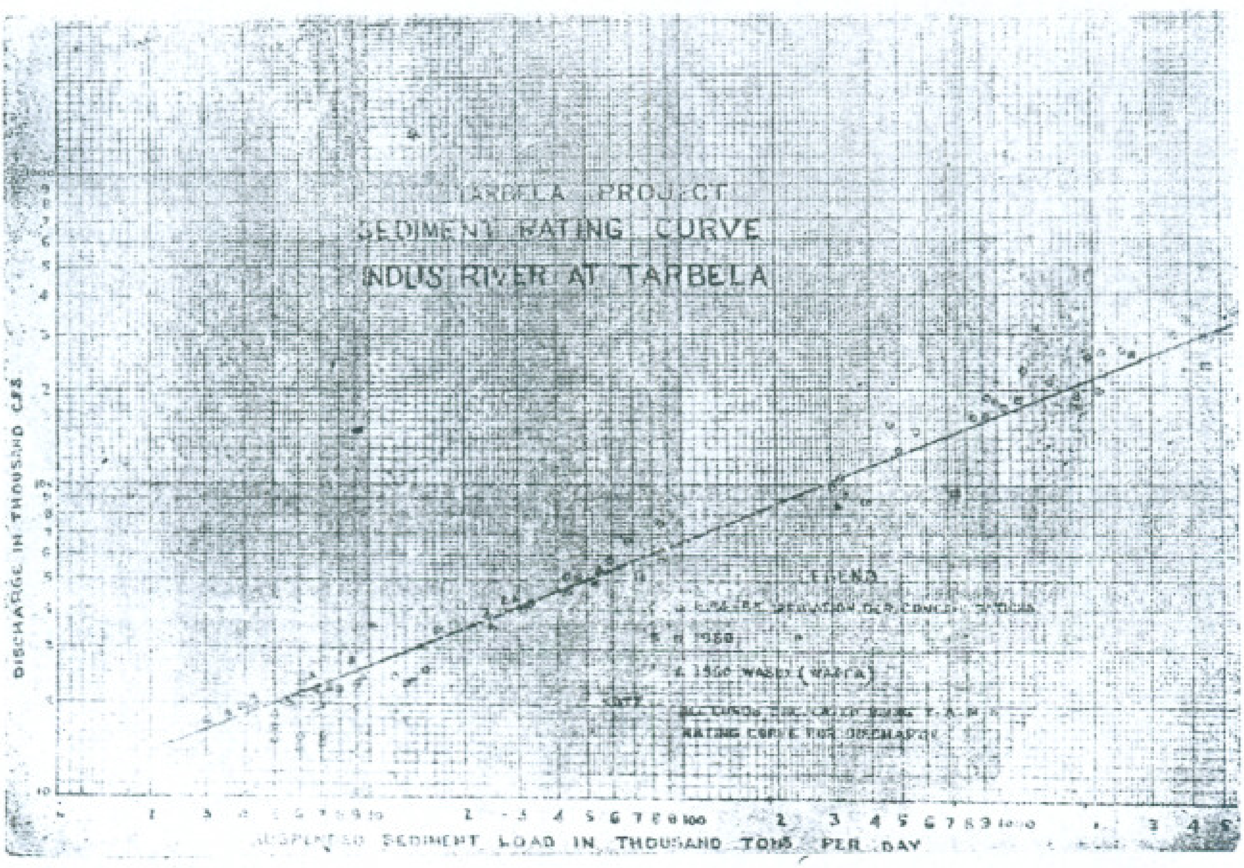
Reservoir	River	Av. Ann flow MAF 'I'	Cap. of Storage MAF 'C'	Drainage are in sq. miles	Ann. Sed.		Trap Eff. %	C/I
					M. tons	A. ft.		
Tarbela	Indus	60.0	7.8	70,000	345	198,000	95*	1.28
Garrison	Massouri	17.6	23.0	...	...	...	95	1.31
Mangla	Jhelum	22.6	(8.0)	13,180	77	44,200	95*	(3.54)
			(5.1)					(2-26)
Elephant Buttee	Rio. Grande	1.1	2.64	26,312	282	16,147	98.6	2.05
Rock Land	Neches	1.7	6.8	...	...	...	...	4.0
Fort Peck	Massour	4.2	19.4	57,725	6.9	...	100	4.65
Dennison	Red river	4.14	5.5	38,291	2.7	...	100	1.22
Grand Coulee	Columbia	(80.0)	9.6	74,000	...	...	...	1.2
		(53.0)						1.82
Boulder	Colorado	15.0	30.5	167,000	1050	60,000	99.4	2.44
Aswan	Nile	66.0	4.4	620,000	...	...	...	6.67
Hirakind	Mahanadi	50.0	5.98	32,200	45.5	26,000	...	1.2
Bhakra	Sutlej	16.0	7.0	21,960	34.3	19,000	...	4.5

* assumed efficiency.

Sediment Charactersitics of the Indus and the Jhelum :—

Sediment observations on the Indus and the Jhelum were undertaken
(5a)
by the auther in 1954 and 1955 respectively and were continued to the end of the year 1959. Some data was collected on the Indus at Durband during 1960 and 1961 also.

(5a, b, c and d)
According to the estimate of the author, the Indus at Durband passed 102640 A. ft. of sediment which constituted 63000 A. ft. of sand, 24,500 A. ft. of silt and 15,140 A. ft. of clay. The percentage of each segment was, sand 62%, silt 24% and clay 14% of the total. The total sediment load in terms of tons was 179.4 M. TAMS, consultants for Tarbela
(6)
Dam has, however, estimated that the total annual sediment load of the river is equal to 345 M. tons which estimate they have based upon 92 years recorded flow estimations, starting from 1868 onwards. The proportion of various constituents of the sediment as per their estimate being 8% clay, 29% silt and 63% sand. The sediment rating curve on which this estimate was based, was however, identical to that established by the author. This is shown in Fig. 3.



›f the Indus at Durband together with its g. 4. The discharge of the river on 1-11-54 a minimum order of 16 to 17 thousand it slowly starts attaining a value of 50,000 y. After this period it starts shooting up ısecs at the end of May and often attaining ›re. The fall again starts in August and in to as low an order as 50,000 cusecs.

early steady beginning from September to ; up rising to 1500 to 2500 parts per million ıt content during winter being less than ıe Tarbela storage it is asssumed that the ›diment and with a storage of 6.0 million up in 35 years. A storage capacity of , last up to 40 and 60 years.

c, 5c & d)
langla, the author started sediment estima- to the end of 1958. During these 6 years ›und to pass this site was equal to 44200 A. 2870 A. ft., of sand, 16584, A. ft. of silt and nd, 37.8% silt and 12% clay. This cor- of annual sediment load.

