4.5.3 Design of Dam Body

(1) Design Conditions

The design conditions of the main dam is as follows:

(a) Design Water Level

1) Reservoir Water Level
   - H.W.L. = E.L.52.7 m
   - N.W.L. = E.L.47.5 m
   - L.W.L. = E.L.28.5 m
2) Downstream Water Level
   - Normal time :EL. 20.0 m
   - Flood Time :EL. 38.2 m

(b) Elevation of Dam Top

The elevation of dam top is EL. 53.2 m, which is the larger, comparing the levels of "normal water level + concrete dam freeboard" and "flood water level + concrete dam freeboard", as shown below.

Items	Water Level	Freeboard	W/L + Freeboard
Normal Time	N.W.L.: E.L. 47.5 m	1.5 m	E.L. 49.0 m
Flood Time	H.W.L.: E.L. 52.7 m	0.5 m	E.L. 53.2 m

(c) Dam Foundation Rock

According to the results of the geological survey covering the dam site, it is evaluated that C_M class rock at the dam site is strong enough to construct gravity concrete dam of 50 m class. Therefore, Vaza Barris Dam is installed on the C_M class rock foundation. The core boring revealed that the depth of C_M class rock is E.L. 15 m at the left bank and 6 m at the right bank. It is necessary to confirm the strength of C_M class rock through the sheer test before preparation of detailed design. In this design, strength of C_M class rock in the dam site is assumed to be C= 80 ton/m^2 of cohesion and $\phi = 38^\circ$ of internal friction angle.

(d) Dam Height

The design foundation level of C_M class rock is set at E.L. 5 m. As the elevation of dam top is E.L. 53.2m, the dam height is 48.2 m.

(e) Arrangement of Drain

Three (3) drains in one block (15 m) were arranged at the dam foundation of 5 m downstream from the dam axis. It satisfies the drain arrangement standard, while the length between upstream edge and drains is more than 8 % of reservoir water depth (5 m / 48.2 m = 10 %).

(f) Width of Dam Top

The width of dam top is set as 5 m considering entrance of crane truck in the case that gates are installed for low flow outlet and for temporary drain hole in dam body.

(2) Result of Dam Stability Analysis

The sectional form of the main dam, which satisfies the design standard in the dam stability analysis (see Table-4.14), was set as follows:

Upstream Slope: Vertical Downstream Slope: 1:0.88

The sectional form of the dam, the drawings of Dam plan, longitudinal sections of the upstream and downstream view and standard sections, is presented in Figure-4.24, Figure-4.25 and Figure-4.26. Additionally, image sketch of Vaza Barris Dam is shown in Figure-4.28.

Table-4.14 Results of Dam Stability Analysis

Case	Section and allowable value	Safety Coefficients to Fluctuation	Safety Coefficients against the Overturning	Factor of Safety to the Sliding	Tension (ton/m²)		Safety Factor by Henny
					Upstream compressive stress σ vu	Downstream compressive stress σ vd	
Case of Normal Load	Non-overflow section	2.53	2.76	1.61	32.23	37.63	5.1
	Overflow section	2.50	2.75	1.59	29.31	39.00	5.1
	Allowable minimum value	1.3	1.5	1.0	0	0	4.0
Case of Exceptional Load	Non-overflow section	1.61	1.71	2.74	0.79	48.71	5.0
	Overflow section	1.59	1.67	2.77	4.11	43.89	5.0
	Allowable minimum value	1.1	1.2	1.0	0	0	4.0

4.5.4 Design of Spillway

(1) Width and Water Depth of Overflow Section

The width of overflow section (L) is set as 150 m, equivalent to the width of the current river section. As described in the above section, the depth of overflow section is given as 5.2 m at the design flood discharge Q = 3,600 m³/s. Beside, the influence of the crest bridge pier was taken into account on the calculation of over flow section.

(2) Shape of Overflow Section

As the design water depth of overflow section is high as 5.2 m, the shape of overflow section is designed giving larger discharge coefficient so that the negative pressure does not occur on the overflow section. According to the standard of USCE (US Army, Corps of Engineer), the standard overflow section is employed in this design.

(3) Height of Training Wall

The heights of training wall (water depth + free board) are calculated as below: each figure is perpendicular to channel surface.

Table-4.15 Height of Training Wall

Location	Head (m)	Velocity (m/s)	Water depth h (m)	Freeboard Fb (m)	h+Fb (m)	Height of Training Wall (m)
EL. 40 m	12.7	14.2	1.69	1.23	2.92	3.0
EL. 30 m	22.7	19.0	1.26	1.36	2.62	2.7
EL. 20 m	32.7	22.8	1.05	1.46	2.51	2.6

(4) Energy Dissipater

The design conditions for the energy dissipater are as follows:

- Design discharge for energy dissipater: 1,200 m^3/s (100-year return period)
- Difference is large between current riverbed elevation: E.L. 20 m and dam base rock elevation: EL. 5 m.
- Layer of deposits in riverbed is 10~20 m in thickness.
- Water depth in flood time is high. In design flood: 1,200 m^3/s, water depth is 10.8 m (E.L. 30.8 m).
- Width of energy dissipater is 150 m as same width as the overflow section of the spillway.

As the riverbed deposit is thick and water depth is deep, hydraulic jump basin (with chute blocks and sills) equivalent to Basin II from USBR standard. Dimensions of the energy dissipater are designed as follows:

- Elevation of basin: E.L. 20 m
- Width of basin: 150 m
- Length of basin: 26 m
- Conjugate depth of jump: 5.8 m

As the water depth of downstream river (10.8 m) is higher than the conjugate depth of jump (5.8 m), hydraulic jump occurs in the basin and flood stream is dissipated.

(5) Height of Basin Wall

The elevation of the basin wall is set as E.L. 32 m considering water depth (30.8 m for 100 year return period) of downstream river and some freeboard. Higher elevation of the basin wall than river water depth prevents water intrusion from side to basin. Stream in basin can flow straightly as two-dimensional flow from upstream to downstream.

4.5.5 Design of Low Flow Outlet

Low flow outlet is composed of conduit and discharge regulating valve. To take water effectively, the low flow inlet is installed at the lower elevation where reservoir sedimentation does not disturb. According to the reservoir operation plan, the reservoir sedimentation level (L.W.L) is E.L. 28.6 m. The level of the inlet is set at E.L. 29 m to effectively release design low water and discharge density layer. The occurrence of the salinity water layer is not confirmed yet. As the design water head is 25.5 m in this case, high-pressure outlet facility is employed. Water from the outlet is discharged to the stilling basin. The scale of the low flow outlet, after the hydraulic study, is set as 250 mm of the gate diameter and 800 mm of the low flow pipe.

