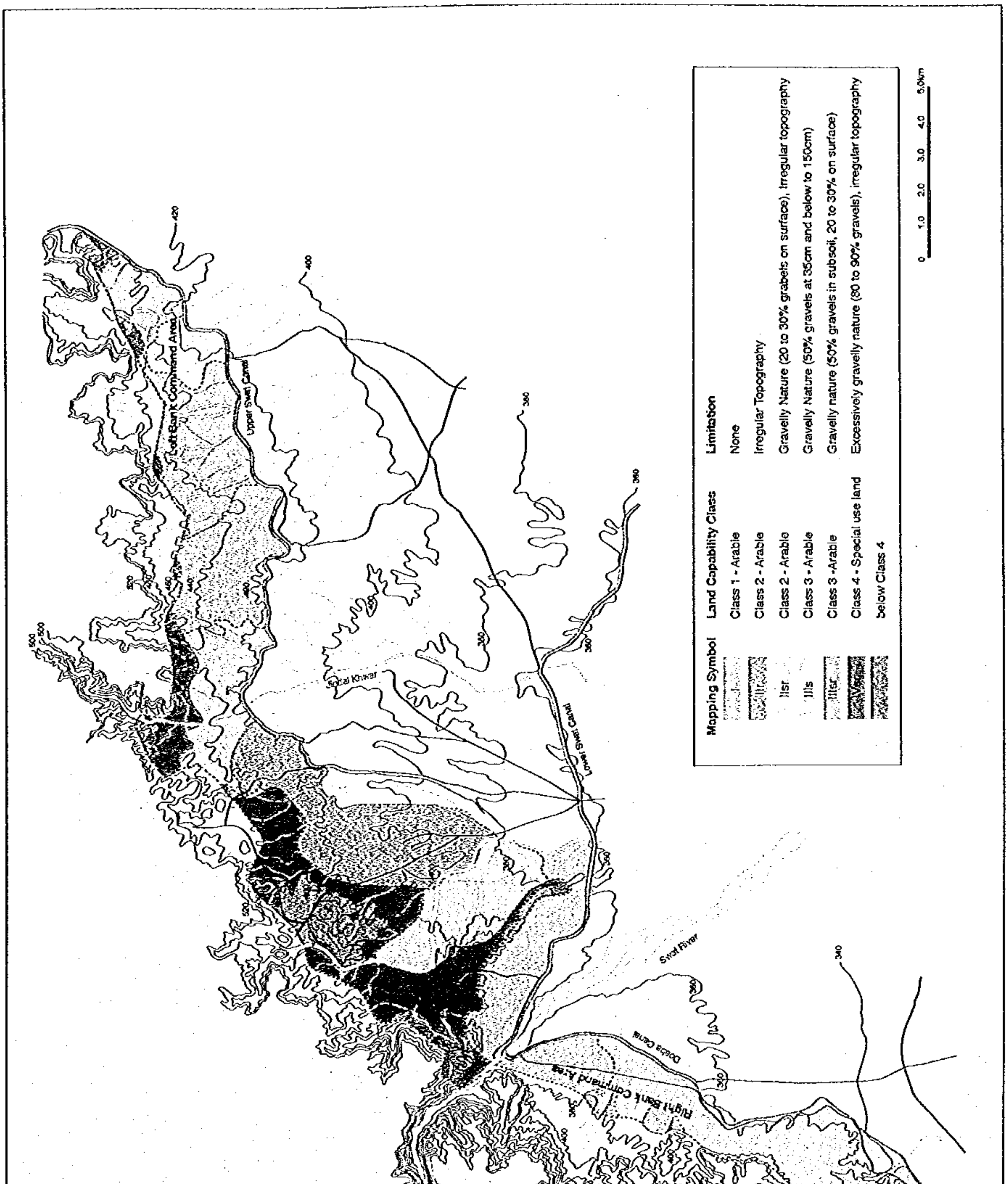
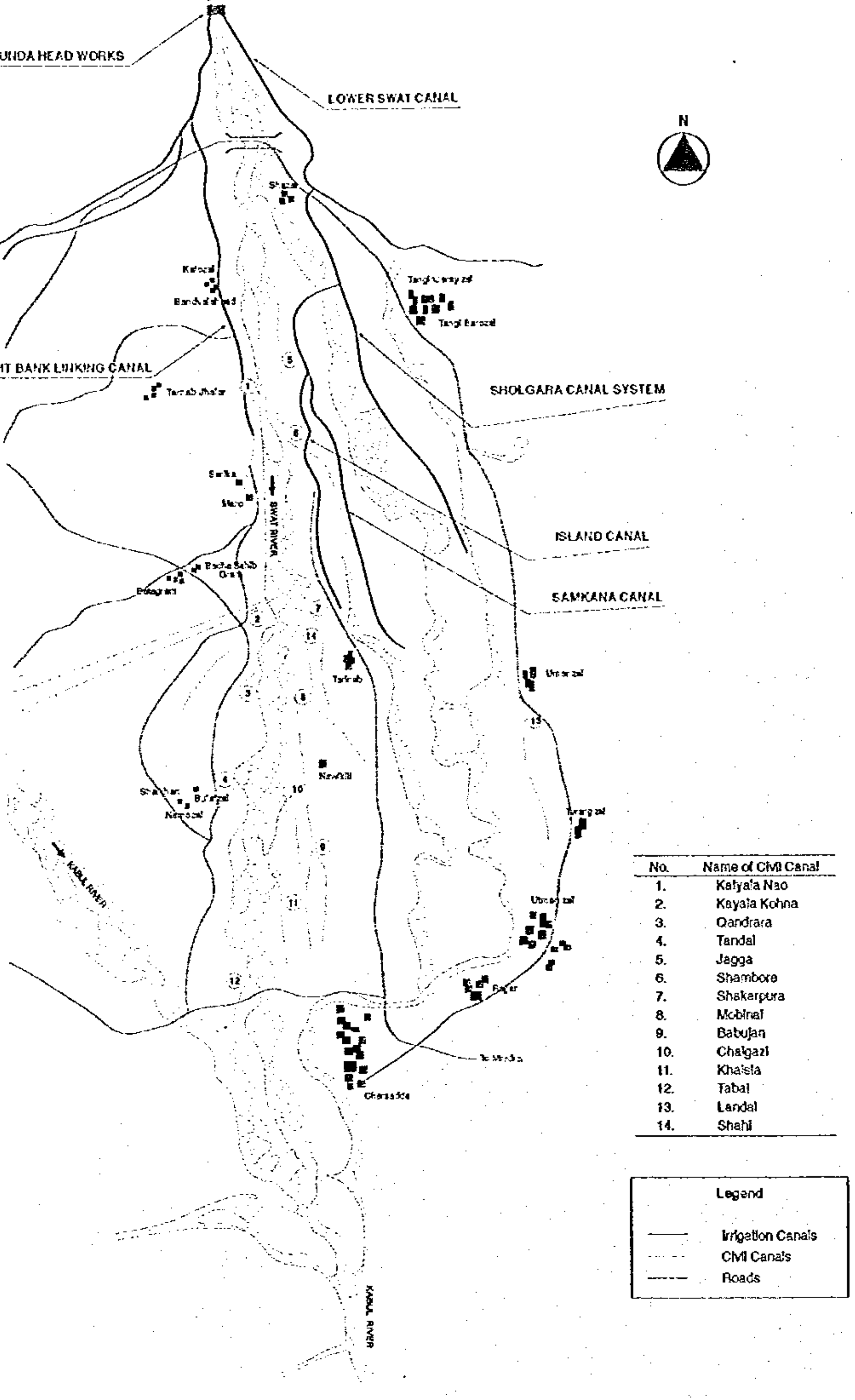
APPENDIX E

FIGURES



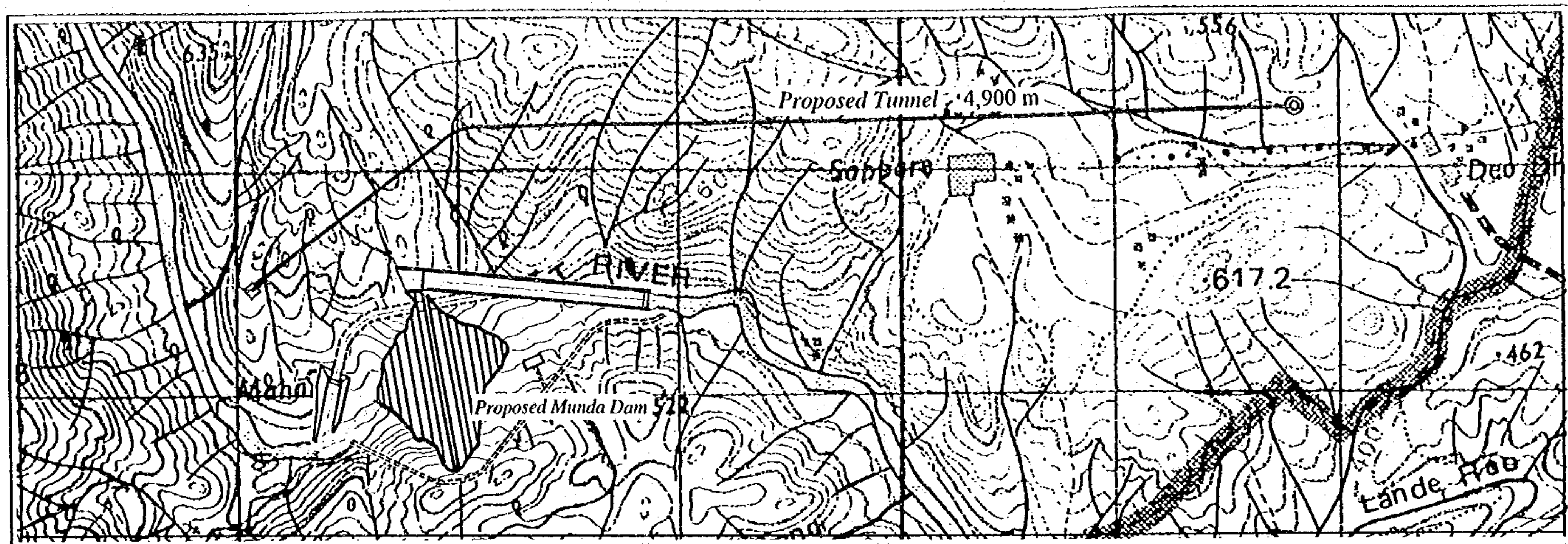
FEASIBILITY STUDY ON THE DEVELOPMENT OF MUNDA DAM MULTIPURPOSE PROJECT IN ISLAMIC REPUBLIC OF PAKISTAN	**Figure E1.1** **Command-wised Land Capability Classes**
JAPAN INTERNATIONAL COOPERATION AGENCY	

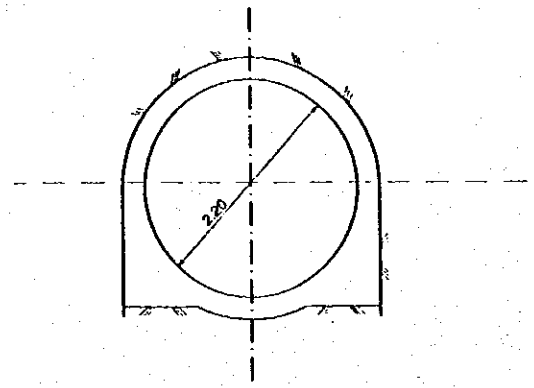


FEASIBILITY STUDY ON THE DEVELOPMENT OF MUNDA DAM MULTIPURPOSE PROJECT IN ISLAMIC REPUBLIC OF PAKISTAN	Figure E3.1 Location of Civil Canals downstream of Munda Head Works
JAPAN INTERNATIONAL COOPERATION AGENCY	