ı and Gourley evaluation of sediment load from 1922 to 1957. The total sediment ons. Taking about 95% as trap efficiency, ks out to be 130 years. After 50 years the equal to 3.0 MAF. This will be the con- ım at a pond level equal to R.L. 1202.

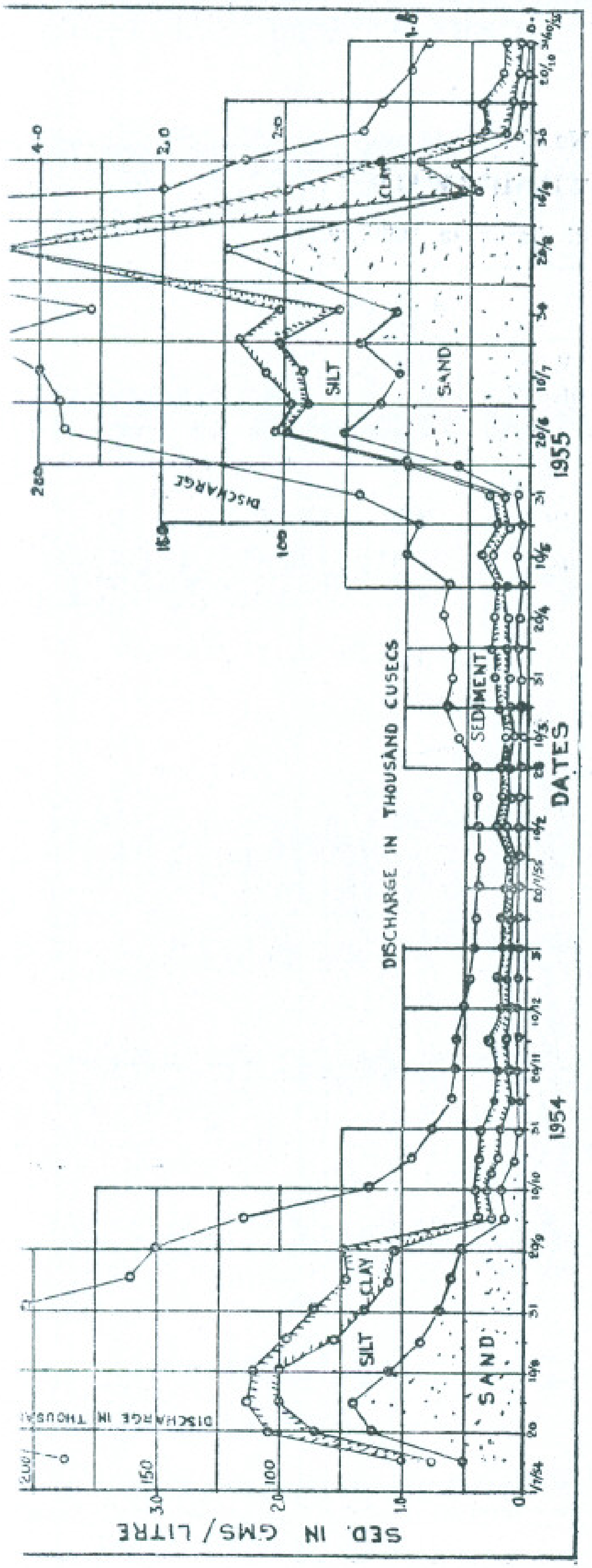
ıydrograph for the year 1956 is shown in ıd from the end of June to the beginning h order of silt grade going up from 1600 The winter silt content is, however, as

ıwal from Tarbela Dam is given in the

:en days with-drawal for a year together cess or shortage as a result of with-drawal 'able 2. After meeting with the full demand ›e spilled over unused. This table also with-drawal it will be necessaɹy to store water of August also. The total with- amount to 9.15 and 34.73 MAF respective- › June with-drawal being 4.68 and 16.65 rawal has been made possible in the design number release conduits located about 100

Excess with-drawals over inflow
0
0
0
—98.7
—230.0
0
—628
—1606
—140
0
0
—188
—2890.7

ı-used = 10.86 M. Cusecs.



TABLE

TARBELA DAM

Means of 10 Days

2nd ten days		
With drawal	Inflood	Different
41.2	43.4	2.2
18.6	29.2	10.6
19.0	24.0	5.0
24.8	19.0	—5.8
24.7	16.0	—8.7
24.4	34	9.4
56.7	35	—21.7
113.7	45	—68.7
110.7	198	87.3
128.3	215.0	86.7
92.6	305	212.4
80	116	36