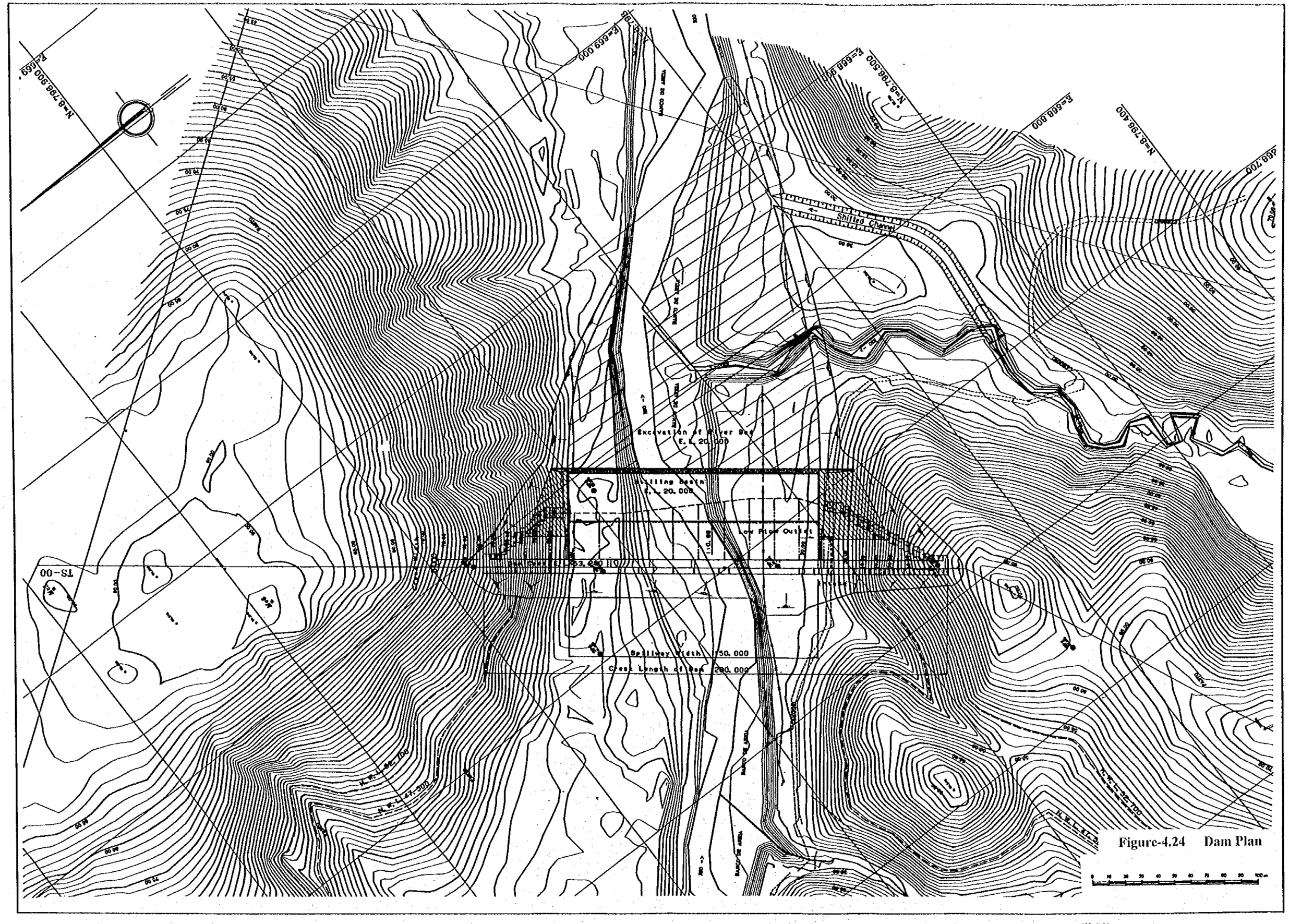
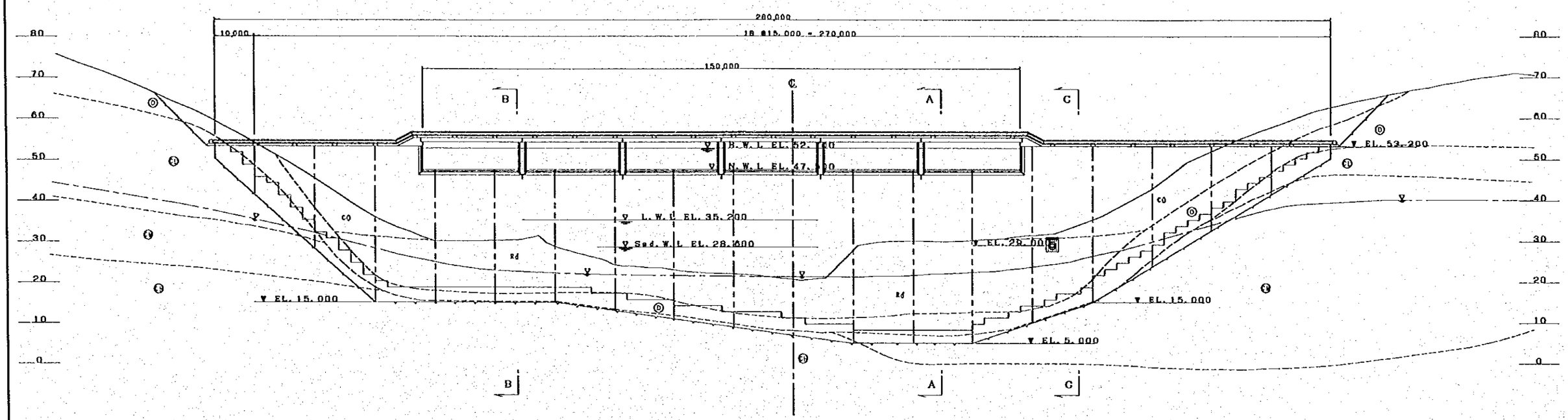
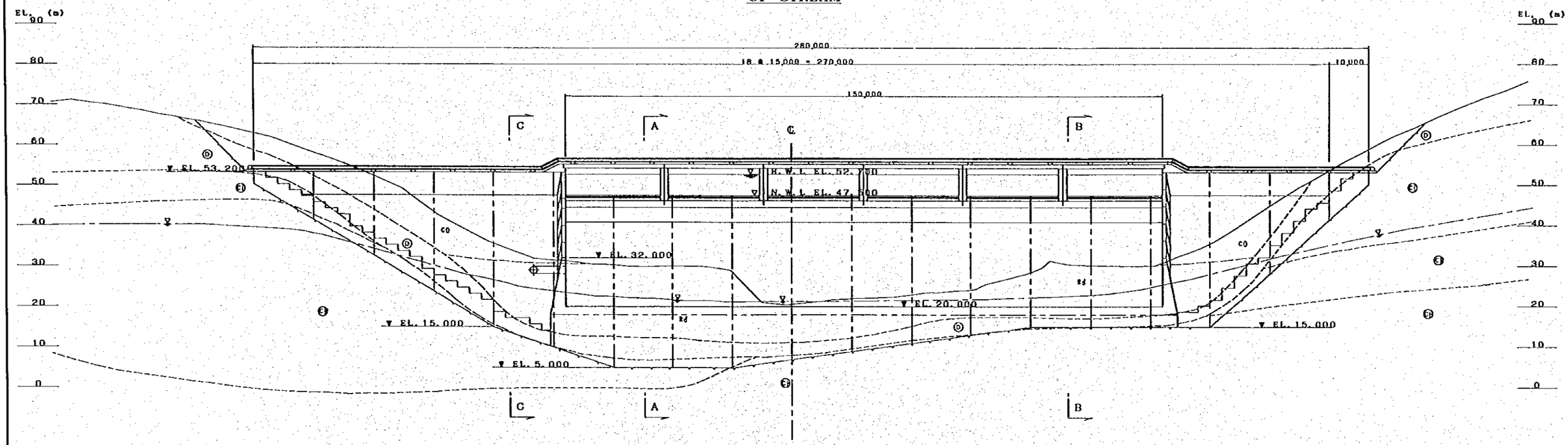