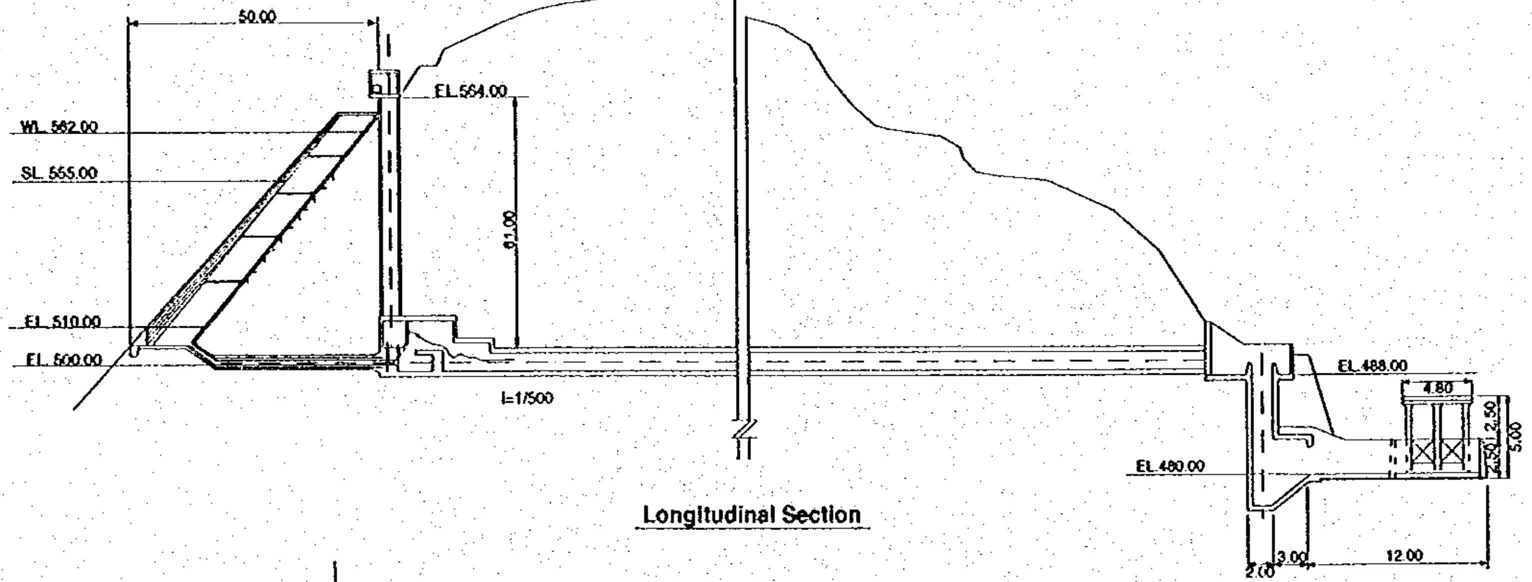
APPENDIX E

DRAWINGS

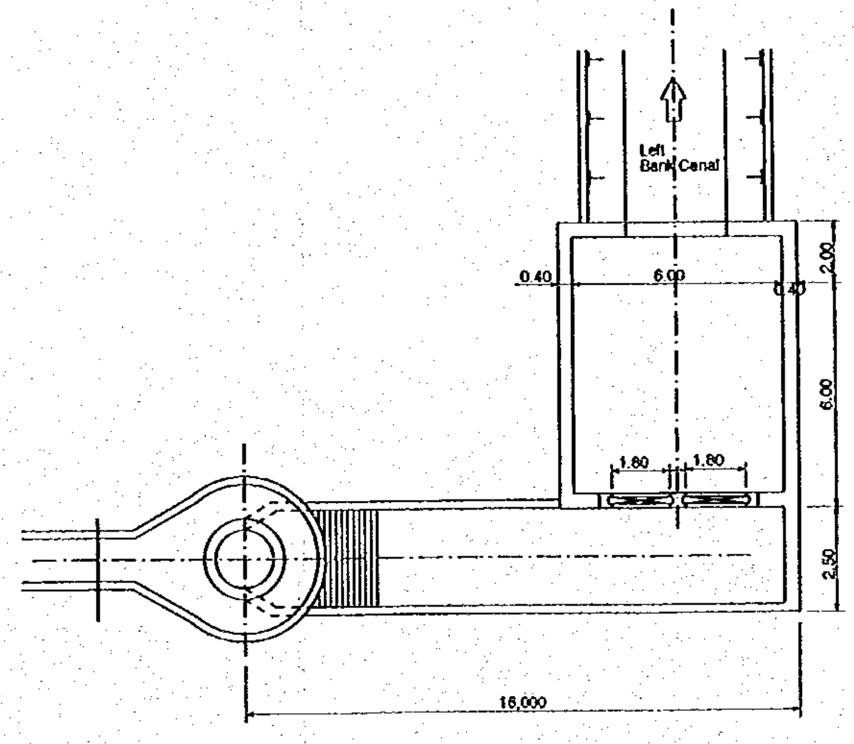




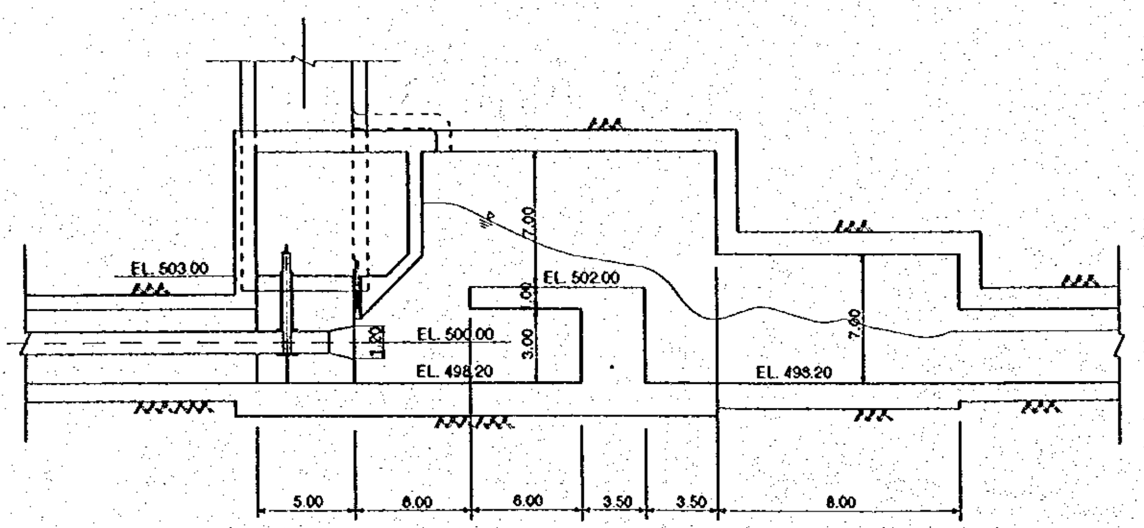
Typical Tunnel Section



Longitudinal Section



Plan of Link Section



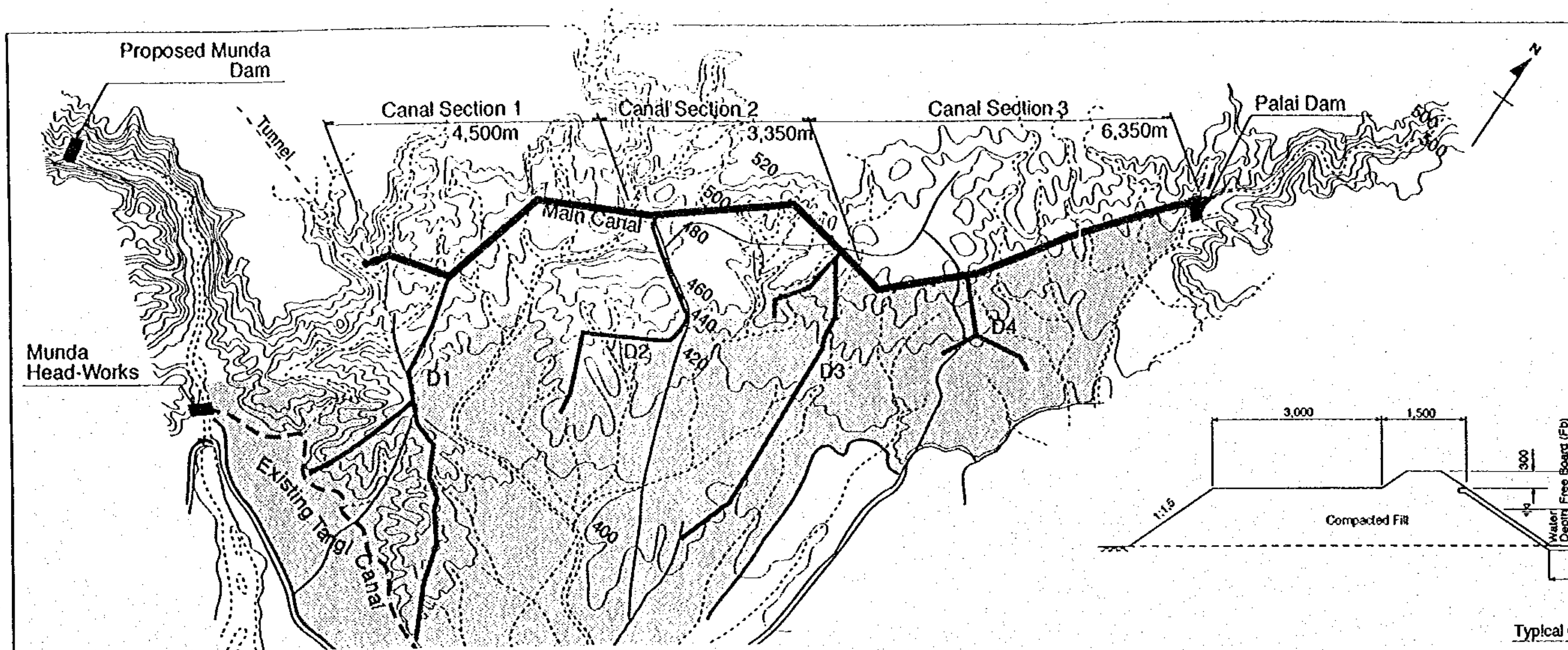
Detail of Energy Dissipator

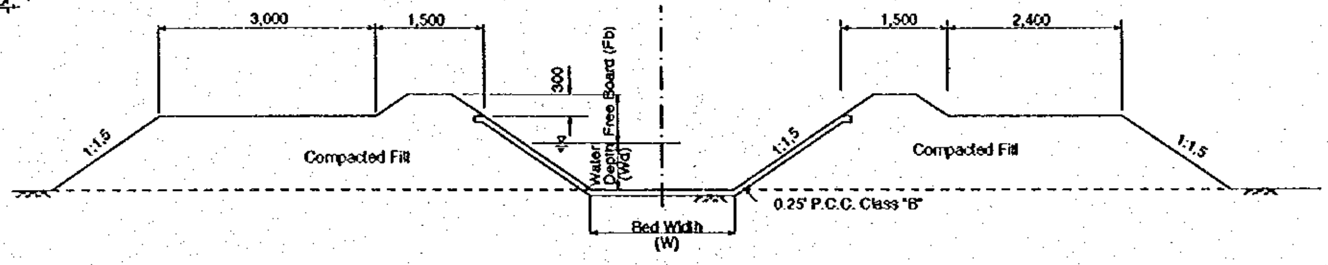
FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

JAPAN INTERNATIONAL COOPERATION AGENCY

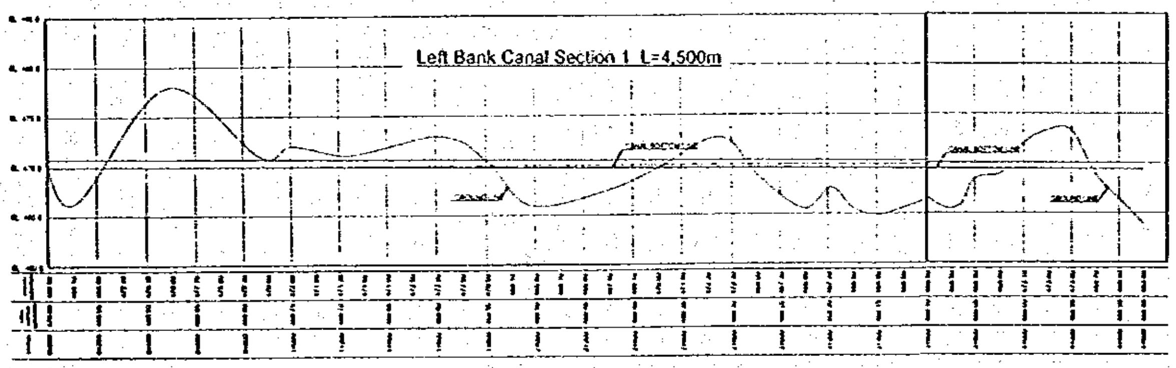
DWG. I01

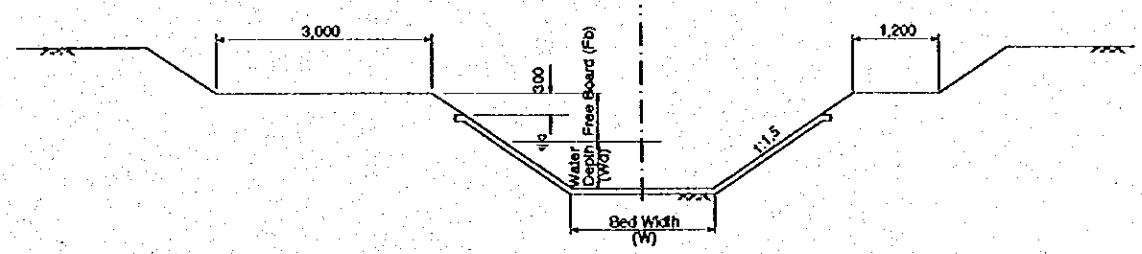
Feeder Tunnel of Left Bank Area



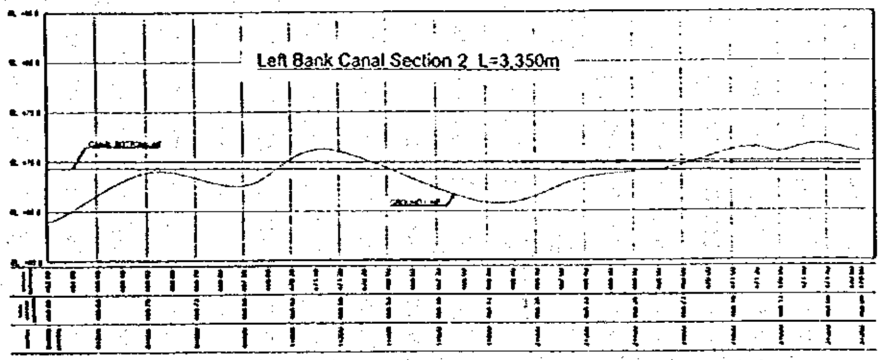


Typical Canal Section In Filling

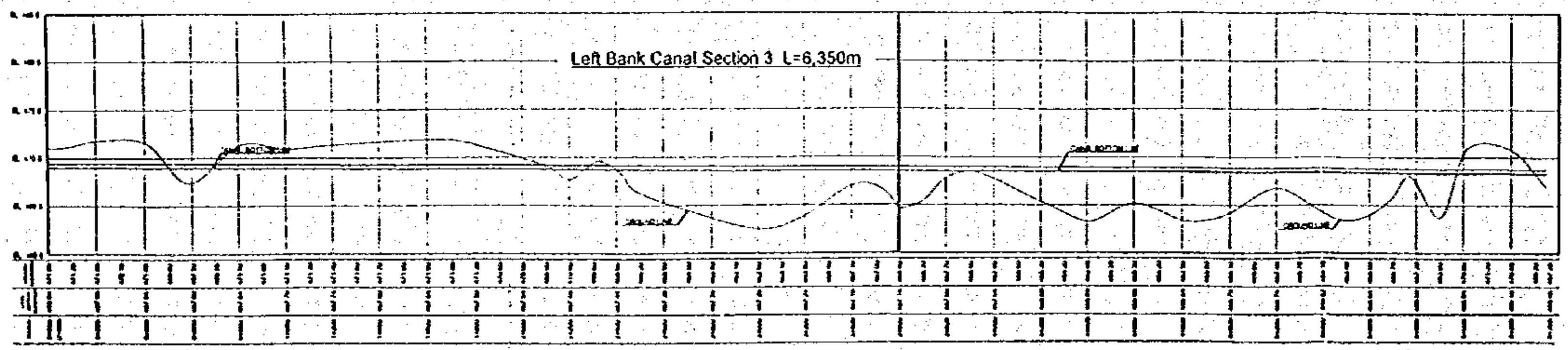




Typical Canal Section In Cutting



Canal-section	Q(m3/s)	N	Bed Slope	W(m)	Wd(m)	Fb(m)
Main Canal						
Section 1	4.391	0.016	1/4,000	2.00	1.083	0.55
Section 2	2.501	0.016	1/4,000	1.50	0.872	0.54
Section 3	1.016	0.016	1/4,000	1.00	0.656	0.54
Distributary						
D1	1.890	0.016	1/4,000	1.20	0.842	0.54
D2	0.345	0.016	1/4,000	1.00	0.378	0.54
D3	1.140	0.016	1/4,000	1.00	0.695	0.54
D4	0.486	0.016	1/4,000	1.00	0.452	0.54

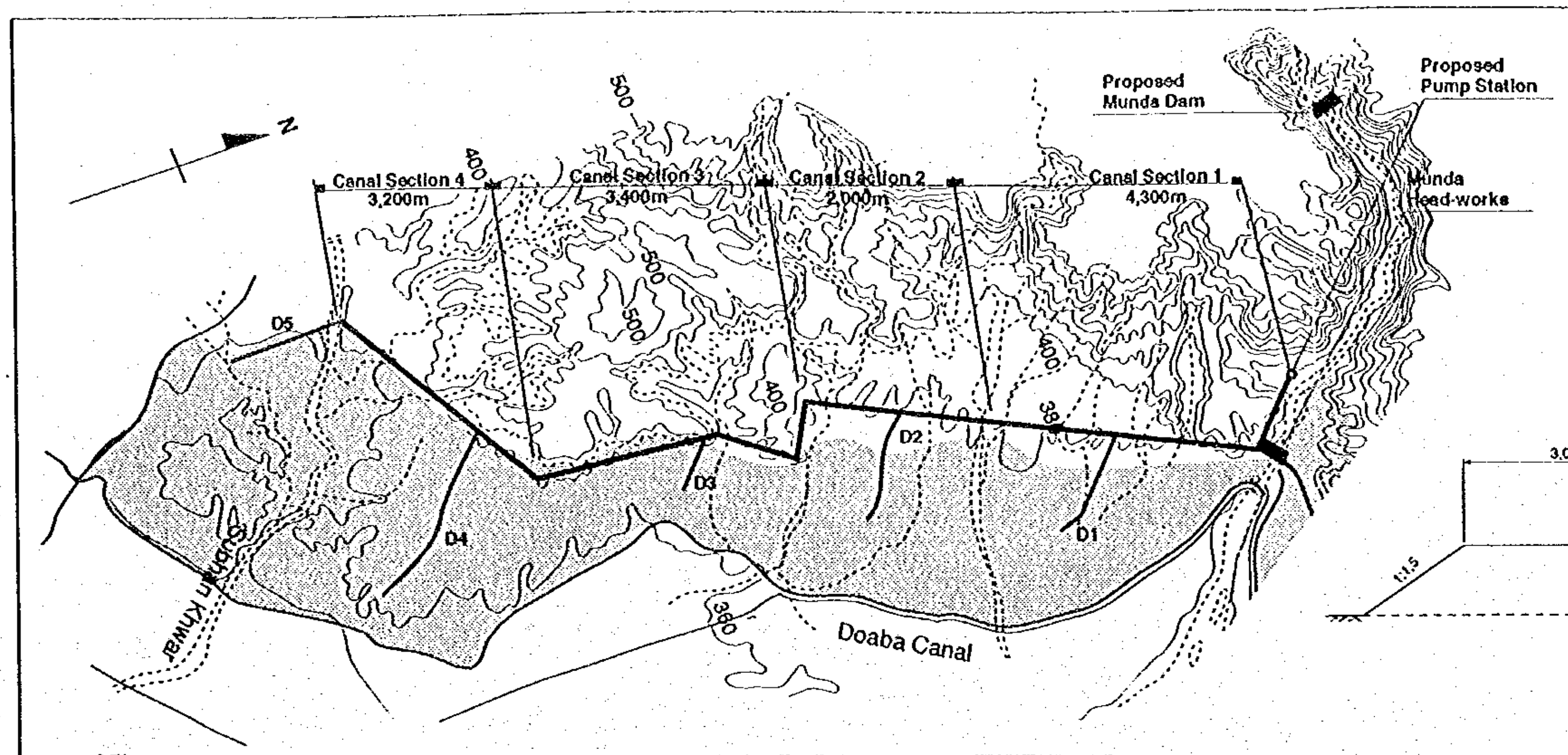


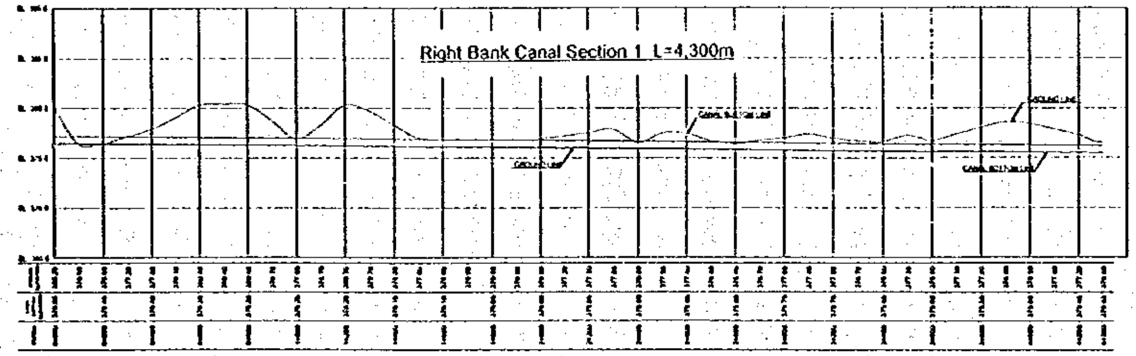
FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

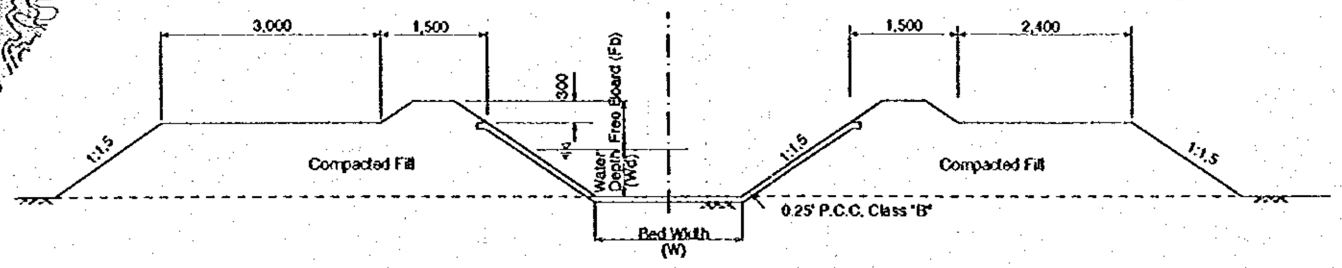
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. I02