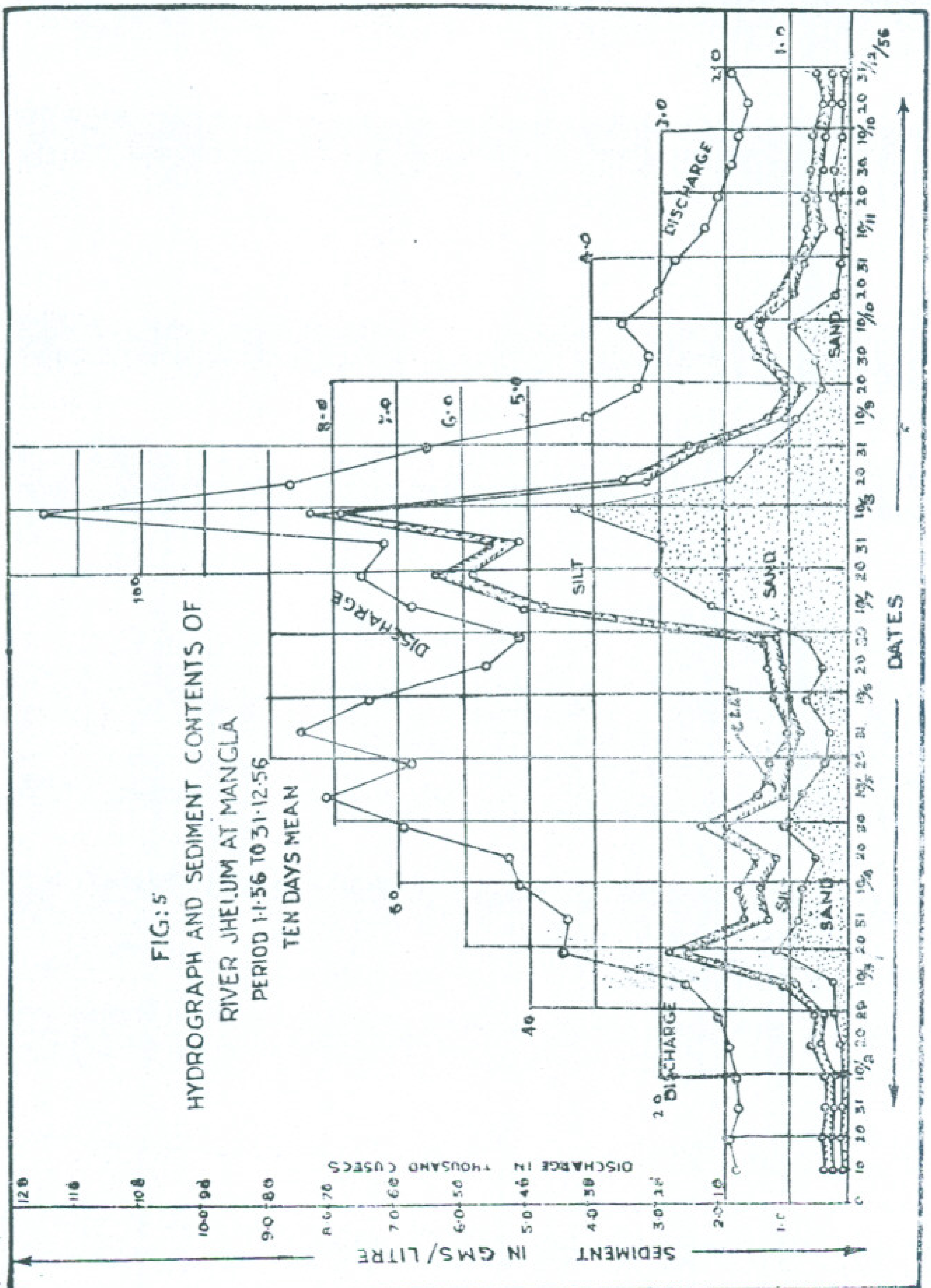
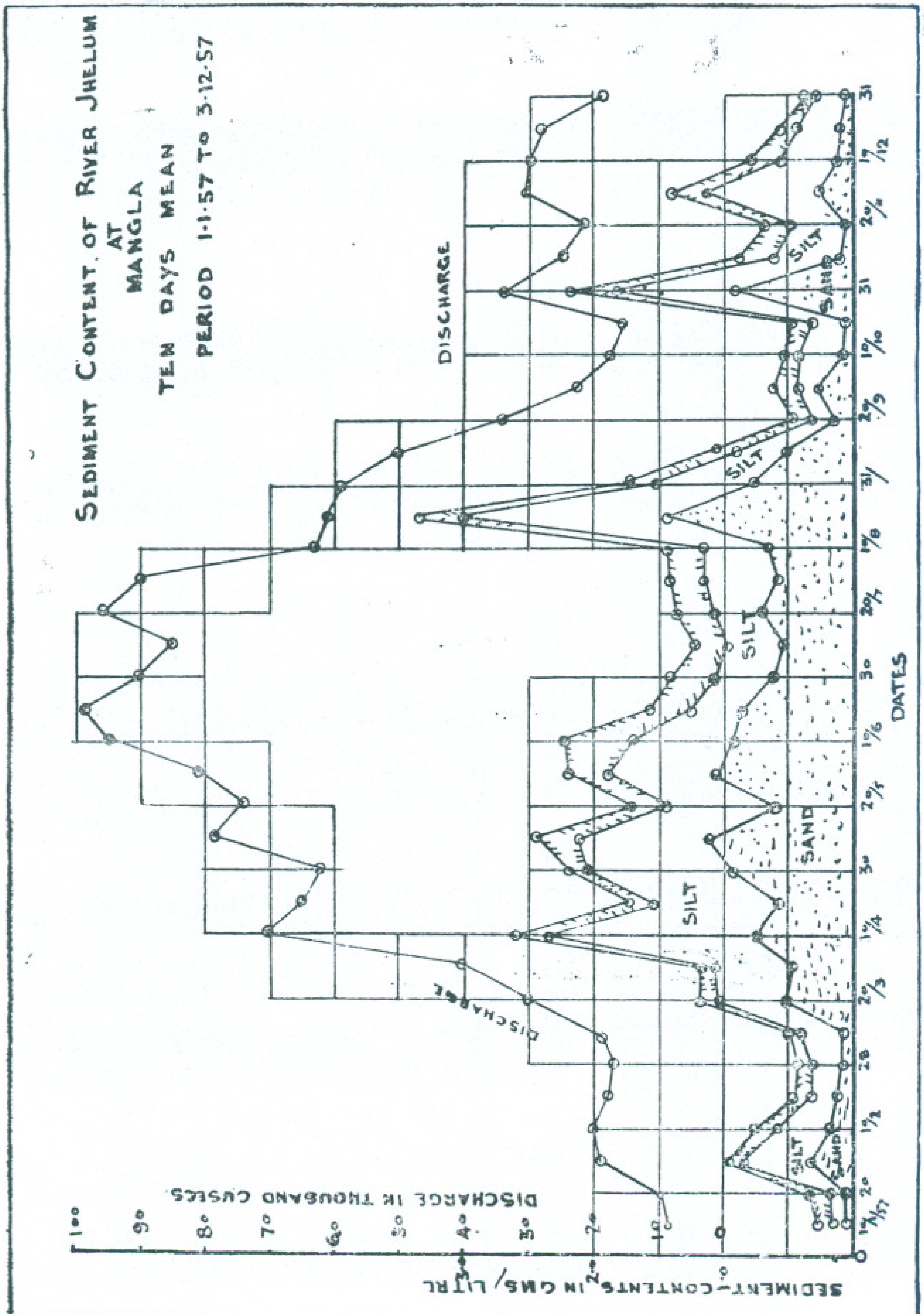


FIG: 5
HYDROGRAPH AND SEDIMENT CONTENTS OF RIVER JHELUM AT MANGLA
PERIOD 1-1-56 TO 31-12-56
TEN DAYS MEAN


SEDIMENT CONTENT OF RIVER JHELUM
AT
MANGLA
TEN DAYS MEAN
PERIOD 1.1.57 TO 3.12.57
DISCHARGE
DISCHARGE
SILT
SAND
DATES
DISCHARGE IN THOUSAND CUSECS
SEDIMENT-CONTENTS IN GMS/LITRE

ft. above the bed of the dam. These conduits will be 6 ft. × 12 ft. in dimension and will have a discharging capacity of 180 thousand cusecs under a head corresponding to R. L. 1440. The discharging capacity of the conduits is plotted in Fig. 6 whereas the position of conduits with respect to other dimension of the dam is shown in Fig. 7.