Figure-4.24 Dam Plan

LONGITUDINAL SECTION OF VAZA BARRIS DAM AXISL S=1:500



UP STREAM



DOWN STREAM

Figure-4.25 Dam Longitudinal Section of Upstream and Downstream View

CROSS SECTION OF VAZA BARRIS DAM AXISL S=1:500

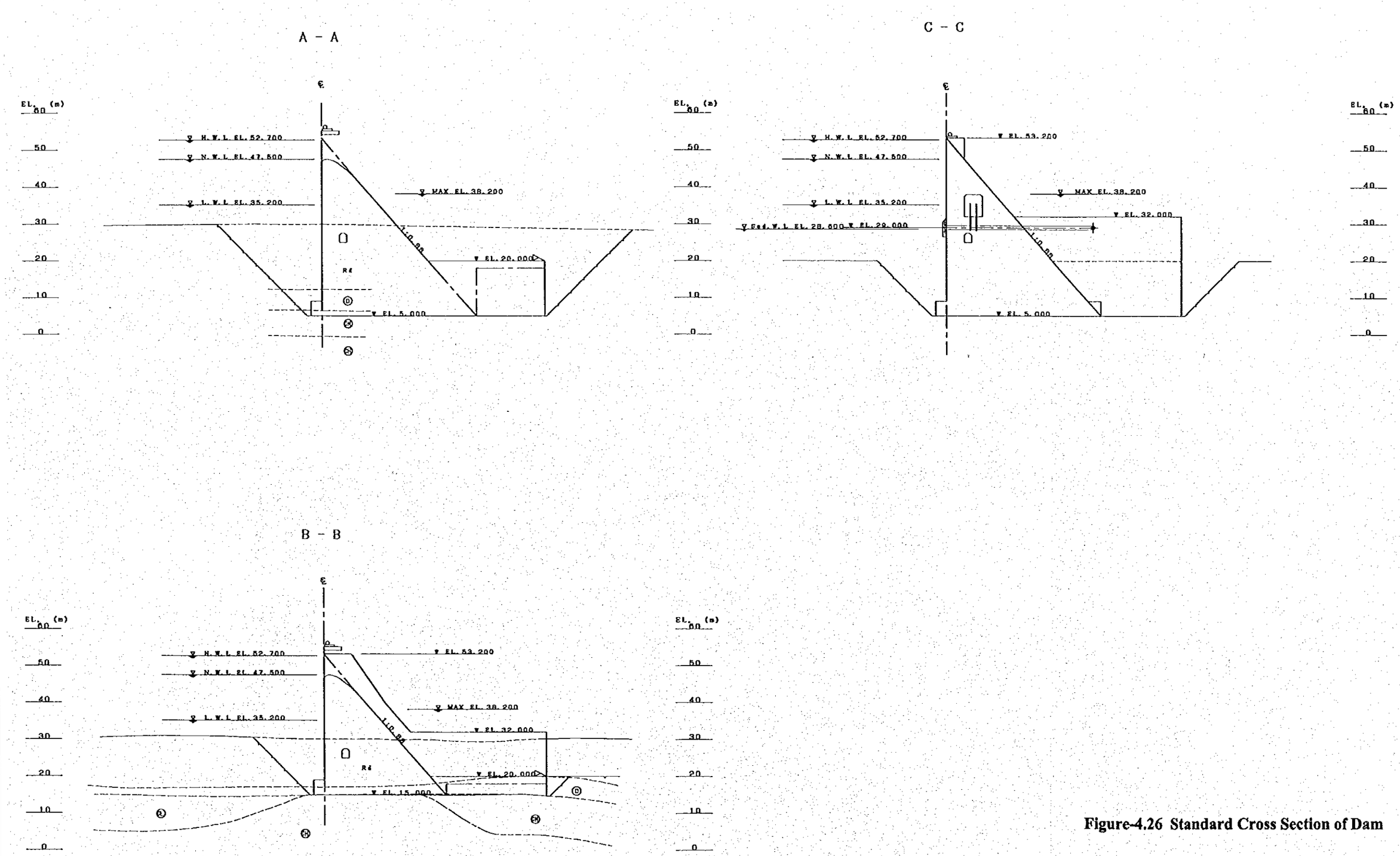


Figure-4.26 Standard Cross Section of Dam

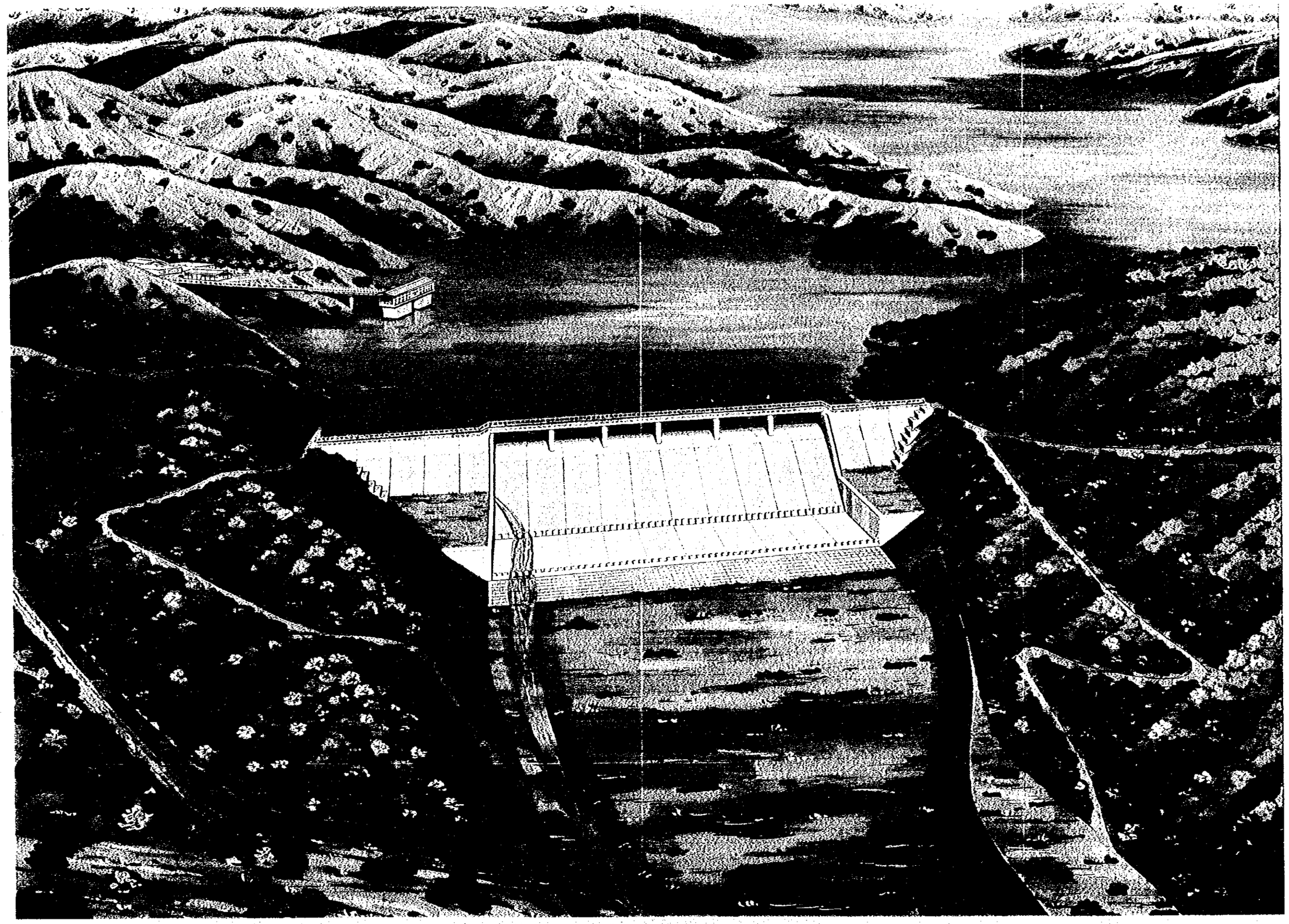


Figure-4.27 Image Sketch of Vaza Barris Dam

4.6 Design of Check Dam

4.6.1 Selection of Check Dam Site

Location of the check dam must be studied in the viewpoint of the reservoir water level, in order to divert design flow through the low flow bypass. An ideal location of the check dam should be at the end of reservoir, and consequently long bypass is needed and relatively high intake weir (check dam) is required. The location of the check dam is presented in Figure-4.28.

The both valley slopes of the proposed check dam site are relatively steep, whereas they become very steep or almost vertical at the upstream. This site has an appropriate width to construct a check dam and accessory structures in a small scale and on a sound rocky ground.