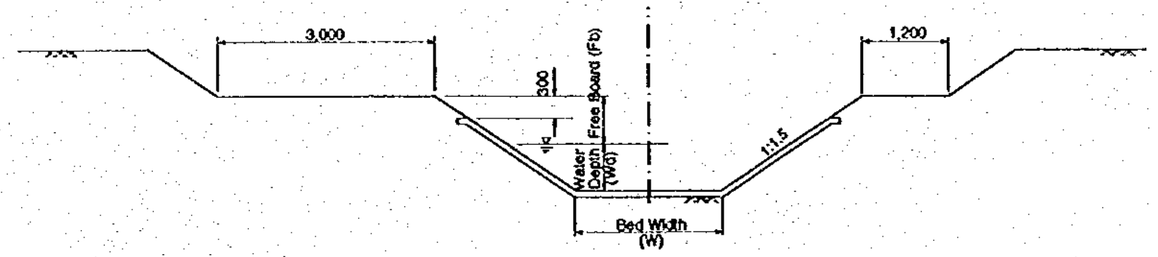
Left Bank Canal



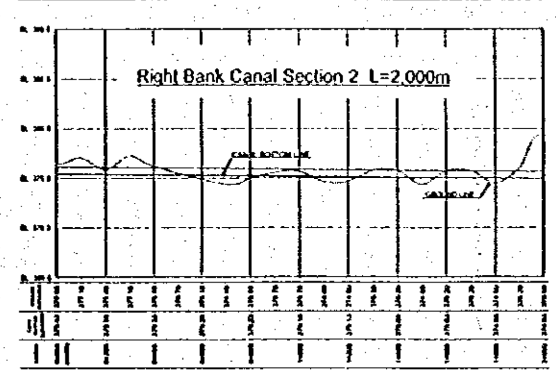


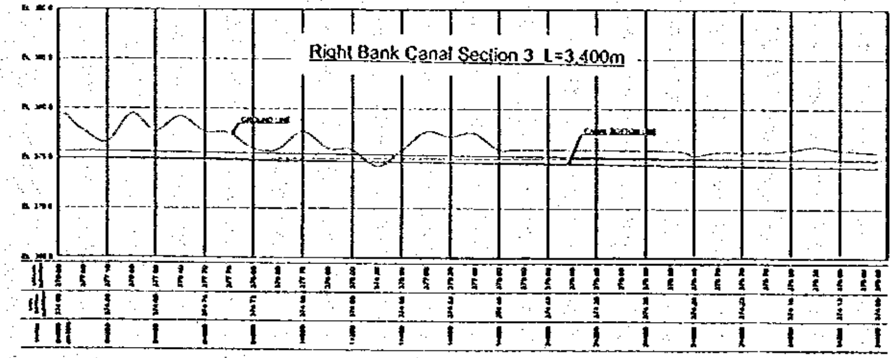


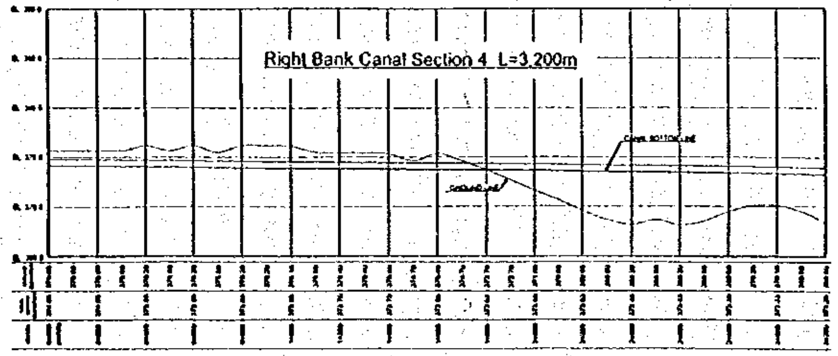
Typical Canal Section in Filling



Typical Canal Section in Cutting







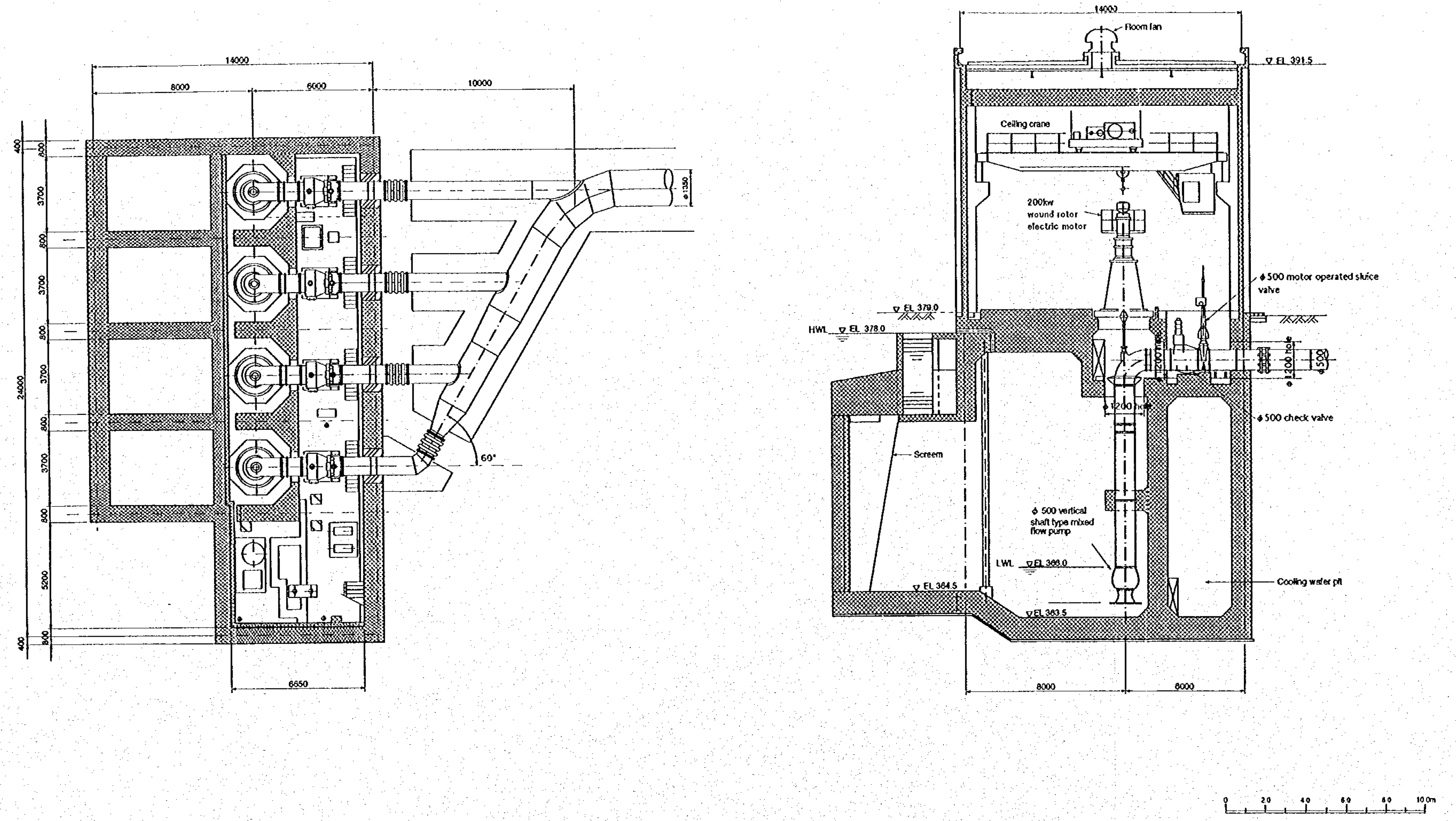
Canal-section	Q(m3/s)	N	Bed Slope	W(m)	Wd(m)	Fb(m)
Main Canal						
Section 1	2.204	0.016	1/4,000	1.50	0.845	0.55
Section 2	1.821	0.016	1/4,000	1.20	0.826	0.54
Section 3	1.548	0.016	1/4,000	1.20	0.763	0.54
Section 4	1.316	0.016	1/4,000	1.20	0.703	0.54
Distributary						
D1	0.382	0.016	1/4,000	1.00	0.399	0.54
D2	0.273	0.016	1/4,000	1.00	0.333	0.54
D3	0.232	0.016	1/4,000	1.00	0.305	0.54
D4	0.879	0.016	1/4,000	1.00	0.611	0.54
D5	0.437	0.016	1/4,000	1.00	0.428	0.54

FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. I03

Right Bank Canal

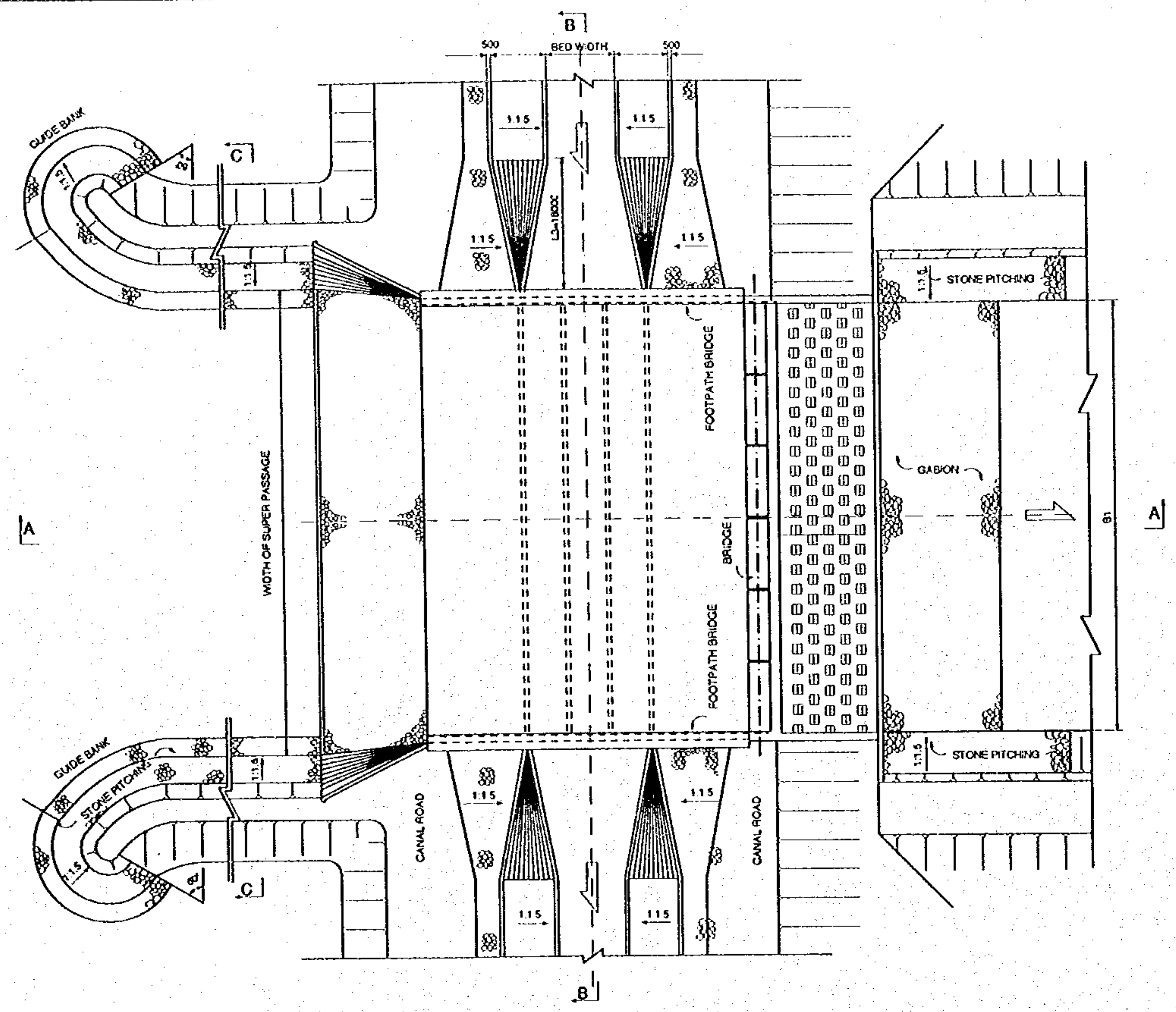


FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

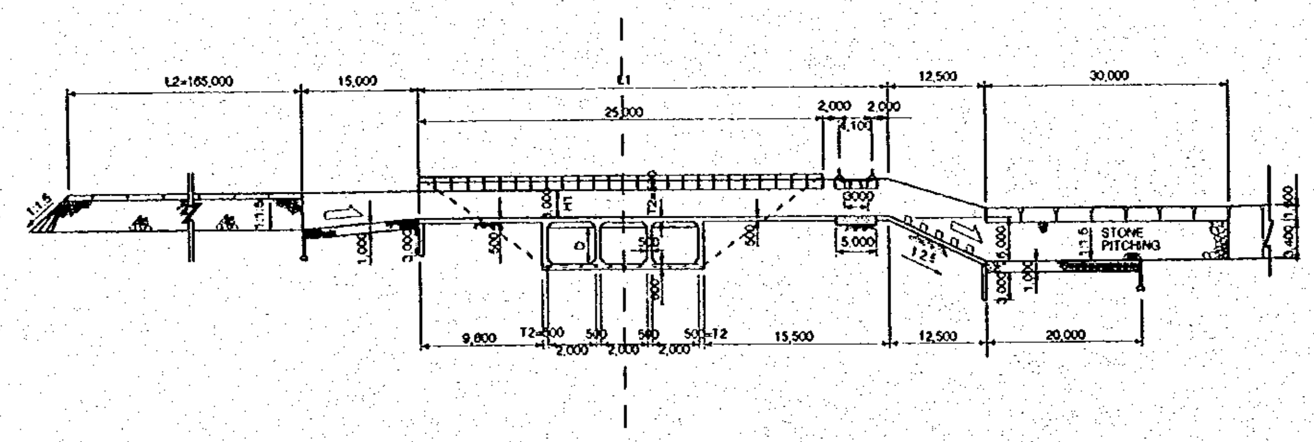
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. 104

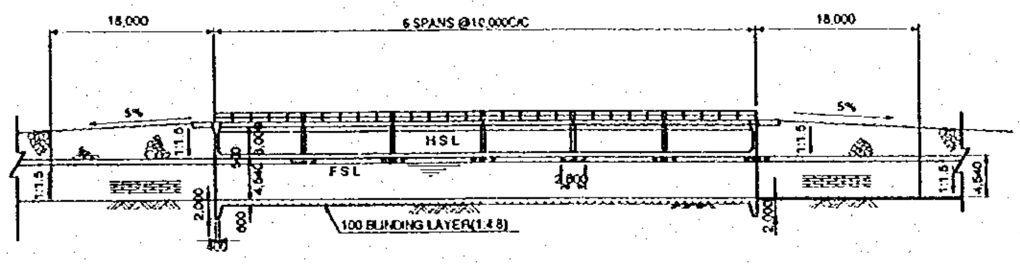
Pump Station (Right Bank Area)



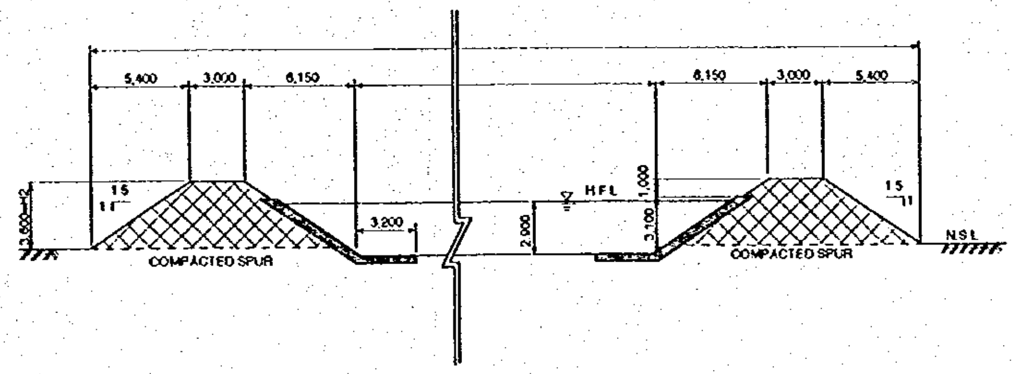
PLAN



SECTION A-A

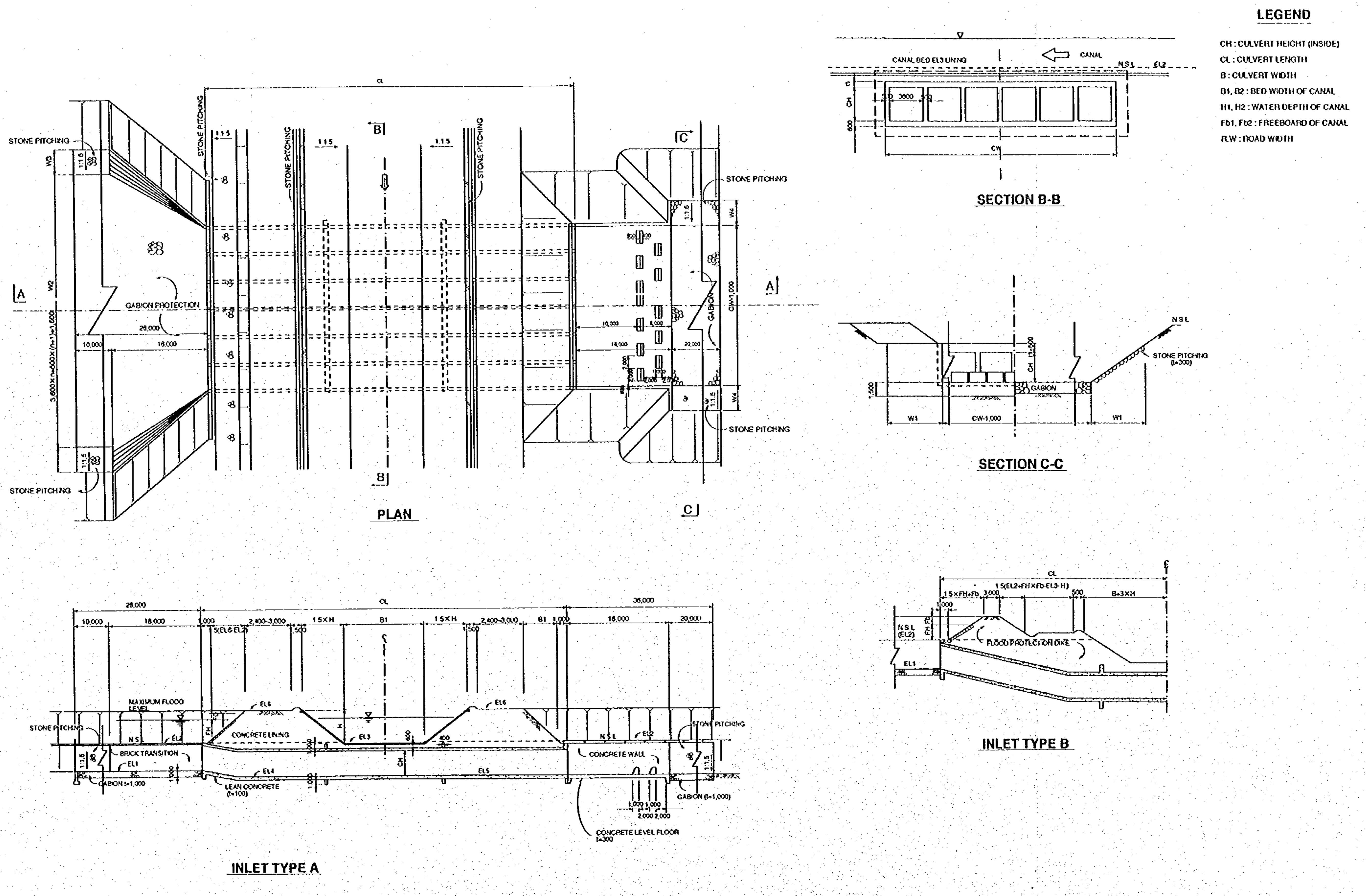


SECTION B-B



SECTION C-C

FEASIBILITY STUDY ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT IN ISLAMIC REPUBLIC OF PAKISTAN	DWG. 105 Super Passage Structure
JAPAN INTERNATIONAL COOPERATION AGENCY	