As for the Mangla Dam, the with-drawals are to be made through 5 tunnels of 30 ft. diameter each. This flow will take place after working the generator. These tunnels will also be located about 100 ft. above the bed of the dam and about 200 to 222 ft. below the pond level of the dam. The with-drawal for a typical year being as under :—

TABLE 3.

Planned with-drawals per day in cusecs.

January	February	March	April	May	June
15,000	15,000	20,200	27,000	38,600	42,000
July	August	September	October	Nov.	December
20,200	20,200	20,200	20,200	1,500	1,500

Reducing Siltation :—

The cost of Mangla Dam is to be 1860 million rupees. The life of the 5.35 MAF storage is estimated equal to 130 years, so that silt deposition will cost the country 14.4 M. rupees per year. Similarly the probable cost of the Tarbela Dam is expected to be 2500 M. rupees and with a storage of 7.8 M. acres the life works out equal to about 50 years, so that silt deposition in the dam will cost the nation 50.0 M. rupees per year. Every year for which the life of the storage is prolonged will directly pay the nation.

So far the known methods to decrease the siltation of a dam are :—

(*i*) Soil Conservation measures taken in the upper catchment areas,

(*ii*) Construction of check Dams,

(*iii*) Filling the dam during the period of low silt content and

(*iv*) Sluicing or venting.

Soil Consorvation to reduce silt entry in a storage :—

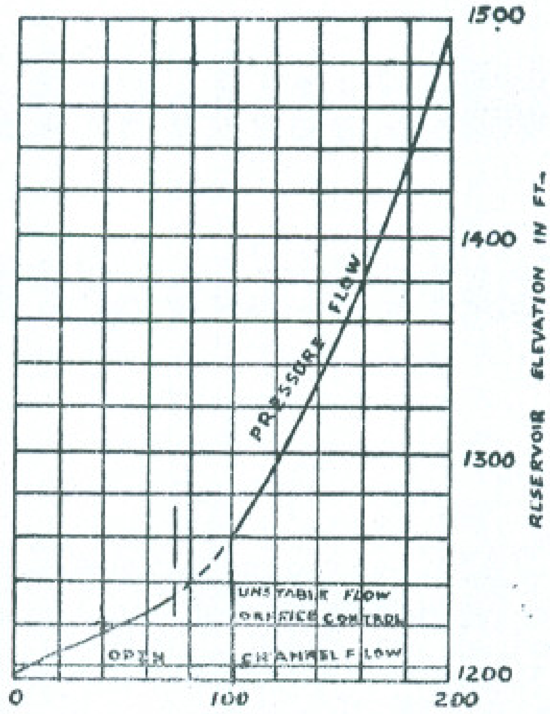
It is well known that soil conservation measures on catchment areas are very effective in reducing land wash and transport of sediment into a storage. In the case of Tarbela, an area of 4000 sq. miles, out of total of 70,000 sq. miles of catchment, receive about 18 inches of rain fall in a year. In the upper catchment, rain fall continues to decrease with increase of height and beyond 10,000 ft. there is very scanty rain. The main sources of the Indus water are a result of the melting of snow and Glaciers. Thus in case of Tarbela some conservation measures in the

FIG. 6

TARBELA PROJECT

SPILLWAY PLAN

DISCHARGE RATING CURVES.



DISCHARGE IN THOUSAND CFS

RATING CURVE FOR 28 NUMBER

IRRIGATION RELEASE CONDUCTS

SIZE 6X12 FT.

T. BY. M. SULTAN

R.H.Y.