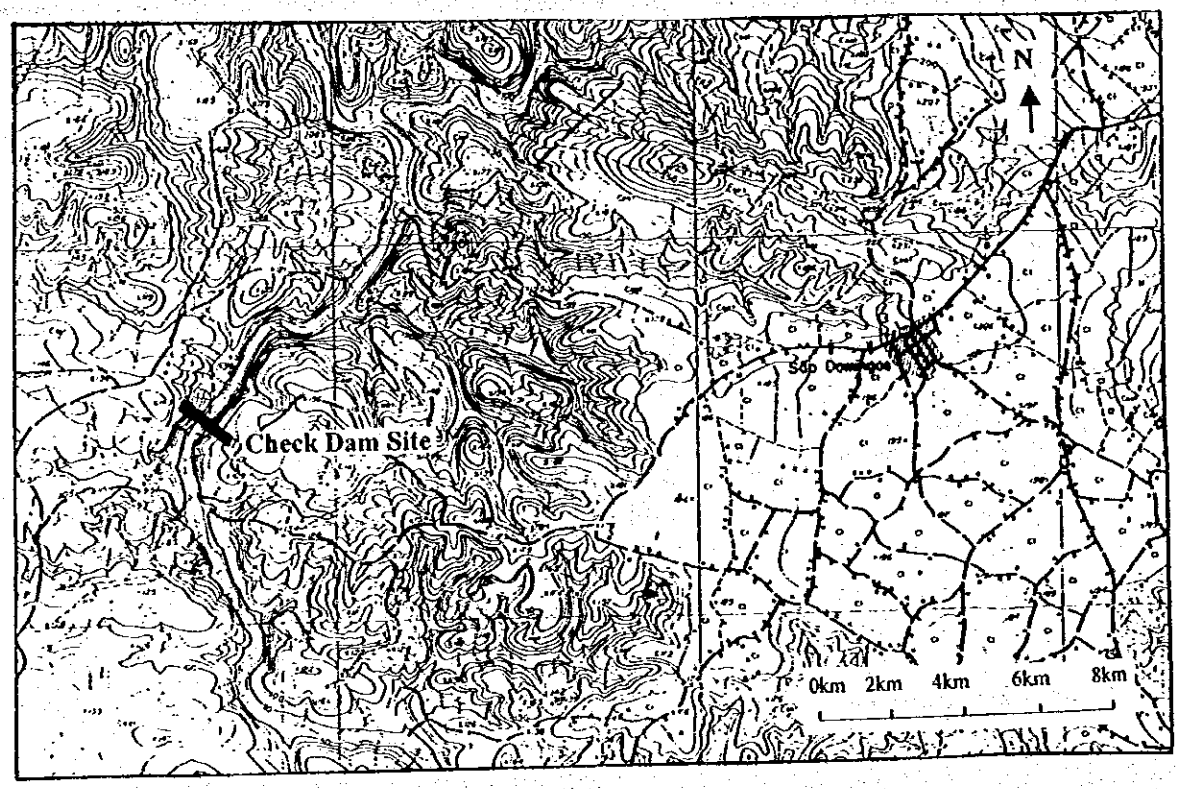


Figure-4.28 Location of Check Dam Site

4.6.2 Geology of Check Dam Site

One (1) drilling survey and geological site reconnaissance were conducted at the supposed check dam site, and geological section was made as shown in Figure-4.29. The rock condition was that of slightly weathered rock. The rock is considered to have an appropriate bearing capacity for concrete dam and sufficient impermeability.

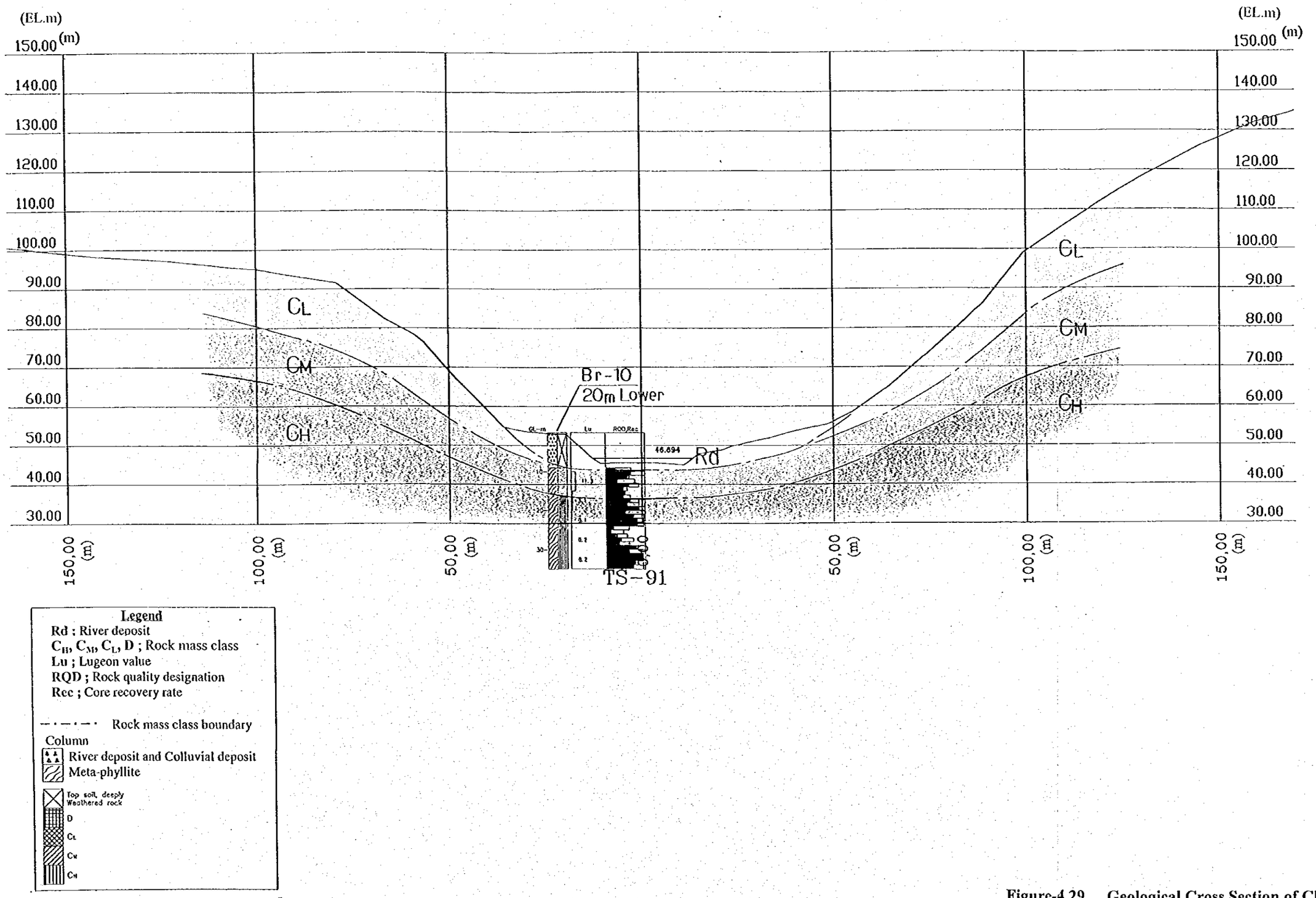


Figure-4.29 Geological Cross Section of Check Dam Axis

4.6.3 Design of Check Dam

(1) Function of Check Dam

According to the reservoir operation plan, design reservoir sedimentation volume was set as 12,000,000 m^3. Out of this volume, 10,000,000 m^3 of sediment volume is to be stored in the check dam reservoir, in order to decrease sedimentation in the main dam reservoir. Therefore, this check dam is inevitable to suffice the proposed reservoir operation plan. Moreover, the check dam has a function as a intake weir for low flow bypass.

(2) Design Condition

(a) Type of Check Dam

Type of the check dam is set as a gravity concrete dam because of having advantages on workability of construction and resistance to flood with sediment.

(b) Location of Check Dam and Top of Dam

The location is the upstream end of reservoir where the design reservoir volume is secured at the normal water level (see Figure-4.28). Also, the location is decided from viewpoint of topography and geology. The proposed location is located 29.5 km far upstream from Vaza Barris Dam. The elevation of the top of dam is E.L. 63 m to secure the design sediment volume of 10,000,000 m^3.

(c) Dam Foundation and Dam Height

According to the core boring survey result at the check dam site, C_L-class rock and C_H-class rock lie on E.L. 43 m and 41 m respectively. C_M-class rock is not identified at the site. The check dam is put on the C_L-class rock. Therefore, the check dam height is 20 m while the elevation of dam top is E.L. 63 m. C_L-class rock is strong enough to construct this class of a concrete dam.

(3) Design of Waterway

Considering the width of the current river, the width of waterway is set as 70 m. The water depth is 4.95 m to pass the design discharge 1,400 m^3/s (120% flood discharge of 100 year return period). The height of the water way is set as 6 m adding a freeboard to over flow depth, consequently the elevation of the top of dam is set as EL. 69 m.

(4) Design of the Check Dam Body

As the dam height is 20 m, the same stability analysis as that of a normal dam was carried out in the stability analysis of the check dam. The design of the check dam is different from a normal dam in the viewpoints of follows:

1) A check dam is planned to have sediment at the level of the waterway top. Since river water including sediment load flows down through a downstream face of the dam, a downstream slope should be steep to avoid abrasion by sediment. The standard downstream slope of a check dam is employed as 1:0.2 following the Japan standard.
2) Curtain grouting for water cutoff is not designed because water storage function is not needed for the check dam

Stability for the check dam body was analyzed following the design standard by SEMIG.