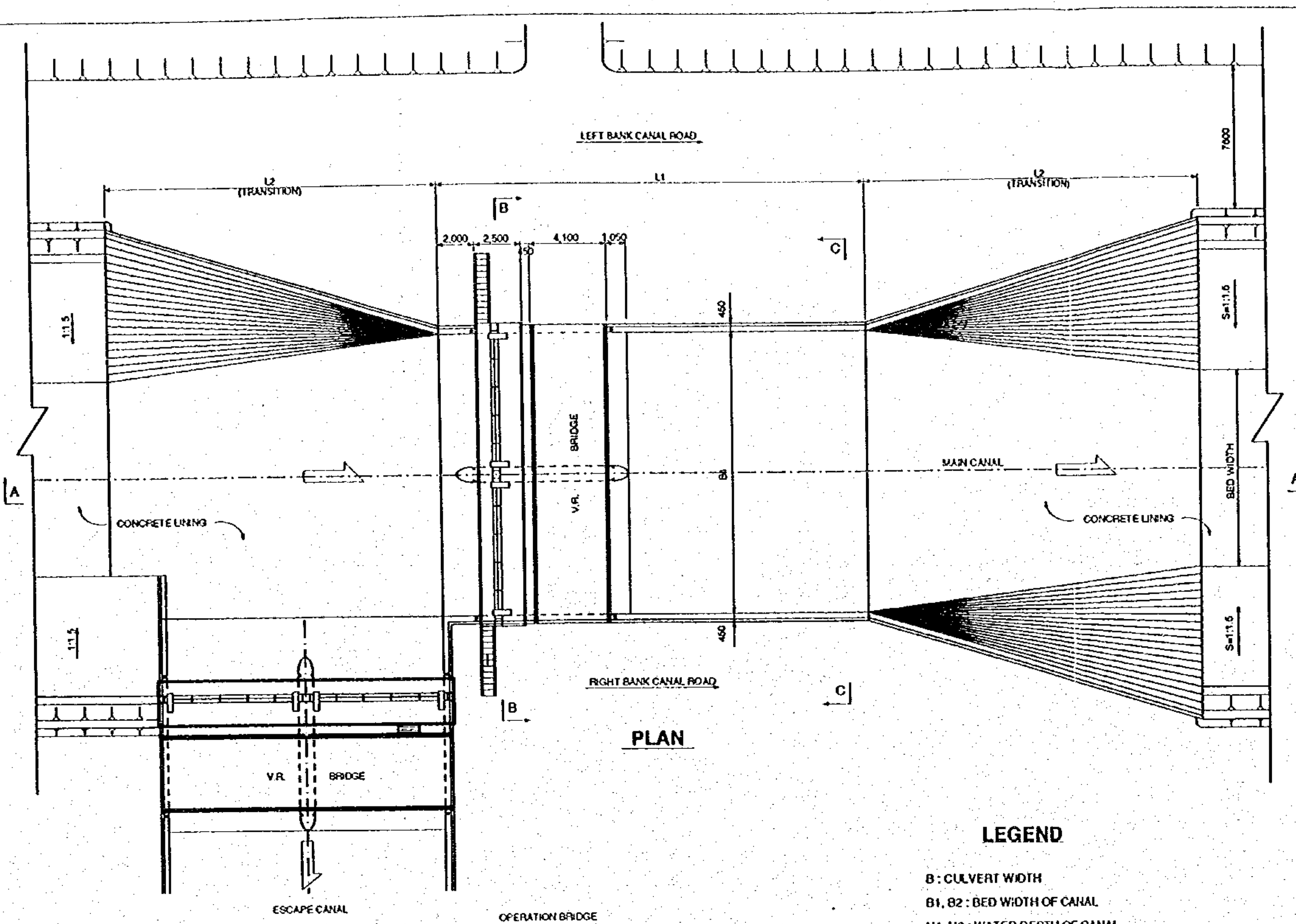
SECTION A-A

FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPURPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

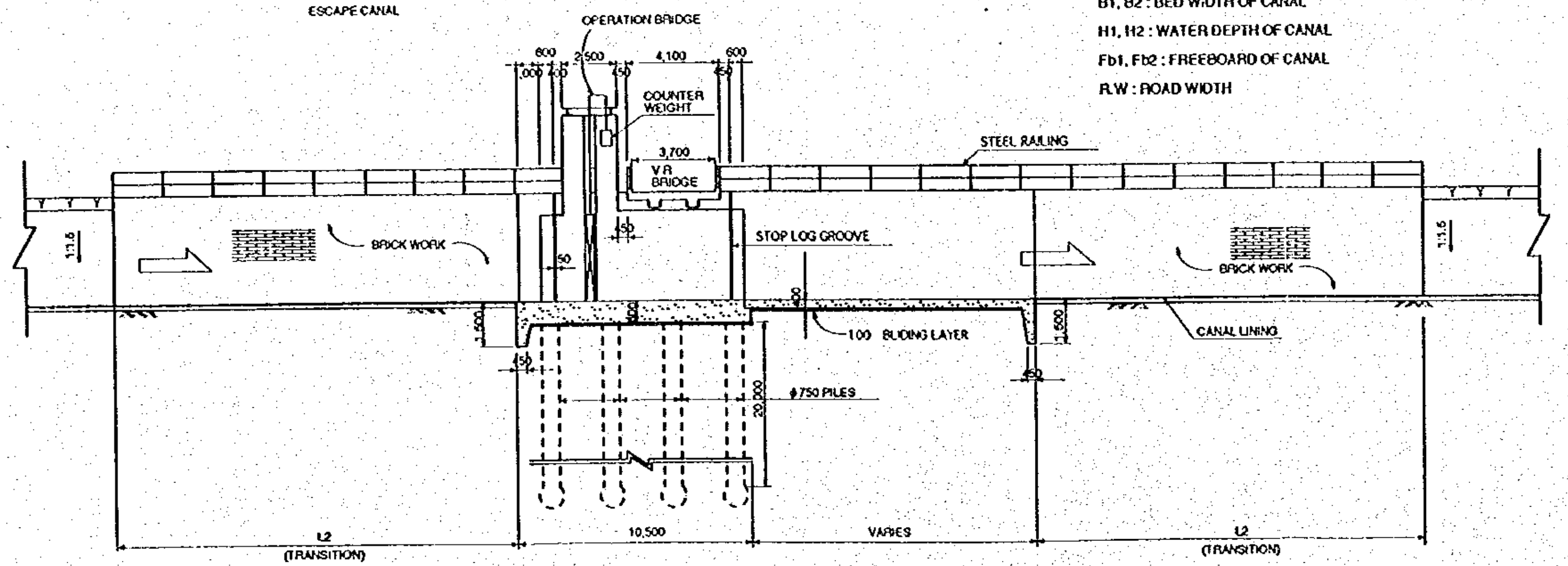
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. I06

Canal Culvert Structure



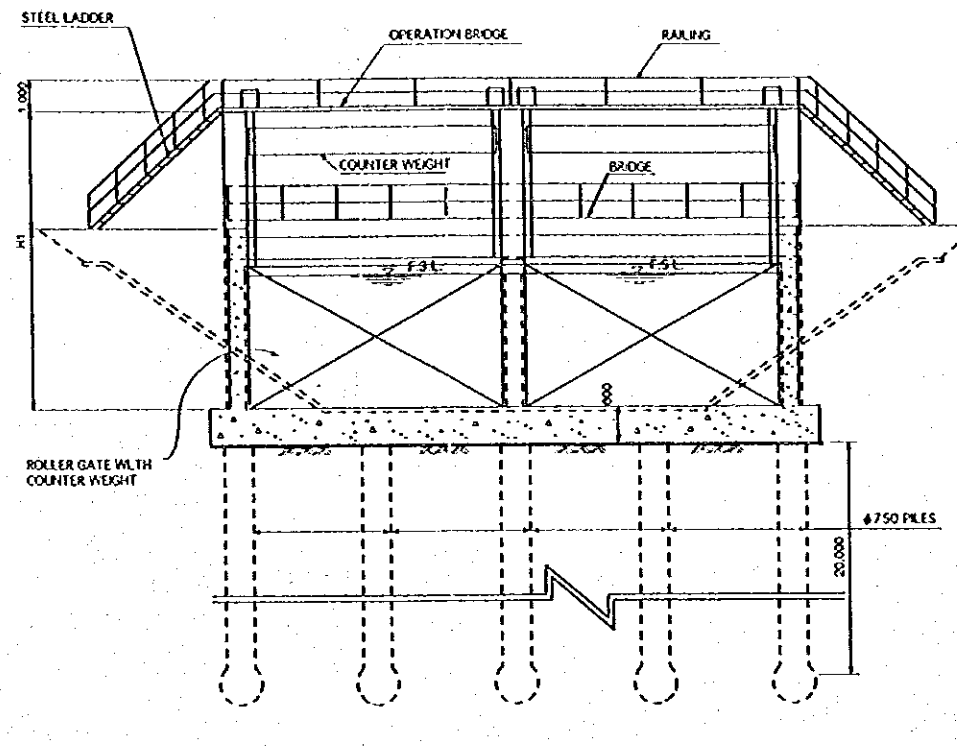
PLAN



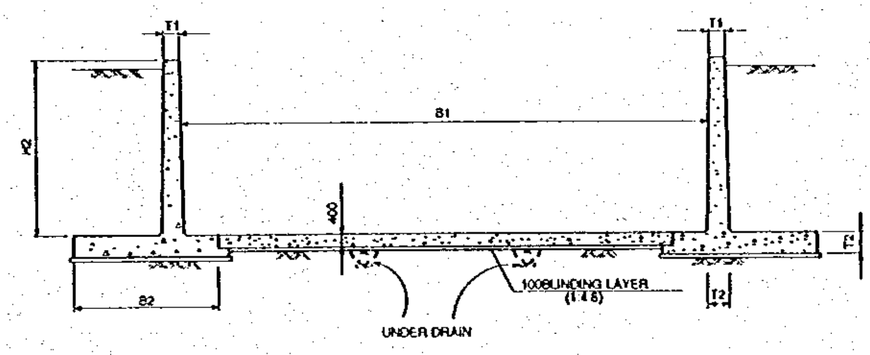
SECTION A-A

LEGEND

B : CULVERT WIDTH
B1, B2 : BED WIDTH OF CANAL
H1, H2 : WATER DEPTH OF CANAL
Fb1, Fb2 : FREEBOARD OF CANAL
R.W : ROAD WIDTH



SECTION B-B



SECTION C-C

DIMENSION TABLE

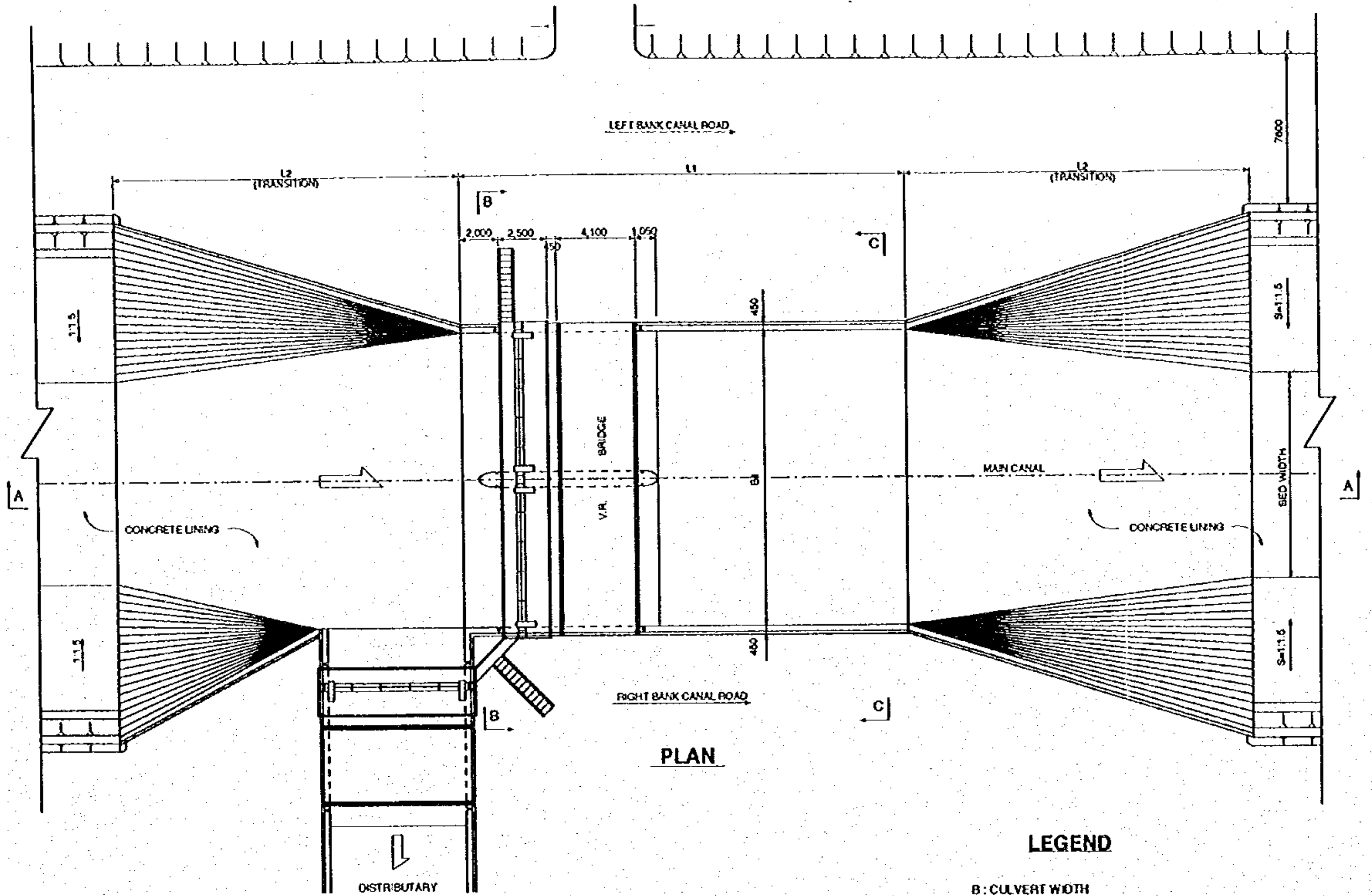
CANAL TYPE	WATER DEPTH [illegible]	NO. OF GATES	HEIGHT OF OPERATION BRIDGE [illegible]	GATE SIZE	THROAT WIDTH [illegible]	THROAT LENGTH [illegible]	TRANSITION LENGTH [illegible]	HEIGHT OF RETAINING WALL [illegible]	BASE OF [illegible]	BASE THICKNESS [illegible]	TOP THICKNESS [illegible]
1	above 1,000	2	4,000	3,000 x1,500	6,500	12,000	12,000	2,500	2,000	400	300
2	below 1,000	1	4,000	4,000 x1,200	4,000	10,000	10,000	2,500	2,000	400	300

FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

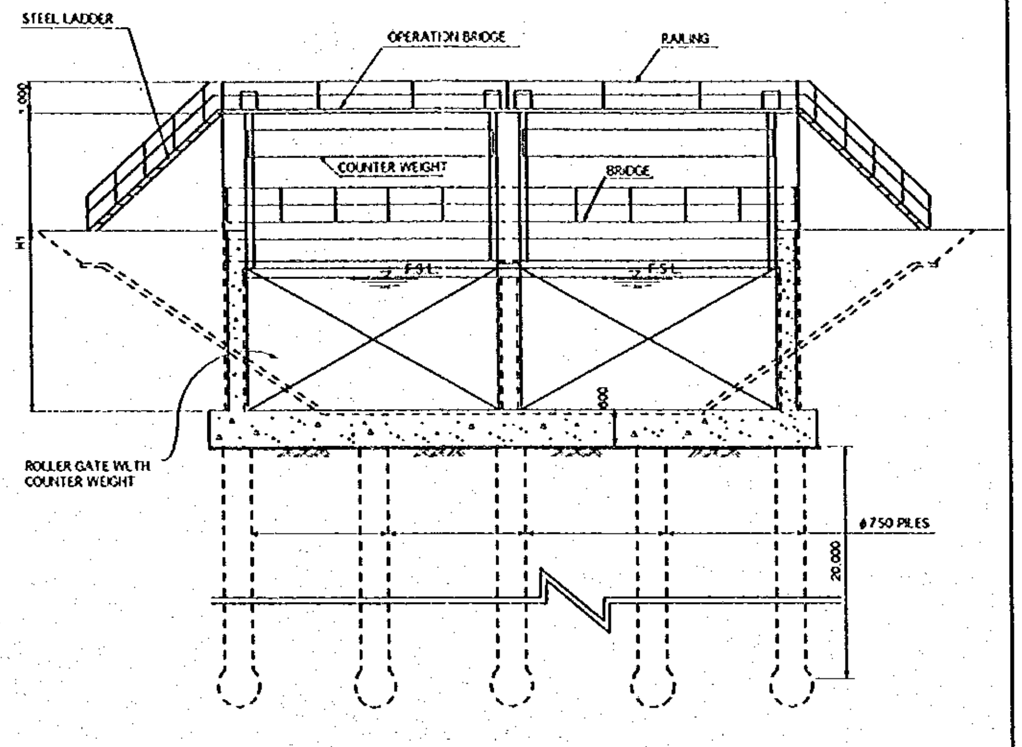
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. I07