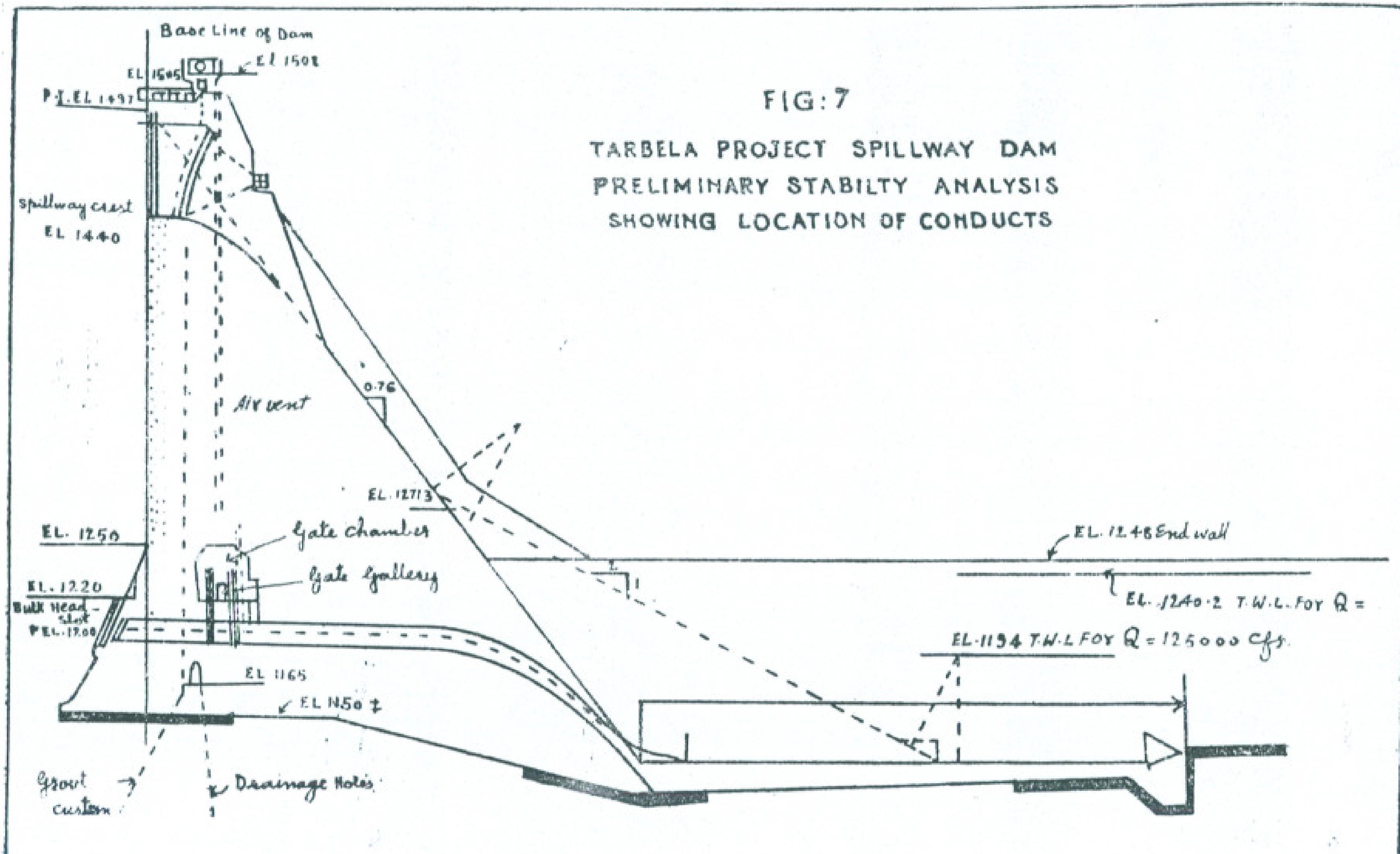


FIG: 7

TARBELA PROJECT SPILLWAY DAM
PRELIMINARY STABILTY ANALYSIS
SHOWING LOCATION OF CONDUCTS

catchment of the Siran and just upstream of the dam can be effective. The main sources of sediment which are a result of disintegration and grinding of rocks do not appear to be within the possibility of soil conservation measures.

As to the Mangla Dam, areas which contribute considerable sediment, are the catchments of the Poonch, the Kanshi and the regions below Domel to the dam site. Soil conservation measures in these areas are within the reach and will be helpful in reducing siltation. Conservation measures in the catchment of other tributaries such as the Kunhar, the Kishan Ganga and the Jhelum above Domel, far away from the dam site may not be as effective as those mentioned previously.

Check Dams :—

Another measure to reduce siltation of a storage is to construct check Dams on tributaries, so that a portion of the sediment is retained in these rivers. For Tarbela no site has yet been investigated nor there appears to be one close to the site of the dam. Perhaps a study of the Siran may be useful. As for Mangla a few sites on the Poonch has been studied. A check dam far away from the storage, loses its effectiveness. The Jhelum flows through Wular Lake in the Kashmir Valley but at Domel its sediment content is as high as if the river had flowed directly. The water passes a high order of sand in addition to the other constituents, and seems to have no effect of the detention in the lake. It seems that during the ninety miles run off the river below Wular lake it again picks up the sand. Closeness of check Dam to the storage seems essential. For Tarbela, there does not appear to be any site where effective check dams can be constructed. The matter, however, needs further investigations.

Filling the Dam at Low Sediment Content Periods :—

This method is effective for those cases in which the with-drawal is limited, storage is small and sufficient flow is available after passing high sediment periods. This is not possible in case of Tarbela and Mangla Dams, as is clear from tables 2 and 3, giving the planned withdrawals.

Sluicing and Venting :—

Sluicing is never very effective,[9] in case of high Dams although this is a common method for silt exclusion in low river regulating structures such as weirs. Brune[4] has put forth some instances of sluicing which have been effective to reduce the trap efficiency by 3 to 10 percent and sediment loss from 39 to 174 percent.

In case of Arrowrock Reservoir in Idaho, sluicing of sediment reduced the trap efficiency from 93 to 90.3% and to increase the sediment loss by 39%. In case of Conches Reservoir, New Mexico, sluicing reduced the trap efficiency from 97.3 to 95.8 percent and sediment loss increased by 56 percent.

In lake Issaqueena, venting lowered the trap efficiency from 94.2 to 84.1 percent and sediment loss increased by 174 percent.

It thus appears that timing of sluicing with gravity flow having high sediment content can result in exclusion of some percentage of sediment. In fact facilities can be created to allow the flow of water having high sediment content and a portion of this can be sluiced out.

The Dimension of Storage of Tarbela Dam.

For Tarbela Dam the following facts are worth nothing. The reservoir with 7.8 MAF capacity will extend to more than 46 miles up-stream in the Indus. The maximum depth at the dam would be nearly 400 ft. andthe top of the spillway gates will be at the elevation 1490, spillway crest at R. L 1440, elevation of irrigation outlet at R. L. 1200 and the river bed at R. L. 1100. The proposed minimum draw-down level is at R. L. 1300. The live storage capacity in the Siran will be about 1.17 MAF and will extend to about 12 miles in the river.

The width of the storage in the main Indus will be very small. A study of figure 8 is instructive. The width at the beginning of the dam will be hardly 300 to 400 ft. and for about 30 miles below the beginning and upto about 15 miles up-stream of the dam, its width will not increase beyond 4000 to 5000 ft. The storage will be in the form of a narrow stream.

In fact the wide storage will be within 10 miles of the dam.

The capacity of 28 conduits at R. L. 1200 nearly 290 ft. below top of the gates of spillway is 180,000 cusecs.

Delt Formation and Possibility of Density Currents.

Normally during summer months of June, July and August, the discharge of river goes above 200 thousand cusecs depth rises to 100 ft. and velocity attains an order of 15 to 19 ft. per second. With the creation of the dam there will be some increase in width and depth of the river but in about 20 miles length of the river from the beginning of the storage, velocities will still remain sufficiently high and some of the sand load will be deposited in this reach and the rest carried further down. There is every possibility that the end of the dropping of sand may be only 10 to 15 miles up-streem of the dam. The deposition of silt will thus take place very close to the conduits and clay will deposit, if at all, still closer to the exit.