Analysis cases are set as same as that of the main dam and the analysis section is set at over the flow section.

The sectional form of the check dam body, which satisfies the design standard in the dam stability analysis (see Table-4.16), was set as follows:

- Width of Waterway: 4 m
- Upstream Slope: 1:0.53
- Downstream Slope: 1:0.29

The dam plan and structural drawings are shown in Figure-4.30 and Figure-4.31.

Table-4.16 Results of Check Dam Stability Analysis

Case	Section and allowable value	Safety Coefficients to Fluctuation	Safety Coefficients against the Overturning	Factor of Safety to the Sliding	Tension (ton/m²)	
					Upstream compressive stress σ vu	Downstream compressive stress σ vd
Case of Normal Load	Overflow section	4.89	6.47	1.88	3.189	51.982
	Allowable minimum value	1.3	1.5	1.0	-7.0	
Case of Exceptional Load	Overflow section	3.59	4.81	2.15	-13.845	66.705
	Allowable minimum value	1.1	1.2	1.0	-14.0	

(5) Design of Sub-dam (Protection for Scouring)

Based on Japan standard, namely Standard for River and Sediment Control Works, protection works for downstream scouring are designed. The length from the main dam to the sub dam is set 33 m and the top elevation of the sub-dam is set as same elevation as the front apron elevation for the prevention of scouring.

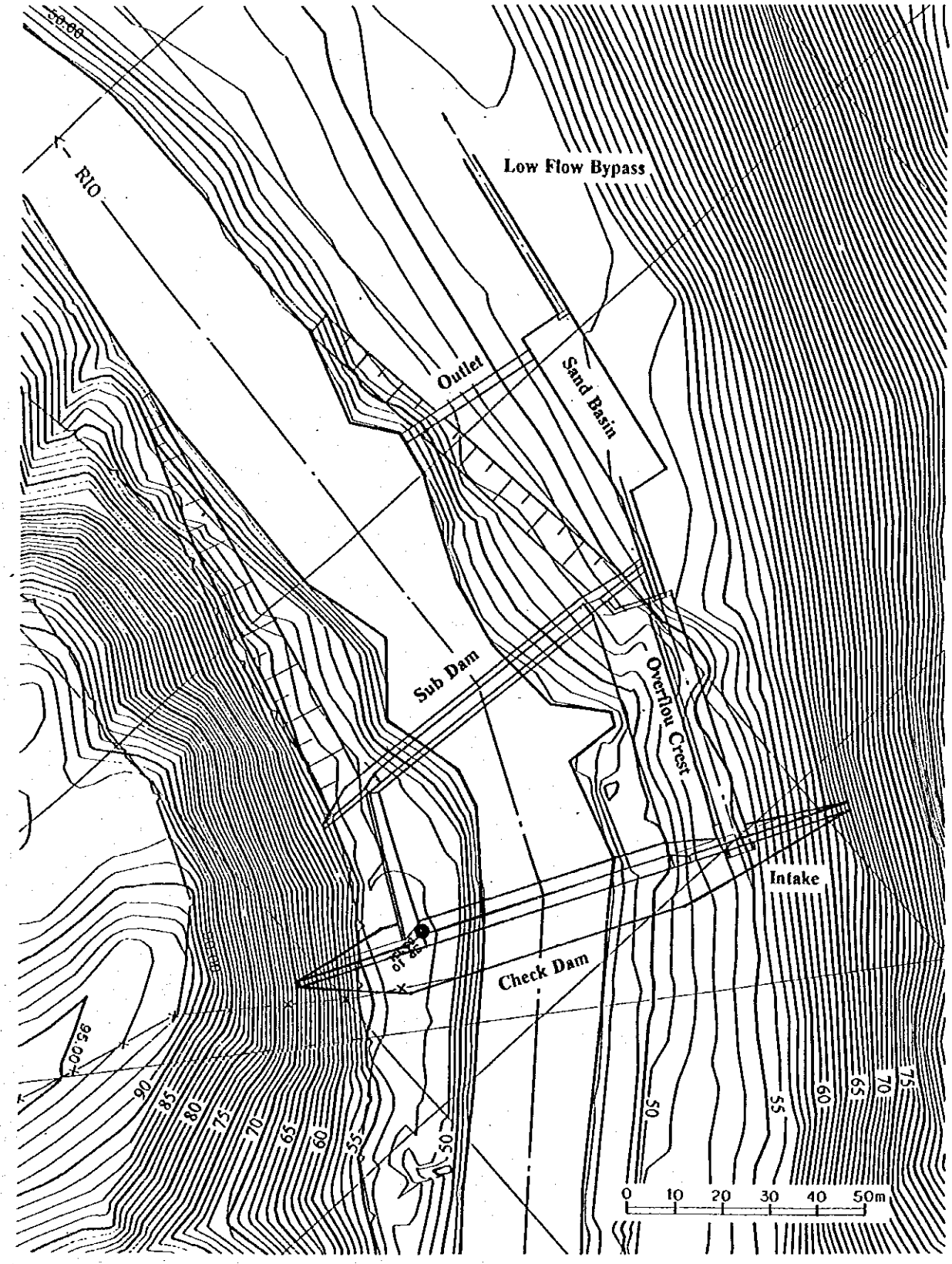
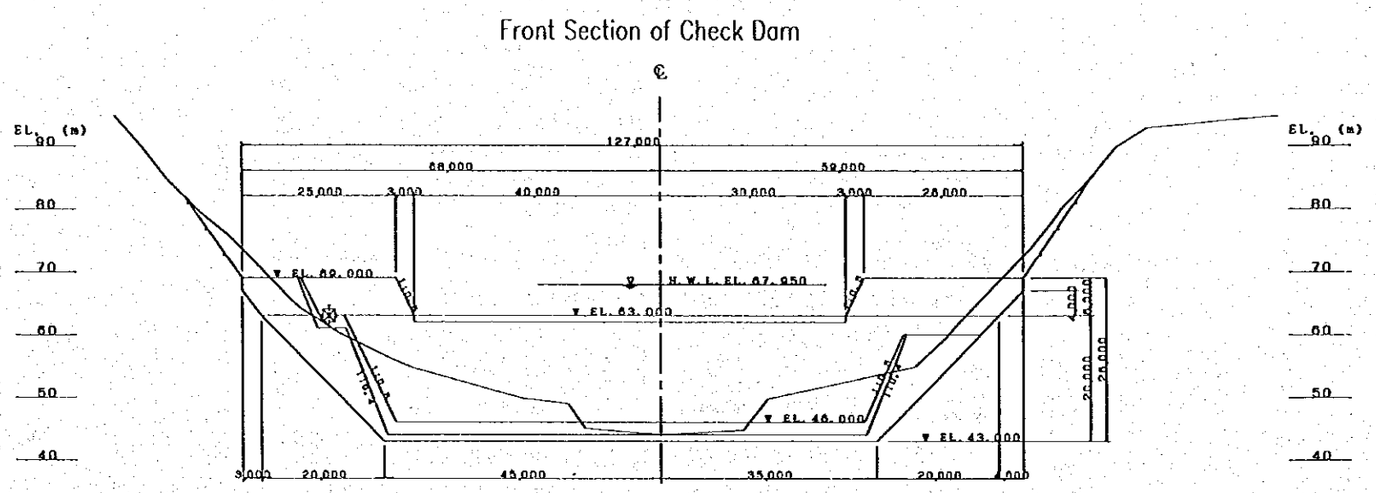
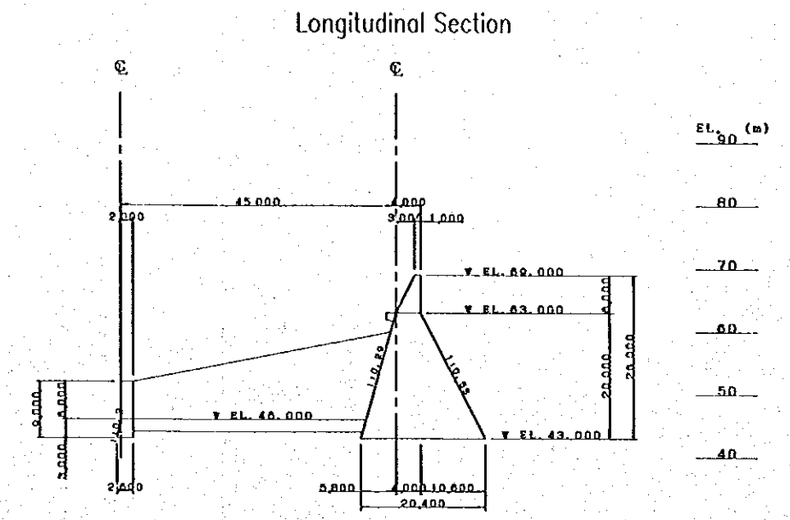
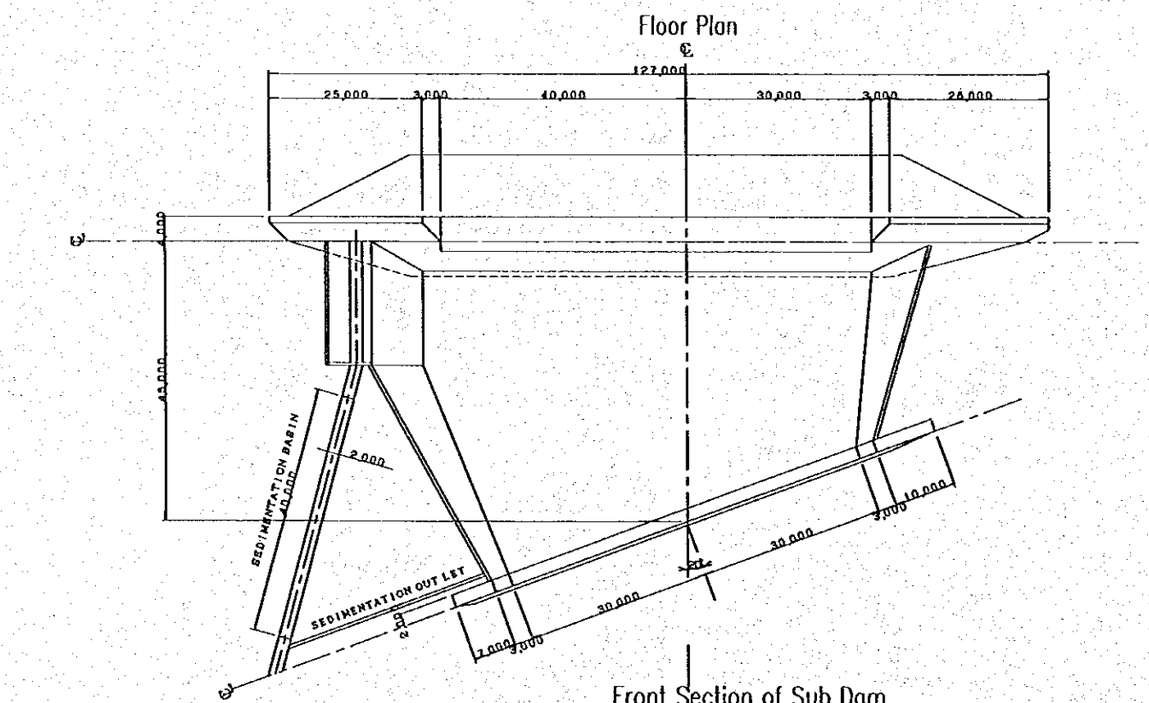