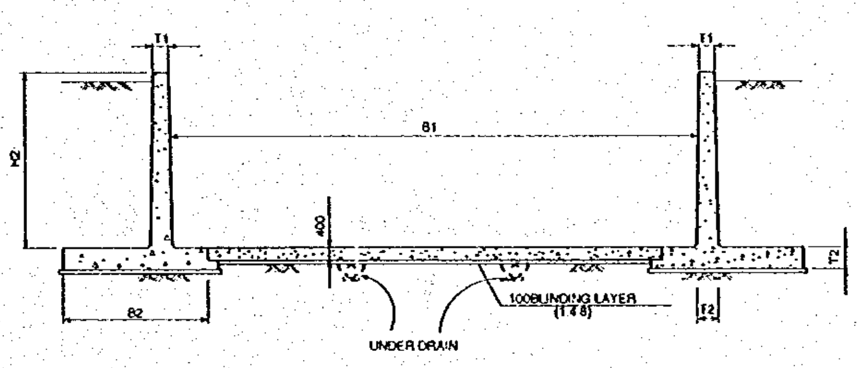
Escape Structure



PLAN



SECTION B-B



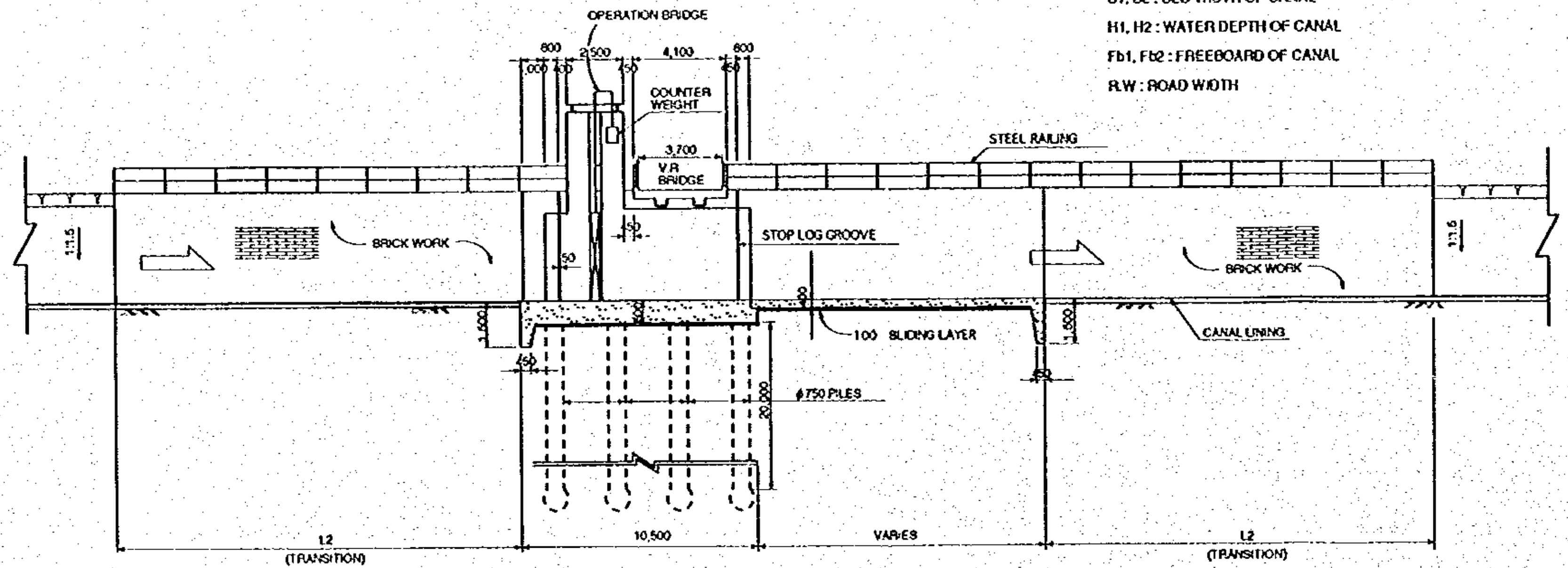
SECTION C-C

LEGEND

B : CULVERT WIDTH
B1, B2 : BED WIDTH OF CANAL
H1, H2 : WATER DEPTH OF CANAL
Fb1, Fb2 : FREEBOARD OF CANAL
R.W : ROAD WIDTH

DIMENSION TABLE

CANAL TYPE	WATER DEPTH (H)	NO OF GATES	HEIGHT OF OPERATION BRIDGE (H1)	GATE SIZE	THROAT WIDTH (B)	THROAT LENGTH (L1)	TRANSITION LENGTH (L2)	HEIGHT OF RETAINING WALL (H2)	BASE OF R.WALL (B2)	BASE THICKNESS (T2)	TOP THICKNESS (T1)
1	above 1,000	2	4,000	3,000 x 1,500	6,500	12,000	12,000	2,500	2,000	400	300
2	below 1,000	1	4,000	4,000 x 1,200	4,000	10,000	10,000	2,500	2,000	400	300



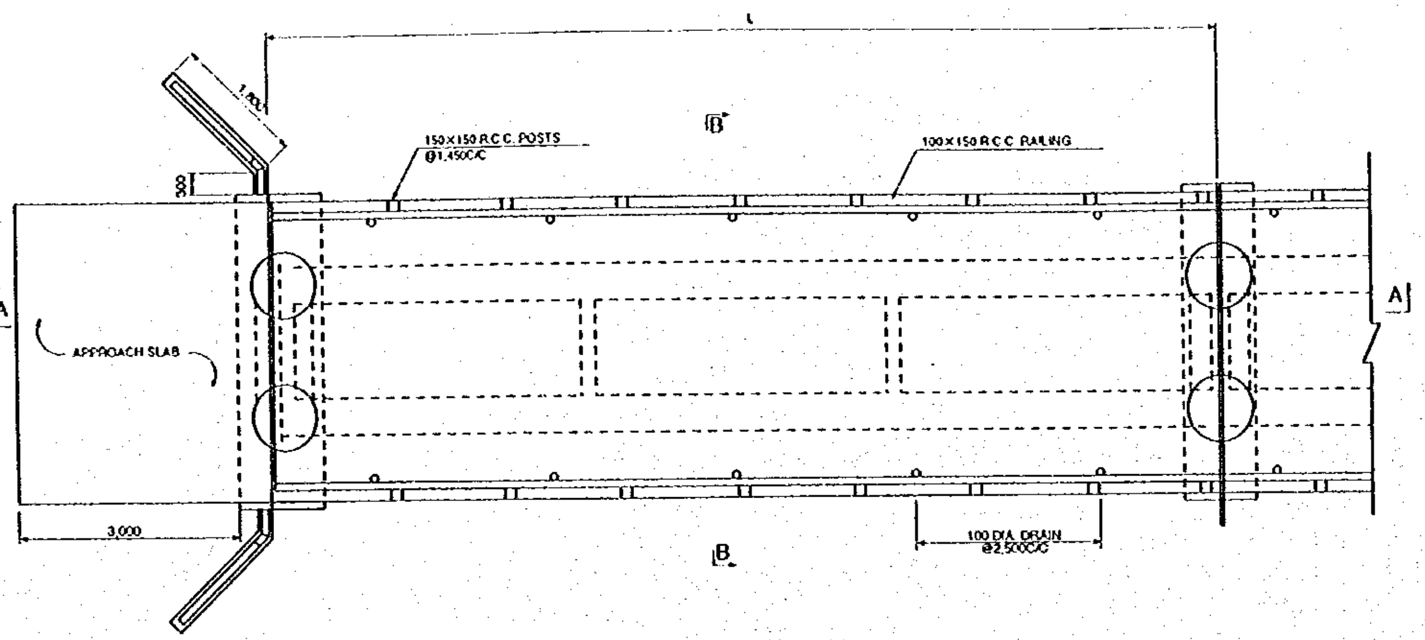
SECTION A-A

FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

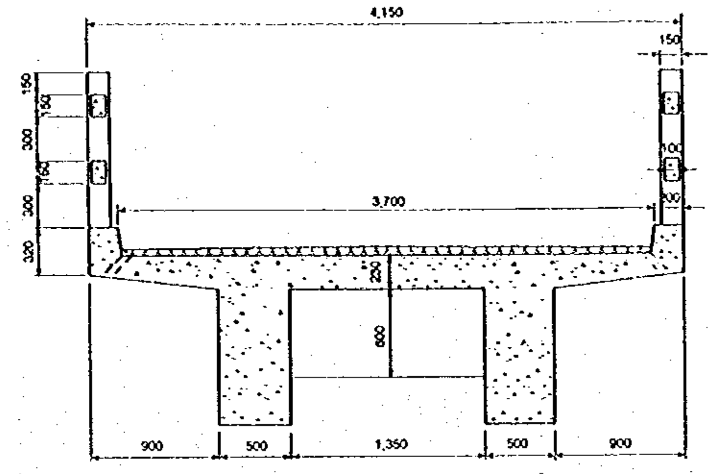
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. 108

Offtaking Structure



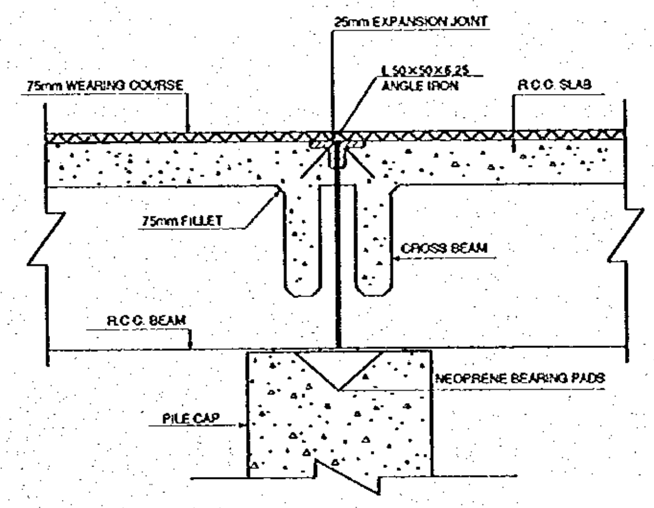
PLAN



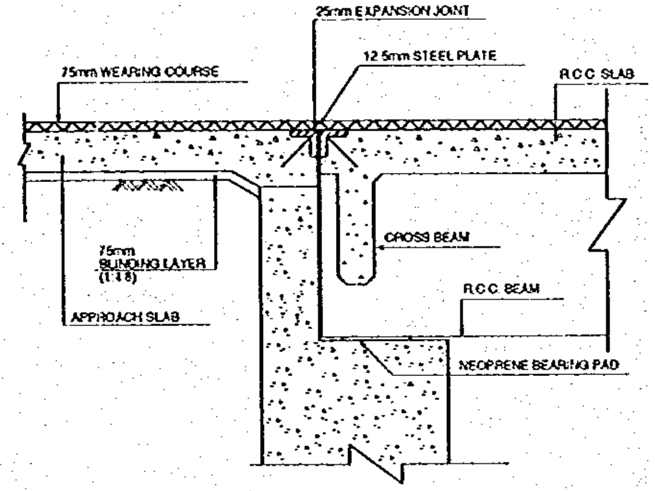
SECTION B-B

LEGEND

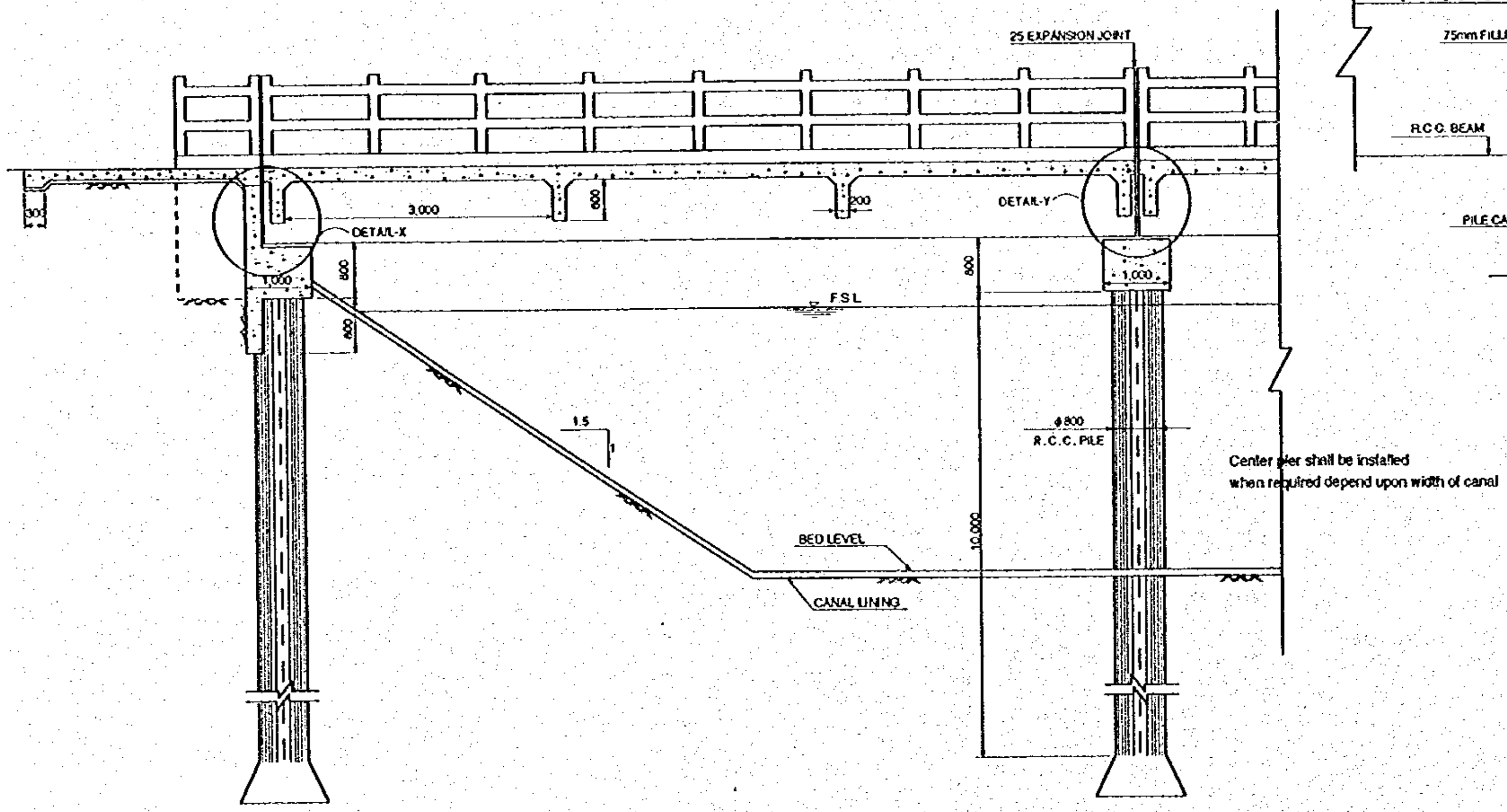
B : CULVERT WIDTH
B1, B2 : BED WIDTH OF CANAL
H1, H2 : WATER DEPTH OF CANAL
Fb1, Fb2 : FREEBOARD OF CANAL
R.W : ROAD WIDTH



DETAIL-X

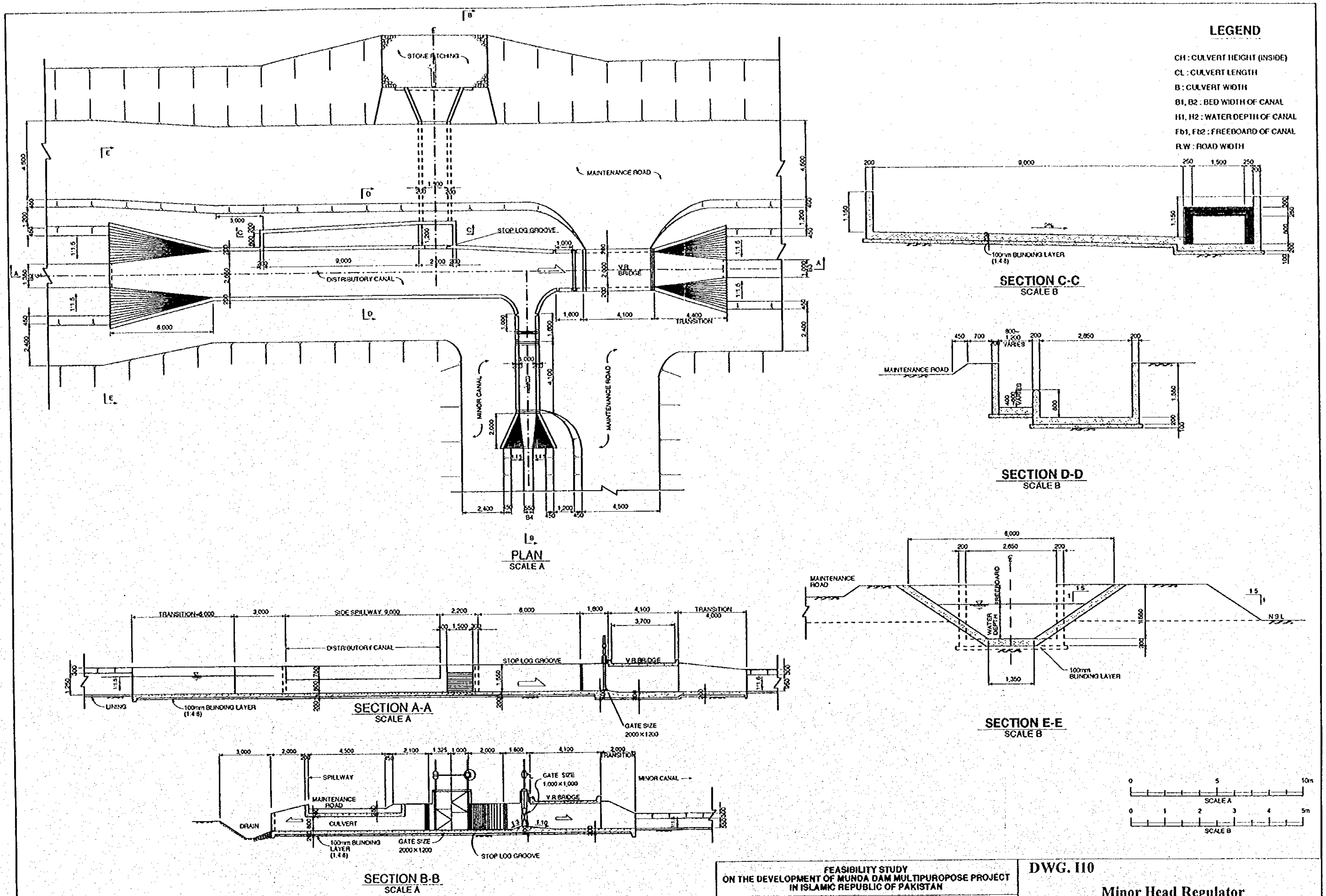


DETAIL-Y



SECTION A-A

FEASIBILITY STUDY ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT IN ISLAMIC REPUBLIC OF PAKISTAN	DWG. I09 Bridge
JAPAN INTERNATIONAL COOPERATION AGENCY	



FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

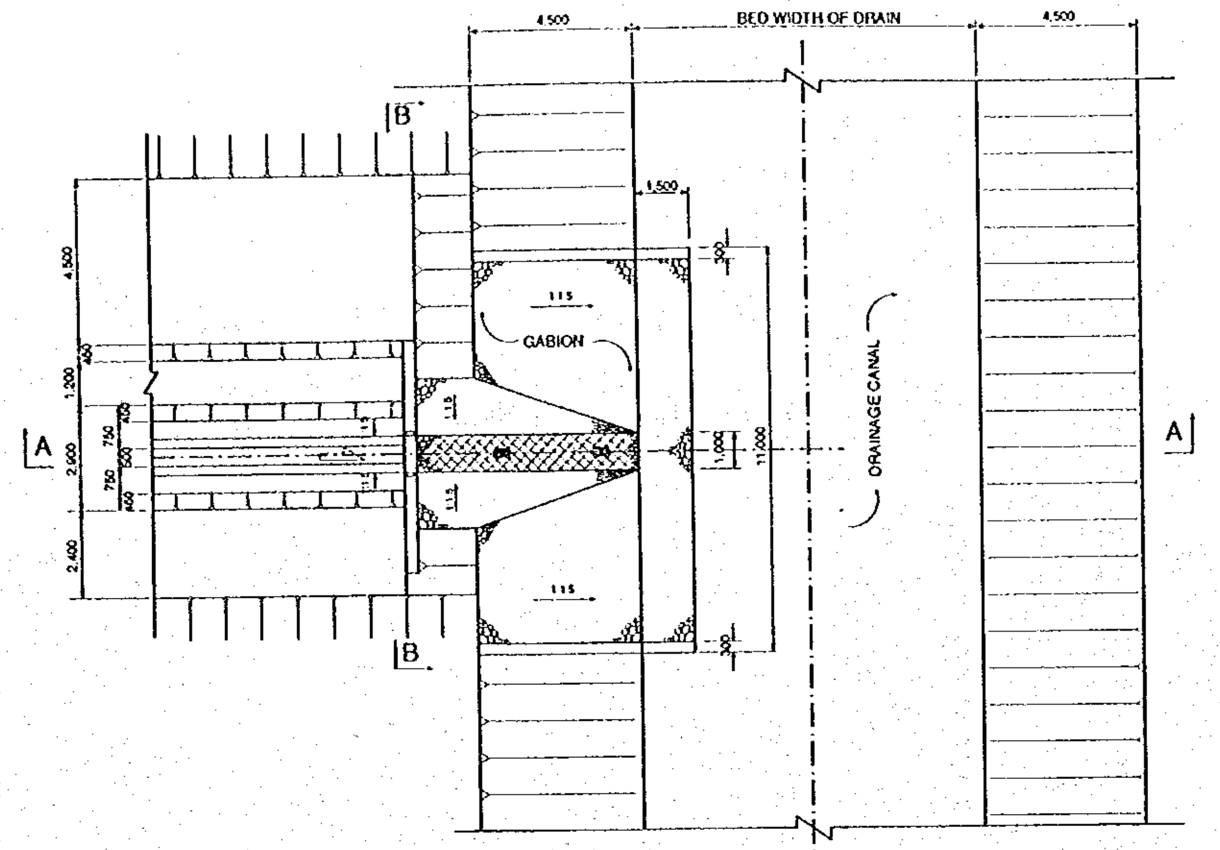
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. I10

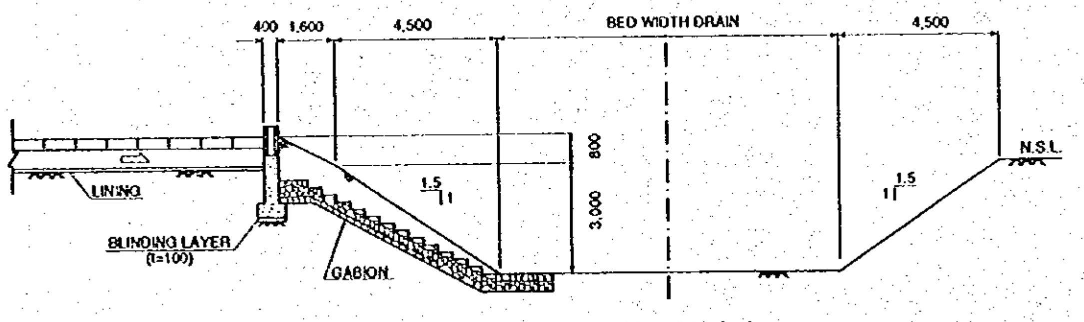
Minor Head Regulator

LEGEND

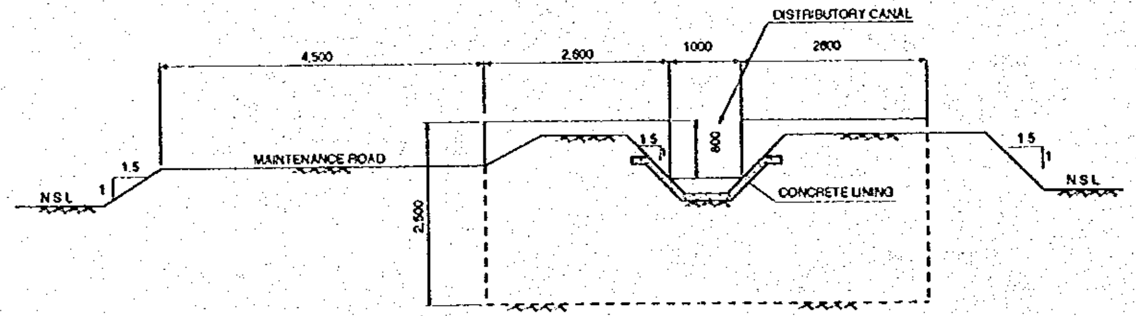
B : CULVERT WIDTH
B1, B2 : BED WIDTH OF CANAL
H1, H2 : WATER DEPTH OF CANAL
Fb1, Fb2 : FREEBOARD OF CANAL
R.W : ROAD WIDTH



PLAN
SCALE A

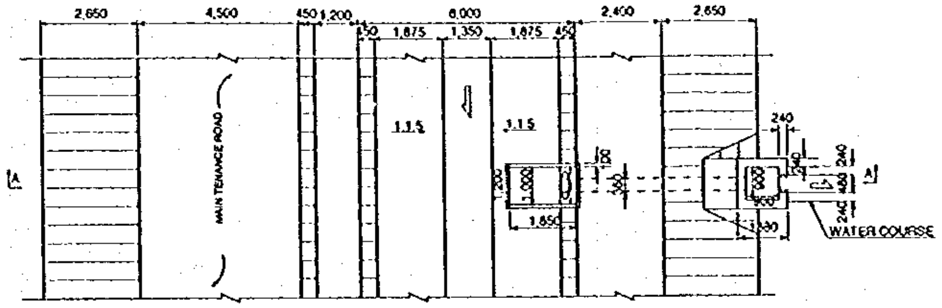


SECTION A-A
SCALE A

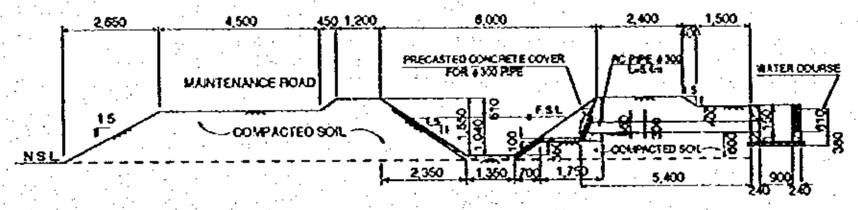


SECTION B - B
SCALE B

TAIL CLUSTER

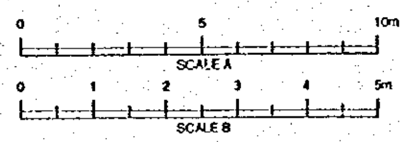


PLAN
SCALE B



SECTION A-A
SCALE B

MOGHA(OUTLET)

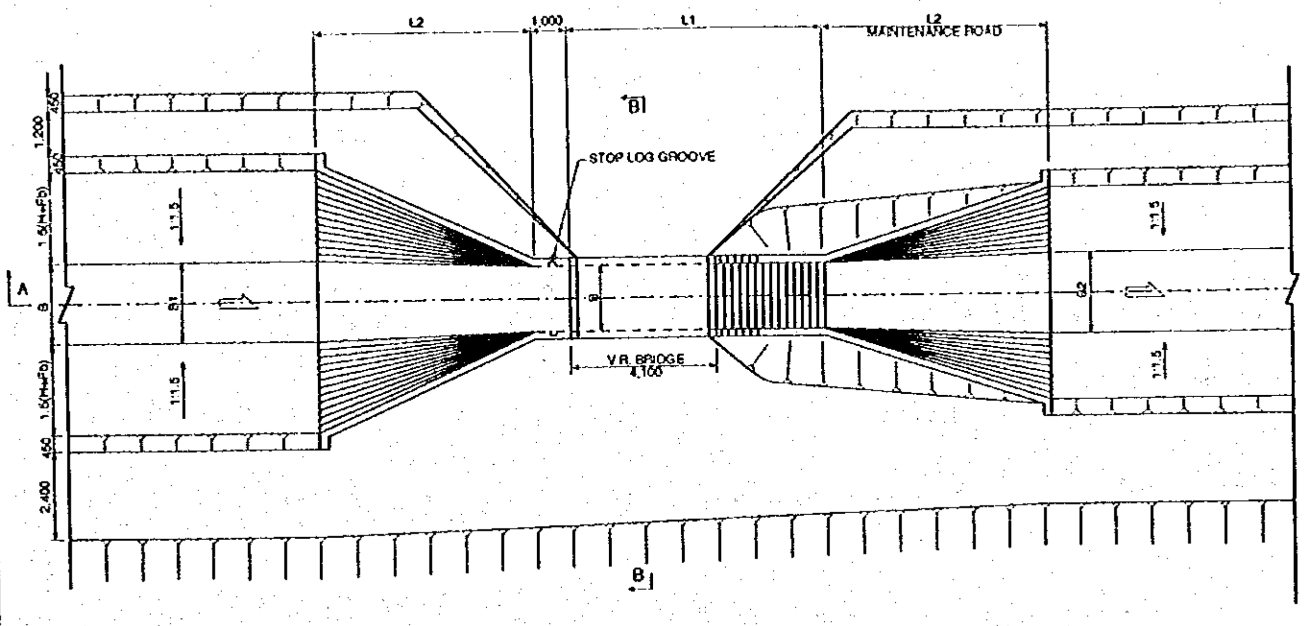


FEASIBILITY STUDY ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT IN ISLAMIC REPUBLIC OF PAKISTAN	DWG. I11
JAPAN INTERNATIONAL COOPERATION AGENCY	Tail Cluster and Mogha

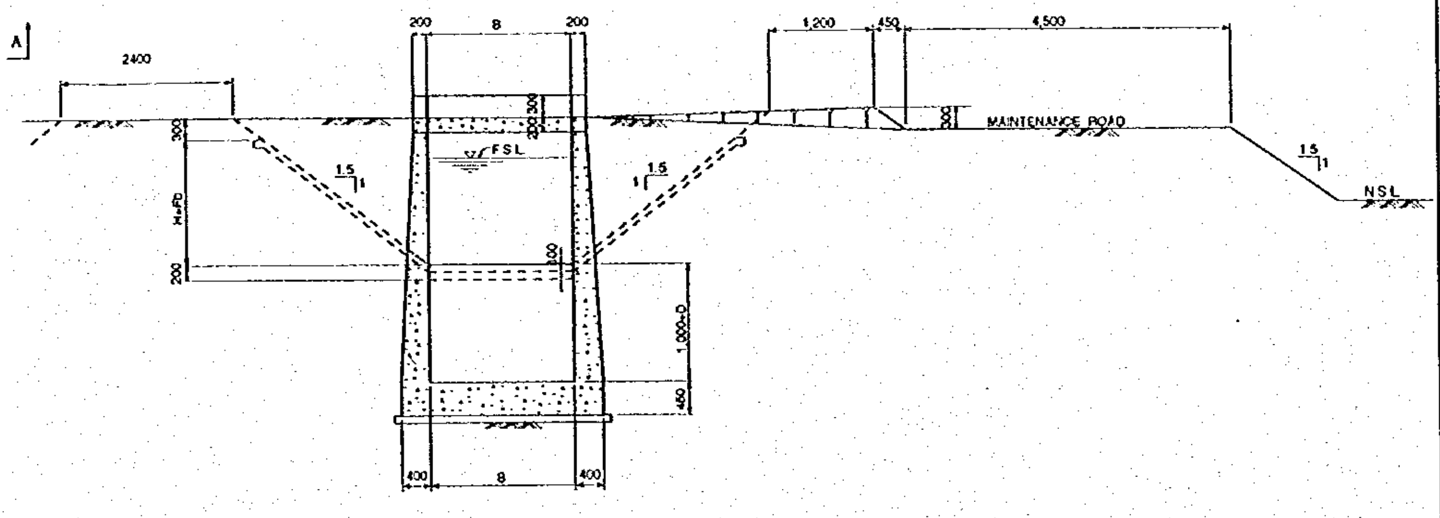
ED11

LEGEND

B : CULVERT WIDTH
B1, B2 : BED WIDTH OF CANAL
H1, H2 : WATER DEPTH OF CANAL
Fb1, Fb2 : FREEBOARD OF CANAL
R.W : ROAD WIDTH

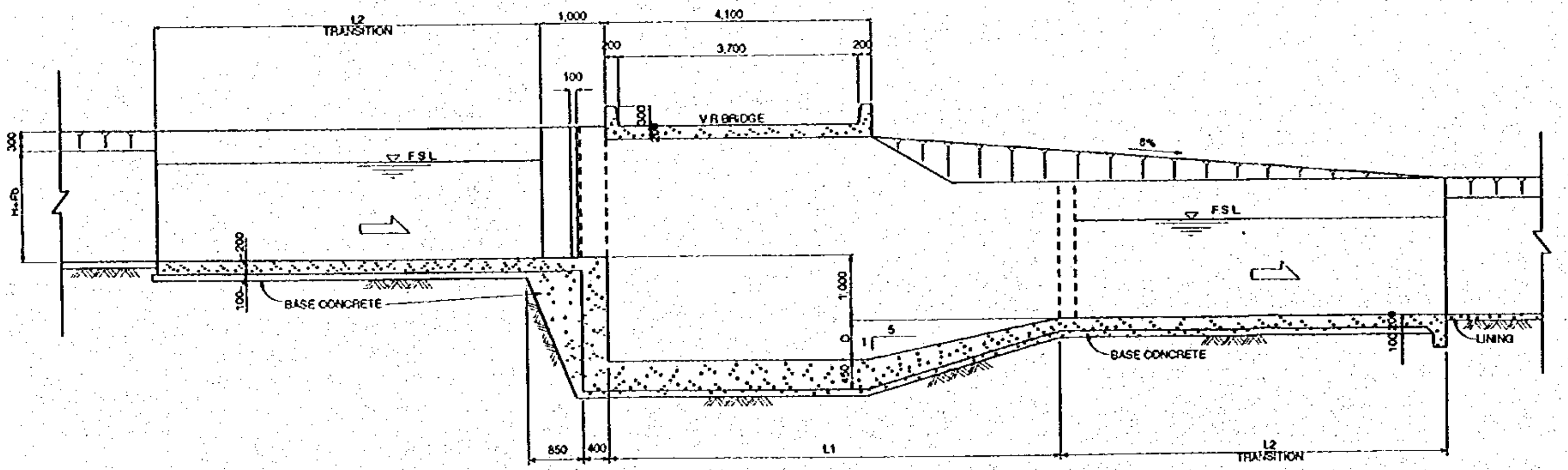


PLAN
SCALE A

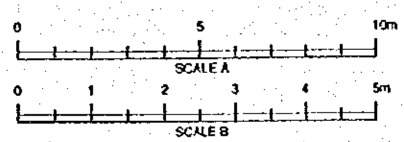


SECTION B-B
SCALE B

TYPE	DISCHARGE (m3/S)	CISTERN LENGHT L1 (m)	CISTERN DEPTH D (m)	BED WIDTH B (m)	WATER DEPTH H (m)	FREE BOARD Fb (m)	TRANSITION LENGHT L2 (m)
2	2.0-4.0	6.0	0.5	1.36	1.04	0.21	4
3	0.0-2.0	5.0	0.40	0.80	0.58	0.17	2



SECTION A-A
SCALE B



FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

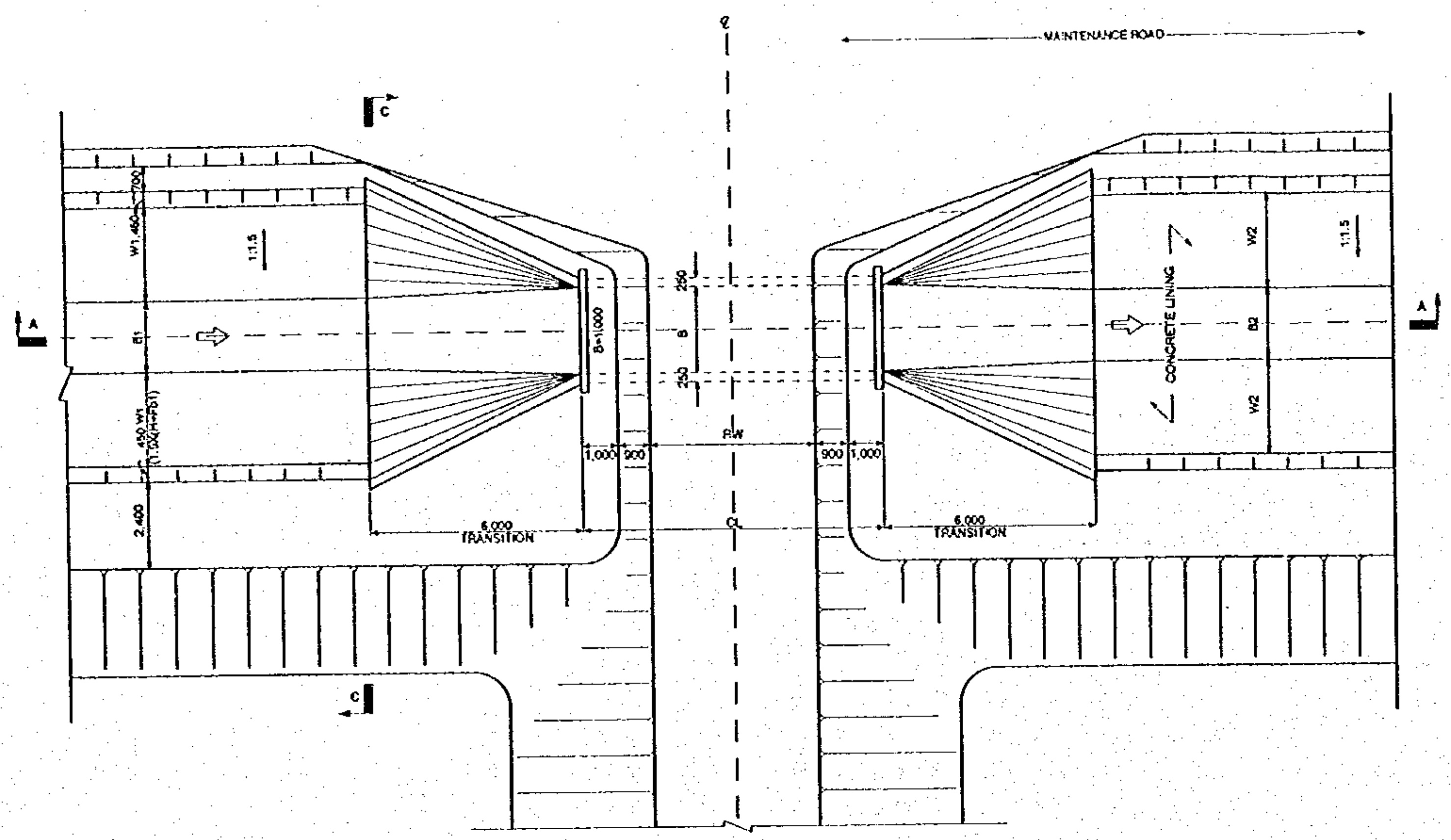
JAPAN INTERNATIONAL COOPERATION AGENCY

DWG. 112

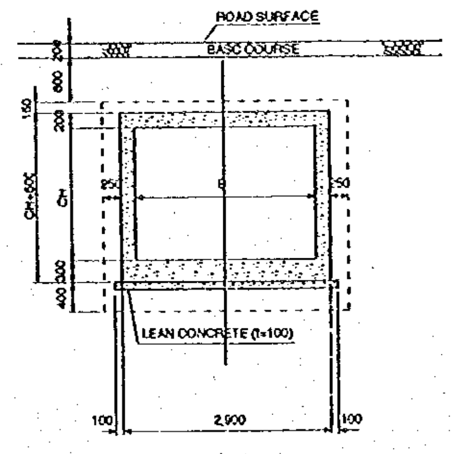
Drop Structure

LEGEND

CH : CULVERT HEIGHT (INSIDE)
CL : CULVERT LENGTH
B : CULVERT WIDTH
B1, B2 : BED WIDTH OF CANAL
H1, H2 : WATER DEPTH OF CANAL
Fb1, Fb2 : FREEBOARD OF CANAL
R.W : ROAD WIDTH