Now density currents are formed as a result of difference of temperature of the water and the intensity of sediment loads both of which cause a change in the density of water as compared to that already in existence at site. Pure water has the maximum density at 4°C and the decrease in density upto 30°C is as under :—

Temp. °C	4	6	8	10	12	14	16	18	20	28	30
Density gm/cu.cm.	1.0000	.99907	.99988	.99973	.9952.	99827.	99897	.9962	.99823	.99707	.99567
% decrease in density with ref. to 40 C°	—	—	.003	.022.	.027	0.048	0.073	.103	.138	0.177	.29 .433

The water at Tarbela contains dissolve salts which range from 200 to 300 ppm. and these remain nearly constant through out the year, so that their presence will not cause a change in the range of the density. The temperature of the water of the Indus in °C together with discharge of a typical year and the sediment is shown in table below 4.

TABLE No. 4.

Temperature, Discharge & Sediment contant of water of the Indus at Durband for a typical year.

Month.	1st ten days.			2nd ten days.			3rd ten days.		
	Temp.	Dis.	Sed.	Temp.	Dis.	Sed.	Temp.	Dis.	Sed.
Jan.	4.2	20.0	0.107	6.0	19	0.102	7.5	19.3	0.123
Feb.	8	18.0	0.169	9	16.64	0.179	11	11.1	0.158
Mar.	11.5	29	0.120	12.5	34	0.194	14.0	32	0 172
Apr.	14	33.0	0.224	15	35.0	0.228	15	34.9	0.110
May.	15	52	0.442	15	45	0.236	16	61	0.309
June.	15	123	1.217	15	198.0	2.385	15	188.	1.827
July.	15.5	198.5	2.14	16.0	215.0	2.362	16.5	179	2.033
Aug.	17.0	263.0	3.47	16.5	305.0	4 433	16.5	272.0	2.410
Sep.	16.0	200	2.01	16.0	197	1.241	16.0	116	0.357
Oct.	16.5	61	0.42	14.0	47	0.258	13.5	41	0.172
Nov.	12.0	30.7	0.152	10.5	29.2	0.106	9.5	26.9	0.149
Dec.	9.6	24.4	0.138	6.0	24.1	0.148	4.5	20.7	0.110

Note :—Temp. is in C°, Discharge is in cusecs and sediment is in gms/litre.

The water of July, August, and September, are comparatively hotter than the winter months and hence are lighter but the range of increase of temperature as compared to April being hardly one or two degrees, so that the decrease in density will be hardly 0.003 per cent. In July and August water will be lighter by 0.027% as compared to that of March and November.

The effect of silt content is, however, different, usually in June and July the silt content is upto 2.0 gm. per litre or say 0.2%. The water of August as a result of Monsoon contains more silt going upto 4 gm. per litre so that it will raise the density to 0.4%. If clay constitutes 10% and silt 30% then even in flood days density of clay bearing water in August will be 0.04% heavier and silt and clay bearing water 0.16% heavier than water of April & March. This will be the case after droping the sand content. It is thus evident that heavy water of the summer monsoon periods will depress down into the storage. Now looking to table 2, it appears that there will be sufficient reserve water available even during the cooler and comperatively less sediment bearing months from October to March. This water will be stored in the reservoir. Heavy sediment bearing water of the late July and August can be discharged through the conduits with discharging capacity upto 180 thousand cusecs. When the storage is full, the reservoir is narrow, conduits are at low elevation and lie in a width of about 400 ft. there will be a possibility of establishing a dense narrow water current flowing through 10 to 15 miles of the reservoir and carrying away some percentage of the silt and clay. Spreading of this dense current may not take place for the reasons given above. Even if clay is excluded which constitutes about 10% of the annual sediment load then we save 50 Lacs of rupees per year. Evidently we shall have to take full measures by regulating the sluices and filling the storage in such period as to induce the maximum possibility of density current concentrated in a narrow jet taking out as much of the sediment as possible. There is every reason to believe that clay and a part of silt can be excluded by such measures. The operation of electric generators will, however, be a disturbing effect to the density currents.

Density Currents in Mangla Dam.

The extend of the Mangla storage is exhibited in Fig. 9. The main storage will be in Khad river which will be a sort of a by-storage. Another area of the storage will be in the catchment of the Poonch.

In the Jhelum itself the main storage will be within about 6 miles of the dam. In the rest of the river, the storage will be very narrow and extending to about 35 miles above the dam proper. As the main flow will be in the Jhelum, the off-storage of the Khad, that of the Poonch and the Kanshi will not be under the direct influence of the main sediment deposition of the Jhelum.

TABLE No. 5

Temperature. discharge and Sediment content data of the Jhelum for the year 1956.

Month	Temp.	1st ten days.		Temp.	2nd ten days.		Temp.	3rd ten days.	
		Dis.	Sed. Gm/litre		Dis.	Sed. Gm/litre.		Dis.	Sed. Gm/litre.
January	8.4	68016	.201	9.0	65905	.206	8.0	70369	.279
February	9.2	57682	.185	10.5	67359	.278	11.2	77223	.378
March	12.5	136662	.909	13.4	333277	2.666	12.0	332288	1.475
April	14.4	394001	1.612	15.2	409956	1.316	14.8	583557	2.150
May	16.2	694227	1.293	16.5	549755	1.085	17.2	737580	.828
June	18.4	632205	1.045	18.6	450194	1.132	18.8	386337	1.333
July	21.2	550344	4.994	22.5	518785	6.292	24.2	662933	5.396
August	23.0	1143885	8.289	23.8	671111	3.407	24.4	591289	2.442
Sept.	23.8	304220	1.098	23.6	226150	.765	23.4	205151	1.252
Oct.	19.4	240168	1.522	19.0	184650	0.971	18.4	181220	0.720
Nov.	14.8	118167	0.485	14.1	94272	0.3771	10.9	81963	0.389
Dec.	10.2	74811	0.251	10.0	69119	0.204	8.2	89135	0.357

NOTE : T is in °C, Discharge in thousand cusecs and Sediment is in gm/litre.