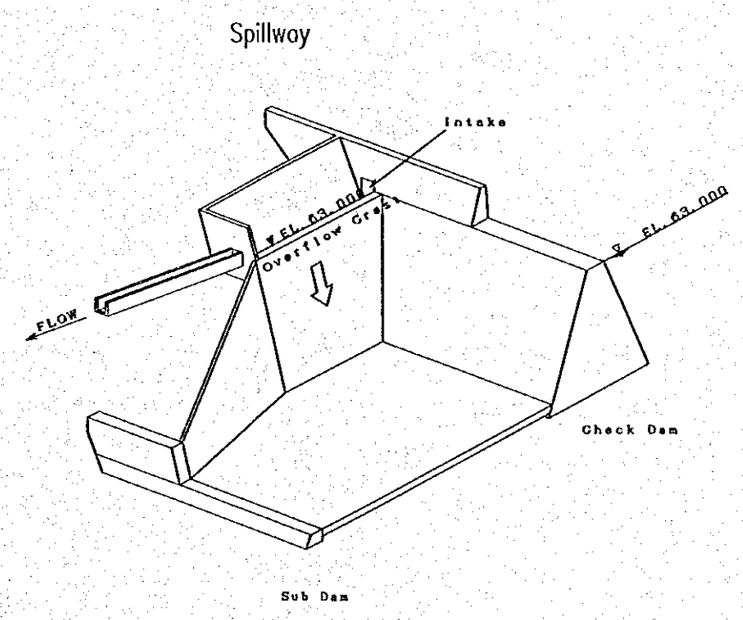
Figure-4.30 Plan of Check Dam

CHECK DAM AND INTAKE OF LOW FLOW BYPASS S=1:500









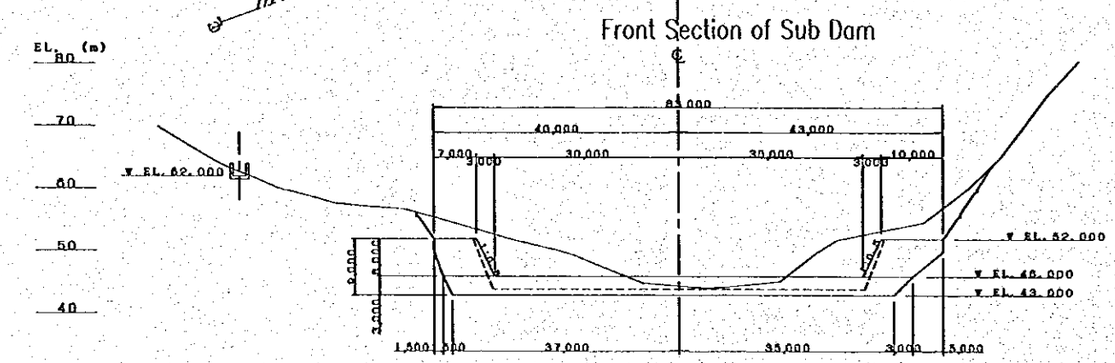


Figure-4.31 Structure of Check Dam

4.7 Plan and Design of Low Flow Bypass

4.7.1 Alternatives of Low Flow Bypass

To convey low flow water not entering reservoir and to decrease salinity of reservoir water, the low flow bypass is planned and compared.

- Open Type :Open type channel is installed along the periphery of reservoir. A channel crosses a valley or steep slope as a bridge.
- Closed Type :Closed type of pipeline or box culvert is installed in the bottom of the reservoir.

(1) Design Condition

< Water Level and Design Discharge >

- Upstream at outlet of Check Dam : EL. 63.0m
- Downstream at Vaza Barris Dam : EL. 56.0m (Open channel)
  : EL. 29.0m (Pipeline and Culvert)
- Design Discharge :0.75m^3/s

< Coefficient of Roughness >

- Steel pipe : 0.015
- Concrete channel or culvert : 0.020
- Friction loss is taken into account in hydraulic calculation.

(2) Description of Alternatives

(a) Bypass Open Channel

Longitudinal slope of the bypass open channel is preferably constant throughout the channel route. In principle, the channel is constructed excavating ground on the middle of hill slope. At the place where the channel crosses a deep valley, a concrete bridge or earth embankment supports it in order to minimize the total length of the channel. At the place where hill slope is very steep and excessive excavation is expected, a bridge supports the channel. The bridge has a span of around 15m and is constructed by cast-in-place concrete.

Maintenance road with 3m wide is provided beside the channel. For bridge sections, the maintenance road is also constructed on hill slope apart from the bridge. The required channel dimension is W 1.5 m x H 1.5 m to convey the design discharge of 0.75 m^3/s with 80 % water depth. Channel slope is 1 : 3,750. Flow velocity is 0.7 m/s. The flow of the channel is sub-critical flow, since Froude Number of the channel flow is 0.17. Although it is rather difficult to precisely construct this kind of channel with slope required by design because the channel slope is very small, some irregularities of slope are acceptable because the flow is sub-critical flow. The construction of this type of channel affects much to environmental conditions.