PLAN
SCALE A



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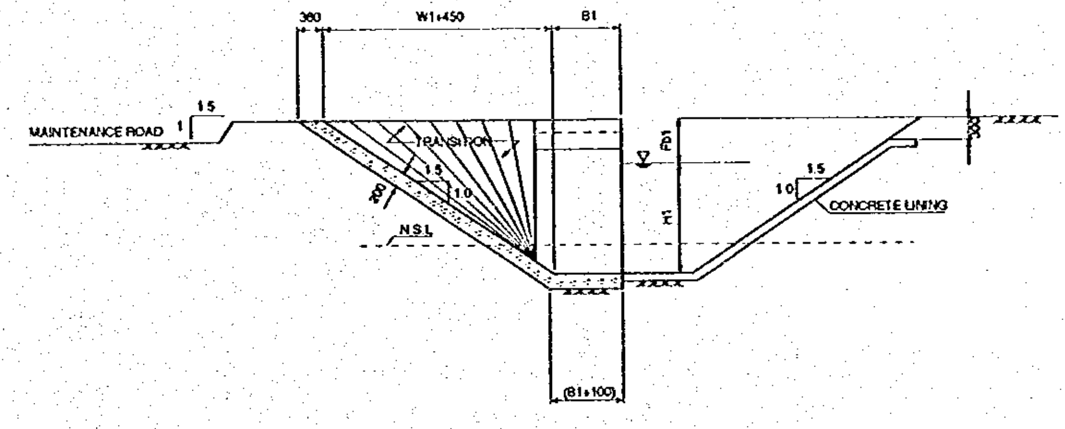

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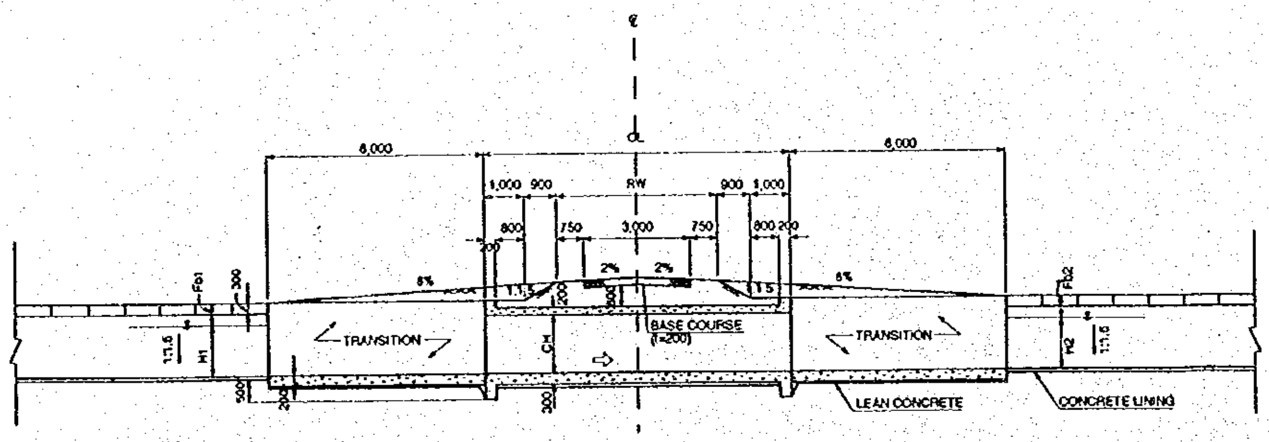
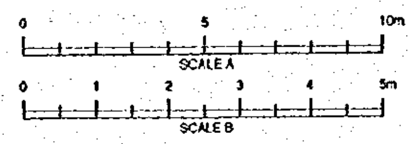


SECTION A-A
SCALE A

DIMENSION TABLE

CASE	KIND OF ROAD	RW	CL	CH	B	B1	B2	W1	W2	H1	H2	Fb1	Fb2
1	D.R.	7,500	11,300	1,450	2,100	1,600	1,600	2,180	2,180	1,200	1,200	560	560
2	V.R.	4,500	8,300	1,600	2,400	1,800	1,800	2,400	2,400	1,360	1,360	540	540



FEASIBILITY STUDY
ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT
IN ISLAMIC REPUBLIC OF PAKISTAN

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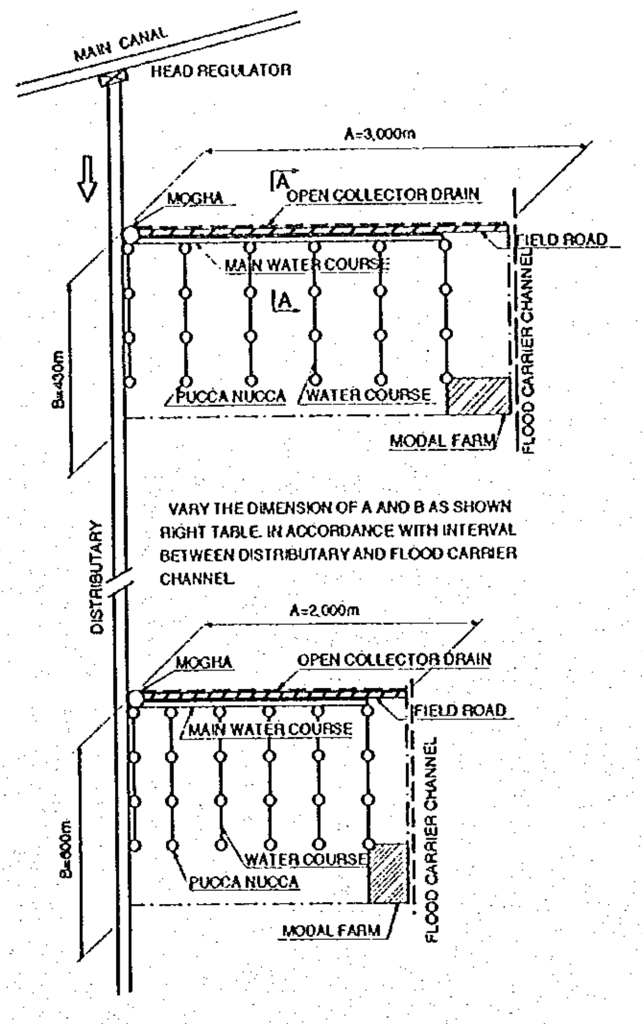
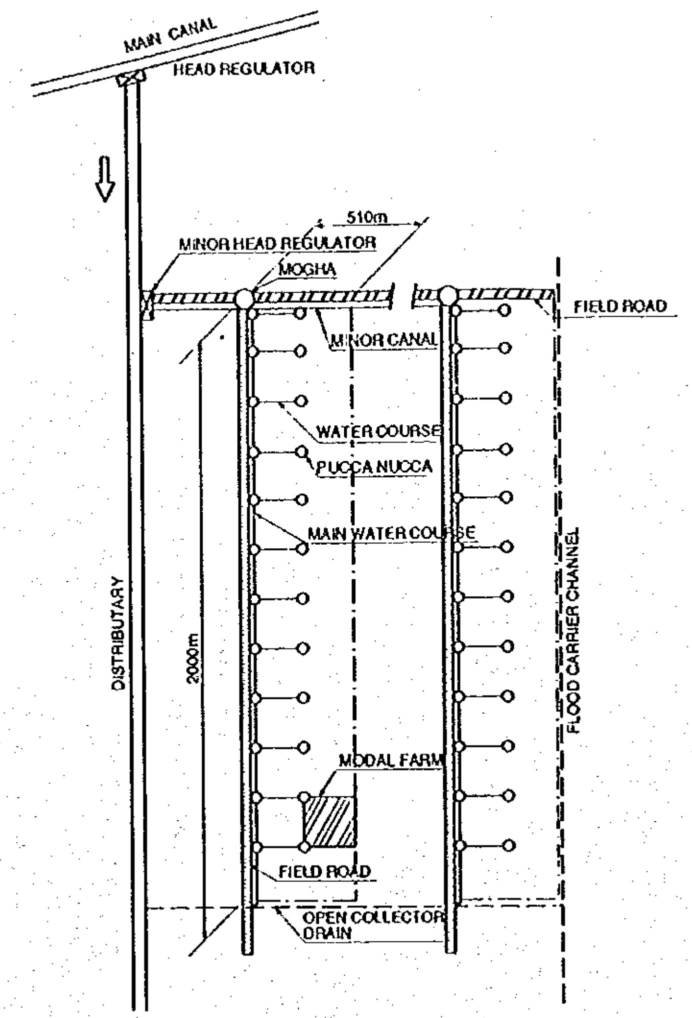
DWG. I13

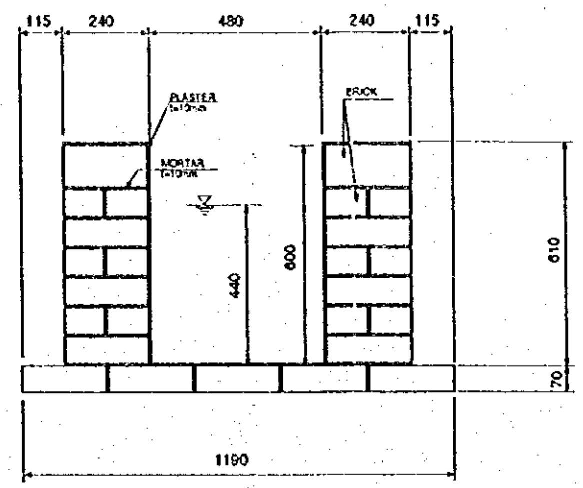
Road Crossing Structure



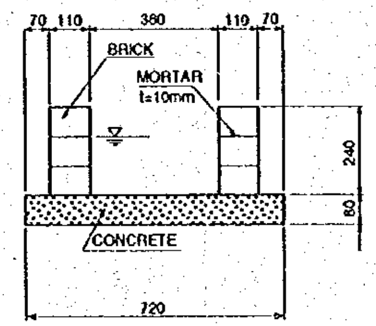
DTW SYSTEM TYPE



MTW SYSTEM TYPE



TYPICAL SECTION OF MAIN WATERCOURSE
SCALE B



TYPICAL SECTION OF WATERCOURSE
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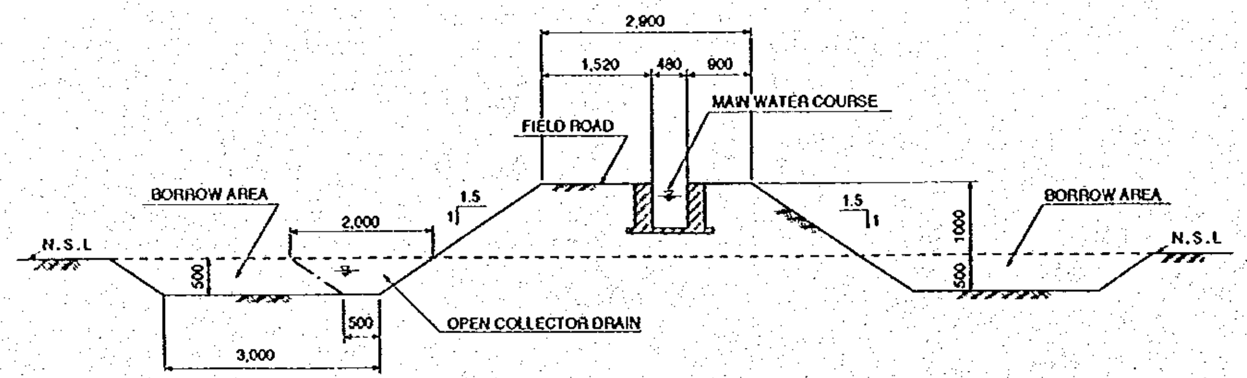
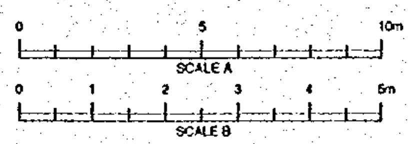


SECTION A-A
SCALE A



FEASIBILITY STUDY ON THE DEVELOPMENT OF MUNDA DAM MULTIPUROPOSE PROJECT IN ISLAMIC REPUBLIC OF PAKISTAN	DWG. I14 Layout of On-Farm Facilities
JAPAN INTERNATIONAL COOPERATION AGENCY	

Appendix F
Flood Control Study

FEASIBILITY STUDY
ON
THE DEVELOPMENT OF MUNDA DAM MULTIPURPOSE PROJECT
IN
ISLAMIC REPUBLIC OF PAKISTAN

FINAL REPORT
VOLUME III
SUPPORTING REPORT

Appendix F : Flood Control Study

Table of Contents

List of Tables

List of Figures

APPENDIX F FLOOD CONTROL STUDY

F1 Methodology of Flood Benefit Estimate

The Swat River, a tributary of the Kabul River in the Indus basin, after the Munda Headworks, bifurcates and flows down as the Abezai and Khiali Rivers. These branches rejoin at the confluence point near Charsadda about 20 km upstream of Nowshera and flow into the Kabul River. The Kabul River then joins the Indus at Attock. A number of tributaries join the Indus River downstream of Attock before it empties into the Arabian Sea.

In the Pre-F/S report, the flood benefits of the Munda Dam were assessed for the whole reach downstream of the dam site through to the Arabian Sea, based on the calculated benefits for the reach between the dam site and Nowshera; amplifying the benefits at a ratio of cumulative river length between those up to Attock (64 km) and up to the Arabian sea (1,739 km).

In the present Study, the assessment of the flood benefits was limited to effects on the reach from the dam site, virtually the Munda Headworks in the Khiali River to Nowshera in the Kabul River. Additional benefits may be expected in the reach downstream of Attock in the Indus River but quantification of such benefits is extremely uncertain due to the cumulative impacts of flows from other tributaries which join the Indus River. Thus, the estimates of flood benefits derived at this time are considered on the conservative side.

Assessment of flood benefits was carried out as shown in the following flow chart:

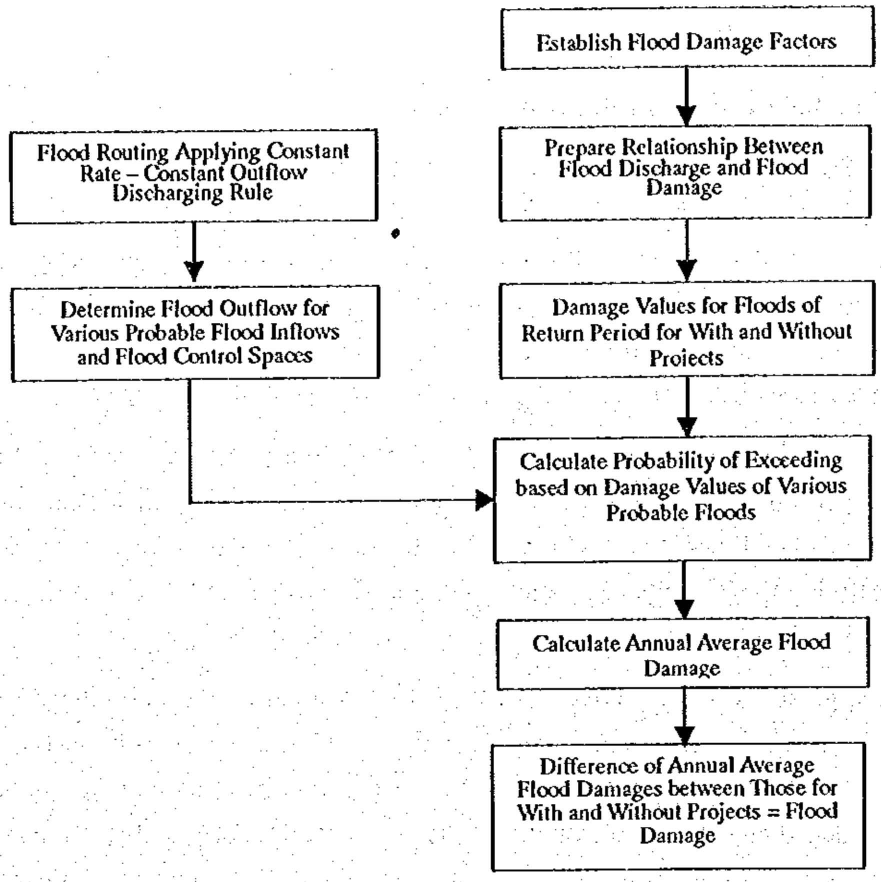


Figure F1.1 Methodology of Flood Benefit Estimate

The assessment method of flood benefits is to first establish flood damage factors as measured in Pakistan Rupees per square kilometers flooded for each classified land use and then to prepare a relationship between flood discharge and damage at the inundated area based on field flood damage investigation results.

Reservoir operation and flood routing were carried out by applying a constant rate – constant outflow discharging rule against the inflow hydrographs. Outflows regulated by the reservoir were computed for probable flood inflows of selected return periods assuming several flood control spaces in the reservoir.