The sand deposits of the delta will extend after a few years to the very mouth of the wide Jhelum river storage and silt and clay content shall have to move a length of about 6 miles to reach the five tunnels each 30 ft. in diameter discharglng as much as 34 thousand causecs. The temperature variation of this river as shown in table 5 iies between 8°C and 24°C, so that during the summer months, the water will be lighter by 0.17%. Now in table 5 the data for the year 1956 is given. During this year the heavy sediment load was observed during July, August and September which are the heavy sediment bearing months when the sediment order rises from 2 to 8 gms. per litre, so that if 52% sand is removed the weight of water with silt and clay will be slightly more than the loss in weight due to rise of temperature. It thus seems that in Mangla storage the possibility of density currents will not be as hopeful as in the case of Tarbela. May be in a year of specially heavy sediment order, density currents are formed with possibility of exclusion of some order of sediment. In this storage there is, however, one more defect. The storage has four prongs, two of these in Khad and Kanshi rivers will be much less active. The storage in the Poonch will have the inflow of the river and so will be the main flow of the Jhelum. While depleting, the storage flow from all the prongs will take place and thus distrupting the tranquil flow so very necessary for density currents.

This action will cause turbulence and density currents will not remain effective. It seems that in Mangla, there is less chance of effective density currents to develope. Perhaps a special type of model tests with properly controlled temperature of water and silt charge may give some insight into the development of density currents although such model shall have to be very carefully designed.

Conclusions :—

The following are the main conclusions of the study.

1. Tarbela and Mangla Dams well compare with the other big dams of the world, constructed on high order sediment transporting rivers. It appears that their efficiency to trap sediment will be equally high ranging between 85 and 95% of the total inflow.
2. The original estimate of the sediment discharge of the Indus at Durband based upon a year of observation from June, 1954 to October, 1955 was found equal to 180 M. tons per year constituting 63% sand. 29% silt and 8% clay. The latest observations spread on a period of 92 years have shown that sediment load at Tarbela will go up to 345.0 M. tons (including that of Siran river also), the percentage of the constituents of the sediments, however, remaining the same. On this basis a storage of 7.8 M. acres may last for about fifty & sixty (50 & 60) years.
3. The shape of the storage will be that it will have a 12 miles long prong in Siran river and about 45 miles long prong in the Indus itself but this prong upto a length of 30 miles will constitute narrow stream more than 100 ft. deep and having a significant order of velocities. Under the present conditions of flow the velocities go upto 17 ft. per second during high flow periods.

The wide storage will exist withing 15 miles of the dam. The spillway is to possess 28 conduits each 6×12 ft. placed at 265 ft. below the top level of the gates and with the discharging capacity upto 180,000 cusecs.

4. The range of variation of temperature of river water lies between 4.5°C to 17.5°C, so that water of the months of July and August which indcidently possesses a high order of sediment will be lighter but the sediment content of 2.0 to 4 gm. per litre will increase its density. Due to the shape of the storage it appears that sand will get deposited just 15 miles upstream of the dam, there will be a possibility of development of density currents, forming a thin stream within the stored water and taking away all the clay and perhaps a portion of the silt as well. It is presumed that there are chances to exclude 10% of the clay and a part of the silt and thus saving the nation a portion of 5.0 crores which is otherwise to be a loss to the nation as a result of the depletion of the storage.

5. As for Mangla the author's estimate has put the annual sediment load at 77 M. tons per year which when considered for the flow data of 35 years has been found to be 61.0 M. tons constituting 52% of sand, 39% of silt and 12% of clay. The life expectancy for a 5.35 M. acres storage has put at 130 years, so that the yearly loss due to sediment will amount to Rs. 1.4 crores.

6. The storage is to consist of four prongs, the main one being in Khad river having little in-flow the second prong of slightly less magnitude will lie within the catchment of the Poonch which is considerably in action during the summer and the third prong is to lie in the catchment of the Kanshi which is active only as a result of Monsoon rain. The fourth prong of the storage is to lie in the main river which will extend to about 35 miles upstream and will be a narrow and deep stream. The wide storage will exist within 12 miles from the location of the dam.

7. The range of temperature variation of the river lies between 8°C and 24°C, so that summer water will be 0.17% lighter than the winter water. Now during summer the sediment rises to 2 to 6 gms. per litre and in high flood the sediment content rises still higher. The 20 miles long storage in the main river is narrow and will have velocities sufficient to transport a portion of the sand into the wide storage, so that silt and clay bearing water will move into the 10 miles long storage close to the 30 ft. diameter tunnels discharging in certain months upto 35 thousand cusecs. After depositing 52% sand, the density of water having silt and clay will be slightly more than the decrease in density as a result of rise in temperature. Thus on this storage there appears to be less possibility of development of density currents as inflow from the rest of the prongs during depletion of the storage will be a disturbing factor up-setting the tranquil flow so very necessary for development of the density currents.

It is concluded that decrease in efficiency as a result of density current may not be as efficient in Mangla storage as in the case of Tarbela Dam.