(b) Bypass Steel Pipeline

Longitudinal slope of the bypass steel pipeline is not necessary to be constant because the water in pipeline flows by pressure. It is recommendable to provide downward slope as much as possible to prevent the sedimentation in the pipe. Large degree of bends in horizontal and vertical directions is avoided by means of excavating or embanking the natural ground surface along the pipeline route to secure smooth alignment. Steel pipe under water is backfilled after installation of the pipe to prevent uplift by buoyancy.

The pipe diameter to transport design discharge of 0.75 m^3/s is obtained as ϕ 1,000mm by hydraulic calculation taking into account of the friction loss in welded steel pipes. Flow velocity inside of pipe is 1.0m/s. The cathodic protection with 80 years of service life is provided to external and internal surface of steel pipe to protect the steel pipe against corrosion. At the downstream end of pipe, the diameter of pipe is reduced to 0.45 m to regulate the discharge volume and shut gate is provided for emergency use. The affect of construction of steel pipe to environmental conditions is negligibly small since the pipe is backfilled and installed under reservoir water.

(c) Bypass Box Culvert

The same precaution is required as to the bypass steel pipeline against large degree of bends in vertical and horizontal alignment. No uplift is expected because it is heavier than uplift force by buoyancy. Hydraulic calculation shows that the required section of box culvert to transport the design discharge of 0.75m^3/s is W 1.05m x H 1.05m and flow velocity is 0.7 m/s. The downstream end of box culvert is connected to steel pipe with ϕ 1,000 mm diameter and is lead to inside of dam body. The shut gate is provided as same as for bypass steel pipe. The affect of construction of box culvert to environment is also negligibly small since the box culvert is installed under water.

(3) Comparison of the Design of Low Flow Bypass

As for the alternative designs of low flow bypass, earthwork volume is calculated based on the relation between the horizontal and vertical alignment of each bypass and the natural ground surface condition along the bypass routes. The quantities of other works are also obtained based on the longitudinal and transversal sections of each bypass. Based on the construction quantities, construction cost was estimated.

The alternative designs were evaluated in viewpoints of design, workability, operation and maintenance, environment, economy and so on. Table-4.17 shows the comparative evaluation on the alternative designs of low flow bypass.

In this Feasibility Study, the box culvert bypass of the closed type was adopted as a low flow bypass, which is superior on many points although it has difficulty on maintenance.

Table-4.17 Comparison of Low Flow Bypass

Items	Open Type: Open Channel	Closed Type: Box Culvert	Closed Type: Pipeline
Flow Type	Open type	Pressure type	Pressure type
Section	Concrete rectangular channel: W1.5m x H1.5m	Concrete box culvert: W1.05m x H1.05m	Steel pipe: ϕ 1,000 mm
Length	30.0 km	27.7 km	27.7 km
Head	8.0 m	38.0 m	38.0 m
Flow Velocity	0.6 m/s	0.7 m/s	1.0 m/s
Dam Crossing Method	- Channel is installed on the elevation higher than the top of dam.	- A pipe crosses the dam body. - To control discharge, valve is equipped.	- Same as the left
Sediment Problem	- At the intake, sedimentation basin is installed. - It is easy to clean deposit in the channel.	- At the intake, sedimentation basin is installed. - It is difficult to clean deposit in the box culvert. - Flow velocity of 0.7 m/s seems to cause no sedimentation in box culvert.	- At the intake, sedimentation basin is installed. - It is difficult to clean deposit in the pipeline. - Flow velocity of 1.0 m/s seems to cause no sedimentation in pipeline.
Maintenance	- It is easy because the facility is installed out of reservoir.	- It is difficult because the facility is submerged permanently on the bottom of reservoir.	- Same as the left
Impact to Environment	- Channel installation requires a large amount of earthworks of cutting and embanking riverbanks.	- Impact to environment is very small because most of the facility is concealed under the reservoir water.	- Same as the left
Impact to Reservoir Operation	- Channel divides drain system into the reservoir. It is necessary to put rainwater drain system to across underneath the channel.	- Leakage of water from reservoir into pipeline is avoided by providing careful construction.	- Leakage of water from reservoir into pipeline is avoided by providing cathodic protection to steel pipes.
Construction Workability	- Construction material is carried through the maintenance road to the construction site of channel. - The construction work of bridge with cast-in-place concrete requires much construction time and cost. - Installation of prefabricated bridge is much more difficult than cast-in-place concrete bridge.	- Access to the construction site is very easy. - Construction material is entered from the existing approach road and carried on the riverbed or river terrace. - Concrete work for box culvert is easy and simple.	- Access to the construction site is very easy. - Construction material is entered from the existing approach road and carried on the riverbed or river terrace. - Installation of pipeline in the reservoir area is easy and simple.
Construction Cost	- R$ 47.1 million	- R$ 32.8 million	- R$ 44.5 million
Evaluation	- Maintenance for channel cleaning and repairing is easier. - Water bridge should be carefully designed and constructed based on the proper construction plan. - Impact to environment is larger. - Construction cost is higher	- Careful design is required to assure maintenance free bypass after filling of reservoir. - It is difficult to check and repair box culvert during reservoir operation. - Workability and impact to environment is much better than open channel. - Construction cost is lowest.	- Careful design is required to assure maintenance free bypass after filling of reservoir. - It is difficult to check and repair pipe during reservoir operation. - Workability and impact to environment is much better than open channel. - Construction cost is higher than box culvert.

4.7.2 Design of Low Flow Bypass

(1) Design of Low Flow Bypass

(a) Design Condition

- Type of Bypass : Reinforced Concrete Box Culvert
- Water Level : Upstream at outlet of Check Dam : EL.63.0m
  : Downstream at Vaza Barris Dam : EL.29.0m
- Flow Volume : 0.75m^3/s
- Coefficient of roughness : Concrete surface : 0.020
  (Friction loss is taken into account in hydraulic calculation.)

(b) Required Section

Hydraulic calculation shows that the required section of box culvert to transport the design discharge of 0.75m^3/s is W 1.05m x H 1.05m and flow velocity is 0.7m/s. Thickness of slabs and walls is determined as 0.40m taking the external and internal water pressures into consideration.

(c) Longitudinal Alignment

Longitudinal alignment of the bypass box culvert is shown in Figure-4.32. This section is prepared based on the routing plan of the bypass using the existing 1:5,000 scale topographic map along the Vaza Barris River. Large degree of bends in horizontal and vertical directions is avoided by means of excavating or embanking the natural ground surface along the bypass route to secure smooth alignment.

(2) Design of Intake Facility

Intake facility for bypass is installed at the check dam. The intake works are composed of an inlet, a sedimentation basin, a discharge regulation spillway and a gate to stop water entering. The sedimentation basin is designed as width: 2 m x depth: 2 m x length: 40 m to settle sediment of 0.3 mm diameter. At the front of intake, screen is installed to prevent invasion of floating woods and people for safety reason.

(3) Consideration to Sedimentation

Sedimentation of soils and suspended materials in the Bypass during flood period might cause the less capability of water passage and the blockage of the bypass by sedimentation in the worst case. It is concluded that the following countermeasures are effective to prevent sedimentation in the Bypass:

1) Screen is installed at the entrance to the intake facility to prevent floating woods or particles from entering the bypass.

2) Sedimentation basin is constructed to prevent the soils from entering the bypass. Calculation shows that the grain size of soil less than or equals to 0.3 mm could

be settled down in the basin with dimensions of 40 m long and 2 m deep.

3) Flow velocity in the bypass with the design discharge of 0.75 m^3/s is about 0.7m/s. The relationship between the grain size and critical flow velocity, which is the minimum velocity not to cause movement of settled soils, according to the formula presented by Justin, the critical flow velocity for 0.3 mm particles is 0.056m/s. Therefore, it is judged that the silt or clay with grain size less than or equal to 0.3 mm is washed out to the downstream of the bypass. Although the soils with larger grain sizes may enter into the bypass, it is also washed down since the critical velocity of grain size of 5 mm is 0.229 m/s.

4) The shut gate at the outlet of the bypass controls the flow volume in the bypass. Turbid water with sediment load could not inflow to the bypass when a gate is closed.

5) Aquatic plant might be grown inside of bypass when the velocity is slow. In general, the design velocity over 0.7 m/s is adopted to prevent growing aquatic plant. Although the velocity of 0.6 m/s in the box culvert is less than 0.7 m/s, it seems no problem because: 1) the flow in bypass is of high chlorine concentration, and 2) Inside of the bypass is difficult circumstance for aquatic plant to grow without sunshine.