With use of the flood discharge-damage relationships, damage values for the floods of respective return periods were computed for both without and with the Munda Dam. These values were reworked to derive probability of exceeding from which the annual average flood damage may be calculated. The difference between these annual values for the "without and with" the Munda Dam cases is the value of the flood benefit expressed in Rupees per annum.

F2 Historical Flood Damages

F2.1 Flood Damage Investigation

The field investigation including interviews with local people about flood damage was carried out at 60 points over the Swat/Kabul River flood plain area downstream of the Munda Headworks and between Warsak Dam and Nowshera.

According to the field investigation results (refer to Table F2.1), the lower Swat River reach, downstream of the Munda Headworks is flooded causing damage twice to four times every year during the rainy season from June to September. Based on residents responses through interviews, the experienced inundation areas were found considerably larger than those indicated in the Pre-F/S report. The inundation area covers not only the areas flooded by the Swat River itself but also those flooded from civil canals which are running in parallel with and affected by the Swat, Kabul Rivers, and its tributaries. According to the old residents, the inundation caused by the 1929 flood was the largest ever experienced in about the past 100 years in terms of flood magnitude, inundation area and duration, and they were stranded on the trees for a week at that time.

Downstream of the Munda Headworks , the main crop in the rainy season is sugarcane which does not suffer serious damage from normal floods which occur twice to four times a year. The flood with the return period of a few years may damage half of the production. Houses in the villages are not affected badly by the normal floods but mud walls commonly used for the houses tend to be damaged when the inundation duration is long.

F2.2 Historical Floods

Recorded maximum flood peak is 4,500 m^3/s (159,000 cusec) in 1929 at the Munda Headworks as observed by Irrigation Department (ID) of NWFP. The second maximum peak discharge is 2,413 m^3/s (85,280 cusec) on July 25, 1995 as recorded by ID. The third one is 2,158 m^3/s (76,250 cusec) on July 15, 1988.

River runoff observation was made at the Munda Headworks by reading staff gauges, and the measured water stages were converted to discharges applying stage-discharge relationship. No attention was paid to the observation and recording of the position/opening of the gates for the Headworks. Therefore, the discharge data recorded at the Headworks during low flow season were concluded unreliable. However, in view that the gates would be fully opened during the high flood, the records at high floods could be more reliable to some extent. Since there is no other data or way to estimate more reliably than the records at the Munda Headworks, the flood control studies stated below are based on the discharge records at the Munda Headworks.

F2.3 Inundation Area

A flood inundation area map was drawn for the floods which occurred in 1929, 1988, 1995, and normal year on the basis of interviews with the residents, flood marks survey, and available topographic maps at a scale of 1:50,000, and shown in Figure F2.1 which covers the stretch downstream of the Munda Headworks and between the Warsak Dam and Nowshera.

The area of the inundation for the floods of 1929, 1988, and 1995 as well as that for the normal year was estimated on the basis of Figure F2.1 and is as follows:

Estimated Inundation Area (km^2)

River	Stretch	Historical flood (1929/8/28)	Medium class flood (ex.1995/7/25)	Low class (Normal year)
Swat	From Munda H/W to Swat-Kabul confluence	188.75	95.75	57.50
Swat/ Kabul	Total inundation area	697.75	448.25	244.25

Figure F2.2 is the discharge – inundation area curve showing the relationships between the flood peak discharge and the direct flood inundation area of the Swat River alone excluding the areas affected by the floods of tributaries.

For estimation of flood damages, the inundation areas of "1929 flood", "1995 flood" and "normal year flood" were plotted on a land use map represented by 500 m x 500 m mesh. Those are as shown in Figure F2.3 to F2.5.

F2.4 Inundation Depth and Duration

According to the results of field investigation, the agricultural land along the Swat and Kabul Rivers, where the main crop is sugarcane, is affected by floods occurring twice to four times a year and with an inundation depth of 0.3 to 1.0 m and a duration of 1 to 3 days. However, such floods affected only a small number of houses.

At the time of the 1988 and 1995 floods, the inundation depth was 0.5 to 2.0 m with a duration of 4 days. A lot of villagers' houses made of mud walls collapsed. The inundation duration of the 1929 flood was about one week.

F2.5 Bank Erosion and Meandering

Topography downstream of the existing Munda Headworks forms an alluvial fan, where the river bed slope becomes abruptly gentler. Thereby, sand bars are formed and bank erosions occur at bends in the river course downstream of the Headworks.

ID of NWFP is in a position to take actions such as bank protection and spur dike construction in order to stabilize the river course and protect the banks from erosion. The actions are mainly taken after the problems happened and no overall plan to cope with the issues is formulated. Many bank protection structures were observed to have been collapsed and washed out due to inadequate design and construction executed. Figure F2.6 indicates locations of bank protection works planned and completed under the Flood Protection Sector Projects and Table F2.2 shows the cost spent for the works.

F2.6 Governmental Compensation for Flood Damage

No reliable record nor data with regard to the flood damage in the past were obtained. Among the data collected, the only indicative data are district-wise details of losses and damages due to floods and heavy rains obtained from Provincial Relief Commissioner. Table F2.3 shows those for years of 1995, 1996 and 1997. Summaries for Charsadda and Nowshera districts which are relevant to the Khiali (Swat) and Kabul Rivers are as follows:

Total Compensation Amount (Rs.)

Year	Charsadda District	Nowshera District
1995	4,551,700	861,000
1996	1,760,500	-
1997	592,000	1,508,000

F3 Effect of Swat River Flood on Kabul River

In order to know the area of flood control effect by the Munda Dam, the flood hydrographs measured at Nowshera, Chakdara, Munda Headworks and Warsak were categorized into the following three patterns and frequency of occurrence of these patterns was examined:

Type-A: Flood Events in the Swat River measured at Chakdara and Munda H/W and in the Kabul River measured at Warsak, both of which occurred at the same time

Type-B: Flood Events in the Kabul River measured at Warsak which occurred only in the Kabul River (No floods measured at Chakdara and Munda)

Type-C: Flood Events in the Swat River measured at Chakdara and Munda H/W which occurred only in the Swat River (No floods measured at Warsak)

The examination was made based on the daily runoff hydrographs between 1964 and 1995 at four gauges and all major peak floods over 3,200 m^3/s measured at Nowshera, which is equivalent to a 2-year return flood. During the period examined, 28 floods occurred exceeding 3,200 m^3/s in total. Of these, three floods were categorized as Type-A, which happened at the Swat River and affected the Kabul River, corresponding to 11% of the total. Twenty floods (70% of the total) were categorized as Type-B, which occurred in the Kabul River only. On the other hand, Type-C (floods in the Swat River alone) accounted for five floods, corresponding to 18%. The details are shown in Table F3.1 and Figure F3.1 to F3.9.

As a result, it was known that one-third, 29 - 30% of the major floods which occurred at Nowshera, are somehow relevant to the Swat River.

F4 Flood Damage Estimation Area

The flood damage estimation area was delineated to include the area inundated due to Swat floods in the Swat River, that affected by backwater of the Swat floods in the Kabul River, and that between the confluence of the Swat and the Kabul Rivers and Nowshera. In order to know the backwater effect of Swat floods in the Kabul River it is desirable to conduct flood plain analysis by developing a mathematical simulation model of inundation. However, there were no input data such as detailed topographic maps and river sections except 1:50,000 scale topographic maps for the inundation areas, and hence, it requires many assumptions on the offered data. For these reasons, it was decided not to carry out the flood plain analysis. In the present Study, the flood damage estimation area was decided on the basis of 1:50,000 topographic maps and field investigation results.

The inundation areas experienced in 1929, 1995, and normal year as seen in Figure F2.3 to F2.5 were divided into the following four areas in terms of influence of the Swat and Kabul floods. The result of the division is shown in Figure F4.1.

Area "A" : Inundation area of Swat River
(from Munda H/W to Swat-Kabul confluence)

Area "B1" : Inundation area of Kabul River
(from Warsak Dam to backwater end of Swat flood)

Area "B2" : Inundation area of Kabul River
(from backwater end of Swat flood to Swat-Kabul confluence)

Area "C" : Inundation area of Kabul river
(from Swat-Kabul confluence to Nowshera)

In this flood control study, Area A, Area B2, and Area C were chosen as the flood damage estimation area. This covers the areas of flood control effect of the Munda Dam. Area B1 was not included in the flood damage estimation area because inundation of this area results from the Kabul floods only. The flood damage in Areas A, B2 and C was estimated under the following conditions:

1) 100% of flood damage is computed in Area A, since the inundation in Area A is caused by the Swat floods only.
2) Areas B2 and C are inundated by the floods of Swat and/or Kabul Rivers. The flood damage of these areas is estimated:

$$Dm_{(B2\&C)} = (D_{B2}+Dc) \times Fm \times Rm$$

Where,

$Dm_{(B2\&C)}$: Flood damage in Areas B2 and C, based on which flood control effect of Munda Dam is evaluated.

D_{B2}, D_C : Flood damage in Areas B2 and C

Fm : Ratio of the number of floods in Swat River against the number of floods in both of Swat and Kabul Rivers (30%).

Rm : At the above Fm, ratio of discharge at Munda Headworks against that at Warsak Dam (1:1 then 50% refer to Table F4.1).

Fm of 30% mentioned above was discussed in subsection F3. Rm of 50% was derived from flood discharge data between 1988 and 1995 recorded at Munda Headworks and at the Warsak Dam at the corresponding time.

Consequently, 15%(=30%×50%) of the flood damage in Areas B2 and C was taken as the base of the flood control effect of Munda Dam.

At Nowshera in Area C, the majority of river banks are of flood plain owned by the government and flood damage is considered marginal.

F5 Flood Damage Factors

Flood damage factors are unit damage cost in Rupees per square kilometers flooded for each classified land use of the damage caused by a flood. Flood damages principally comprise damage to agricultural crops, housing, infrastructure and other facilities. The flood damages factors were estimated based on agricultural crops damage factors, private housing damage factors, road damage factors, other direct damage factors, and indirect damage factors as explained below.

F5.1 Agricultural Crops Damage Factors

Damages to standing crops were estimated analytically by a technique that considers depth, duration and time of inundation, flood susceptibility of each crop, the extent of adverse effects on yields due to inundation the farm cost and the farm gate prices. The loss is based on the expected economic farm gate gross revenue minus on-farm cost that would have been incurred post-dated to the flood event. Economic crop production budget which detail monthly net potential flood losses for maize, fodder, sugarcane, pulses, vegetables and fruits are given in Table F5.1. This was done in view of the fact that floods occur mostly during the monsoon season. The monthly crop losses per acre of cultivable command area (CCA) are estimated as seen in Table F5.1 by considering the effect on each of the crops relative to the month of flooding and the cropping pattern which are combined with monthly probability of flood occurrence to obtain crop losses per acre flooded in civil canal command area. The area on either side of the river within flood limits are mostly irrigated by civil canal and Kathas, traditional irrigation methods. On the basis of these assumption, the estimated crop damage factor is Rs 4,439 per ha (=Rs 1,796 per acre) flooded.

F5.2 Private Housing Damage Factors

The damage factor for private housing properties is calculated by considering housing density per square kilometer for local villages and town (city) area, percent distribution of baked (Pacca) and unbaked (Kacha) houses and unit cost of replacement as summarized in Tables F5.2 to F5.5. Housing damage factors were then assumed based on the part studies done in the region.

F5.3 Road Damage Factors

The district-wise total length and density data of metalled (paved) and unmetalled (unpaved) roads were collected from the Communication and Works (C&W) Department as summarized in Table F5.6. However, detailed damage records of roads were not available. The damages to metalled and unmetalled roads in the flood plain area are estimated based on the past studies. The road density of Study Area was assumed using data of Charsadda district in 1996. Unit road repairing cost obtained from C&W Department was updated applying a price increase of 10%. The estimated road damage factors are summarized in Table F5.7.

F5.4 Other Direct Damage Factors

Other direct losses including damages to irrigation canals and Kathas, livestock, stored grain, electrical distribution system, telecommunication, bank erosion, etc. are estimated assuming a ratio of crop/housing/road damages to total direct damages of 1:1.3 which is used in the other flood control projects in the region.

F5.5 Indirect Damage Factors

In the absence of alternative information, indirect damage due to suspension of irrigation supplies and traffic as well as the emergency costs associated with such a flood are estimated at 20% of the total direct damages within the flood plain area.

These flood damage factors per square kilometer for each land use categories for crops, private houses, roads, other direct and indirect damages are summarized in Table F5.8.

F6 Flood Damages

The total potential losses can be estimated by applying the flood damage factors for each classified land use to the area inundated under "with" and "without" the construction of the Munda Dam.

For estimation of flood damages, the recent land use classification data were plotted on a 1:50,000 map and represented as 500 m x 500 m mesh data as shown in Figure F6.1.

The inundated areas of the "1929 flood", "1995 flood", and "normal year flood" were plotted in 500 m x 500 m mesh map as given in Figures F2.3 to F2.5. Inundation areas due to respective Swat floods and Kabul floods as well as the area affected by both floods are illustrated in Figure F4.1.

The inundation areas for each classified land use are calculated on the basis of the 500 m square mesh data for the respective Areas A, B and C as shown in Table F6.1. The total flood damage costs for Areas A, B1, B2, and C are summarized in Table F6.2.

The flood damages associated with the specific flood peak discharges were plotted in Figure F6.2, to obtain relationship between flood peak discharge and damage.

F7 Flood Routing

F7.1 Rule of Flood Regulation

Reservoir operation study and flood routing in the Munda reservoir were made by applying a constant rate-constant outflow discharging rule against the flood inflow hydrographs as shown in the following figure. The rule is to first select an inflow (Qa) for starting gate operation to release the discharge at a constant rate until it reaches a peak discharge (Qp), and then to release a constant discharge (Qp') thereafter.

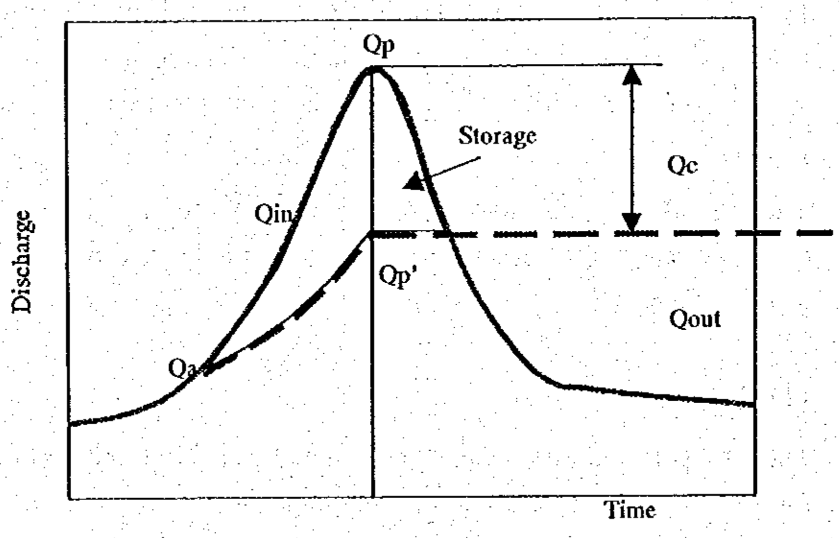


Figure F7.1 Constant Rate – Constant Outflow Rule

The constant rate-constant outflow rule is known effective even for medium to low floods and floods where no river improvement works are implemented in the downstream reach.

For more effective flood regulation, the introduction of a flood forecasting system is to be made. The flood forecasting system will measure rainfall and discharge with use of telemetering system set up in the upstream catchment area and predict flood inflow into the reservoir. Federal Flood Commission has some experience of introducing the telemetering system in Pakistan with the financial assistance of ADB. It is recommended that the possibility of a telemetering system in the Swat basin be studied in the future.

F7.2 Flood Frequency Curve

On the basis of the results of probable flood analysis for selected return periods of 1.5, 2, 5, 10, 20, 25, 50, 100, 200, 500, 1,000, and 10,000 years, the flood frequency curve for the Munda Dam site was developed as shown in Figure F7.2.

F7.3 Flood Control Space

In order to find an optimum flood control space in the reservoir, eleven alternative flood control spaces varying from 0 to 300 million m^3 were taken up for comparison.

The flood outflows after flood routing were then calculated by applying the constant rate-constant outflow rule against respective probable flood inflows and eleven alternative flood control spaces. According to the results, the flood peak inflows are reduced or mitigated depending on the flood control spaces. For example, mitigation effects against a 200-year probable flood of 5,720 m^3/sec are summarized as below:

Flood Control Space and Flood Peak Reduction

Flood Control Spaces (10^6 m^3)	Peak Outflow (m^3/sec)	Reduced Discharge from Peak Inflow (m^3/sec)	Remarks (Equivalent Probable Flood)
0	5,720	0	No Effect
1	5,650	70	180 year return flood
10	5,170	550	120 year return flood
20	4,780	940	70 year return flood
50	3,760	1,960	27 year return flood
75	3,050	2,670	14 year return flood
100	2,420	3,300	7 year return flood
150	1,470	4,250	3.5 year return flood
200	930	4,790	1.9 year return flood
250	670	5,050	
300	470	5,250	

From the above, it is seen that with a flood control space of 100 million m^3, the 200-year probable flood is reduced by 3,300 m^3/sec and mitigated up to a level of a 7-year return flood, almost equivalent to the 1995 flood.

Flood control benefits will be derived from the reduction of inflow discharge toward downstream reach.

F7.4 Average Annual Flood Damage

Using the linear relationship between flood damage and flood peak inflows as shown in Figure F6.2, the annual average flood damage costs for different flood control spaces and probable flood peak inflows of different return periods were calculated. Table F7.1 show calculation results for "Without Project", i.e. with no flood control space while Tables F7.2 (a) to F7.2 (j) tabulate those for various flood control spaces for "With Project".

F8 Flood Control Benefits

The flood control benefits are attained as the reduction of average annual flood damages expressed as difference of annual average damages between with and without the Project. Figure F8.1 shows the relationship between the flood control benefits and control spaces.

According to Figure F8.1, optimum flood control space may fall within a range between 75 million and 100 million m^3. Increment of the benefit is marginal even if the control space is set at more than 100 million m^3 and hence it was concluded that a flood control space of 100 million m^3 be taken if the economic analysis proved viable.

The larger flood control space may provide with more flexible operation for the flood control. In case 100 million m^3 of the space is provided below F.S.L. it would result in the reduction of 0.4% of annual energy production while it causing the heightening of the spillway gate by some 4.4 m in case that the space is to be provided above F.S.L. Since the dam is designed on the basis of the normal reservoir water level (in this case, F.S.L.) against the Probable Maximum Flood as explained in Chapter of "Hydrological Study", it is considered appropriate to allocate the flood control space above F.S.L.