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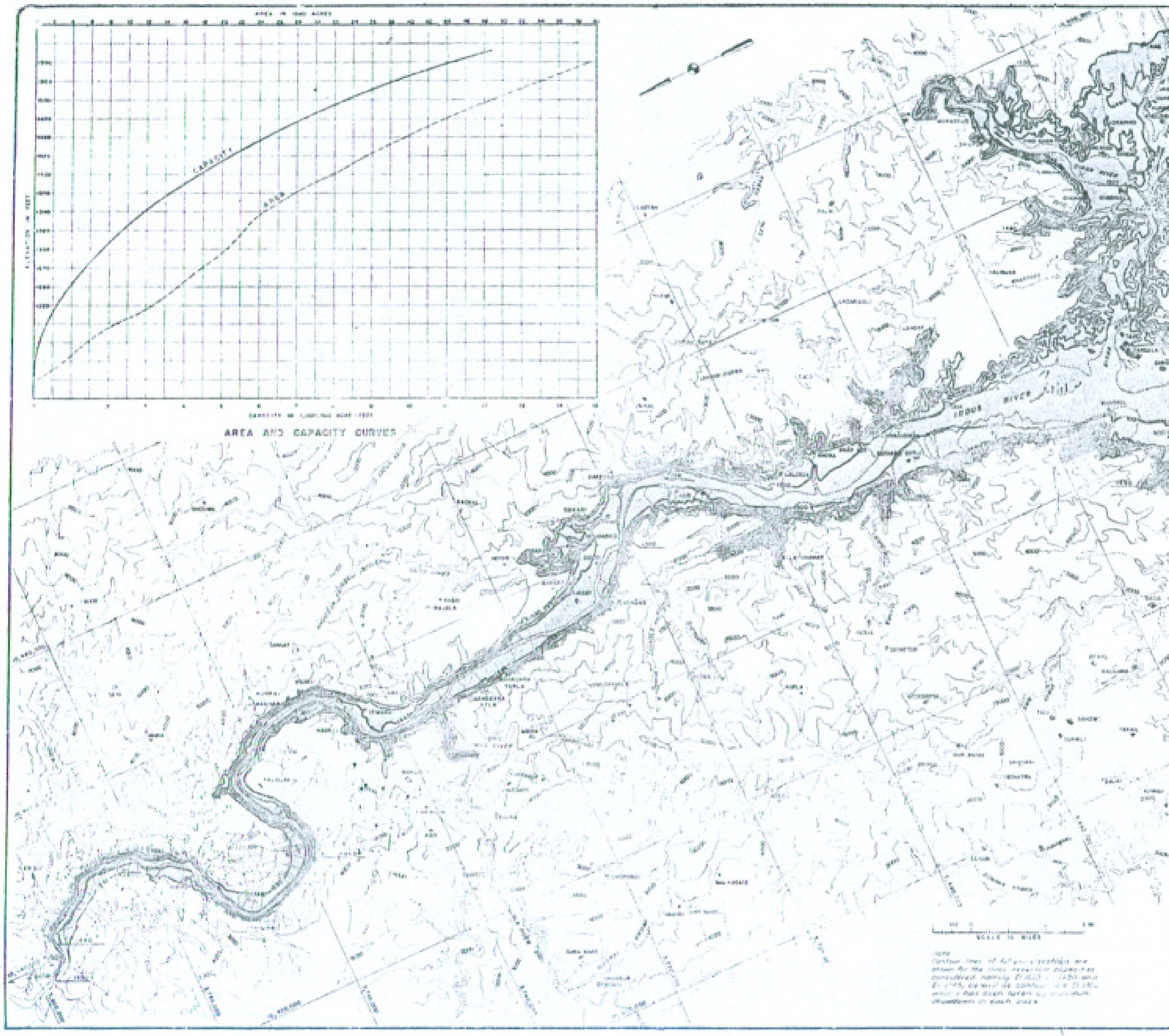
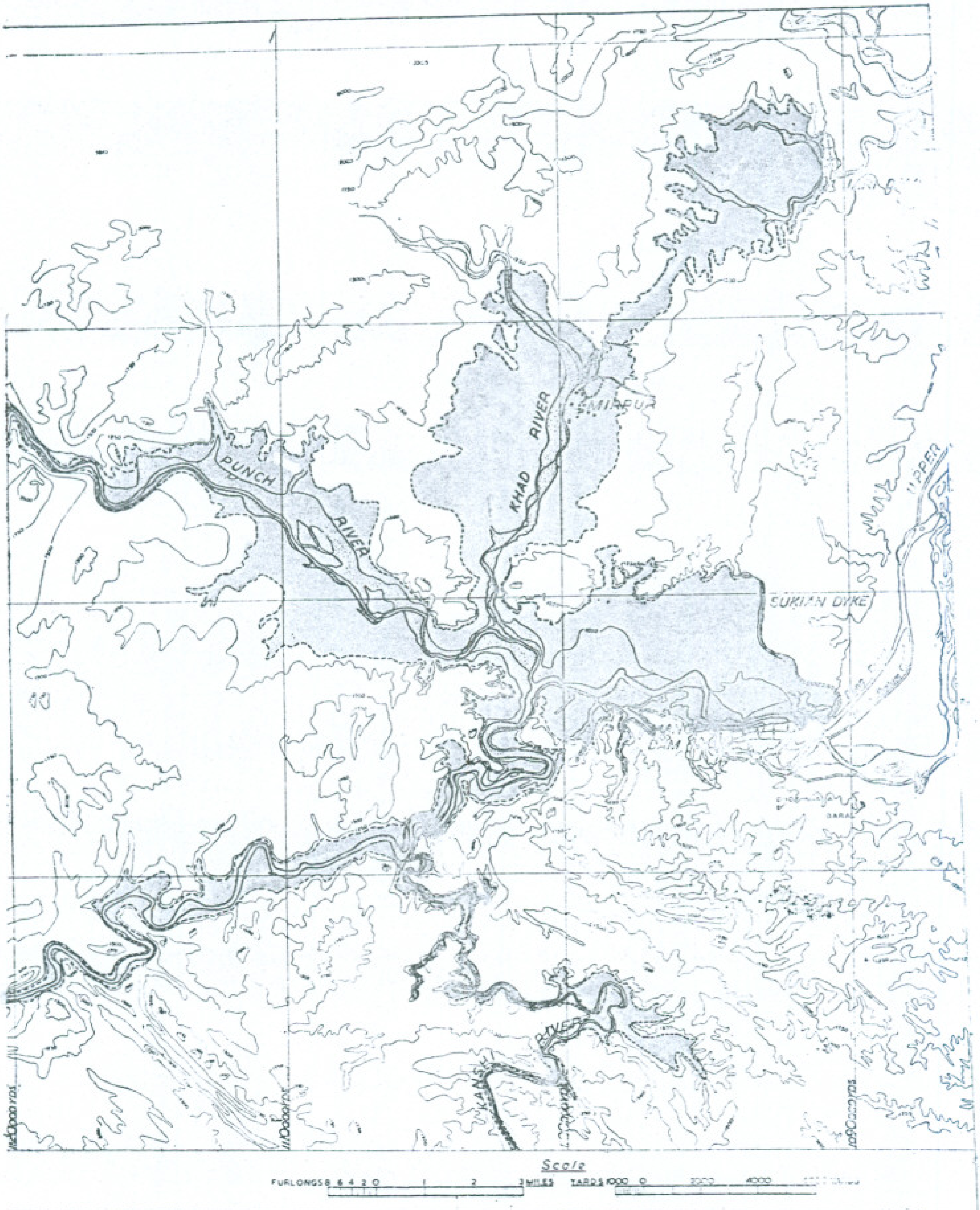


FIG 9

RESERVOIR MAP


PUNCH RIVER
KHAD RIVER
MIRPUR
SUKIAN DYKE
UPPER
Scale
FURLONGS 8 6 4 2 0 1 2 3 MILES
YARDS 1000 0 2000 4000