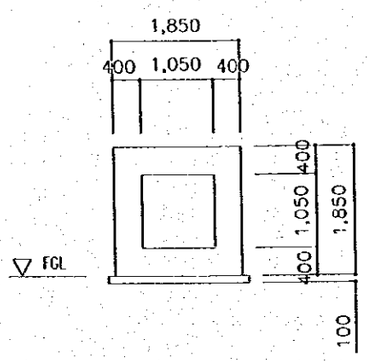
6) Some sedimentation can be allowed by dimensioning of the box culvert larger than the hydraulically required dimensions.

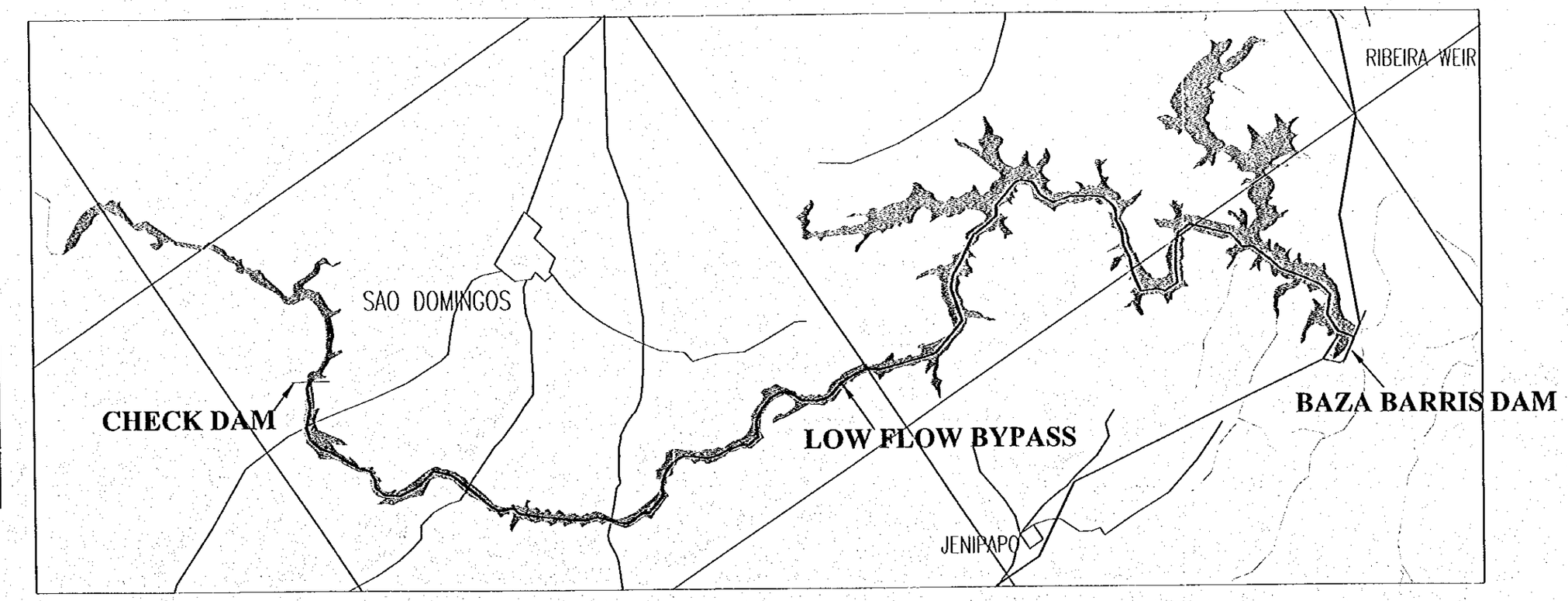
(4) Design Profile

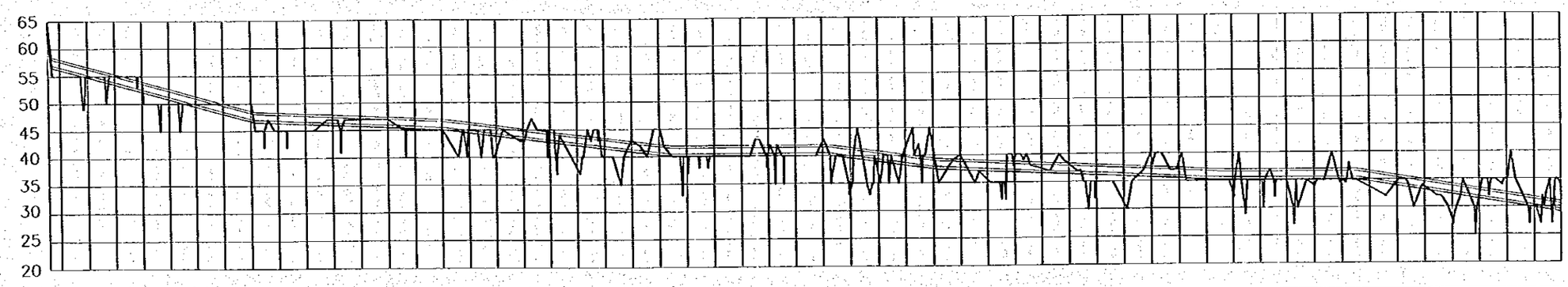
The design Profile of the low flow bypass, the concrete box culvert type, is shown in Figure-4.32.

LOW FLOW BYPASS CULVERT TYPE LONGITUDINAL SECTIONS

CLOSS SECTION







STATION NO.	0	4	190	362	572	710	718	816	1083	1199	1386
TOTAL DISTANCE (M)	0	80	3800	7240	11450	14360	16320	21660	23980	27720	
PARTIAL DISTANCE (M)	0	80	3720	3440	4210	2910	1960	5340	2320	3740	
GROUND ELEVATION (M)	63.0	55.0	45.0	45.0	40.0	40.0	35.0	35.0	35.0	34.0	
INVERT ELEVAION (M)	63.0	56.9	46.9	45.4	40.4	40.4	37.8	35.4	35.4	29.0	

Figure-4.32 Profile of Bypass Box Culvert

4.8 Construction Plan

There are, in general, three methods of temporary diversion works, namely 1) Diversion flowing in half of a river section, 2) Tunnel diversion and 3) Open channel diversion. The first method, diversion flowing half of river section was adopted in this plan, taking into account of 200 m^3/s of design discharge (2-year return period) and topographic feature of the dam site.

Placing of concrete pouring is starting from the left side of the dam, taking into account of arrangement of concrete batching plant and conveyance route of concrete aggregate. Temporary diversion is installed inside of the dam body at the level of EL. 20 m and concrete is placed to all the river section after diverting to bypass in the dam.

The size of temporary diversion is set as follows:

<Excavated Open Channel>

- Trapezium water channel: Base width 15 m
- Slope gradient: 1:1.0
- Water depth: 4 m

<Rectangular Channel Inside of the Dam>

Width 3-4 m x Height 3-4 m

Construction Plan of the dam during three years between 2004 and 2006 is shown in Table-4.18.

Table-4.18 Construction Plan of the Dam

Work Item	Construction Amount	2004		2005		2006	
Main Dam Works							
1) Temporary Diversion	1 set						
2) Foundation Excavation	380,000 m^3						
3) Grouting	4,800 m						
4) Concrete Placing	260,000 m^3						
5) Discharge Outlet facilities	1 set						
6) Closing Works	1 set						
Construction Facilities/Plant							
1) Site Road	km						
2) Construction Facilities	1 set						
Others							
1) Check Dam	1 set						
2) Low Flow Bypass	1 set						
3) Test of Water Filling	1 set						

CHAPTER 5 PLAN AND DESIGN OF WATER CONVEYANCE

5.1 Criteria for Plan and Design

5.1.1 Planning Criteria

(1) Components Included

The components included in the Water Supply Systems are Vaza Barris Dam, Water Pump Station (WPS), Conveyance Pipeline, Water Treatment Station (WTS), Distribution pipeline and Distribution network. General conceptual sketch of the system is as shown in Figure-5.1. The facilities shown by thick line in Figure-5.1 is considered as the water conveyance facility included in the Feasibility Study.

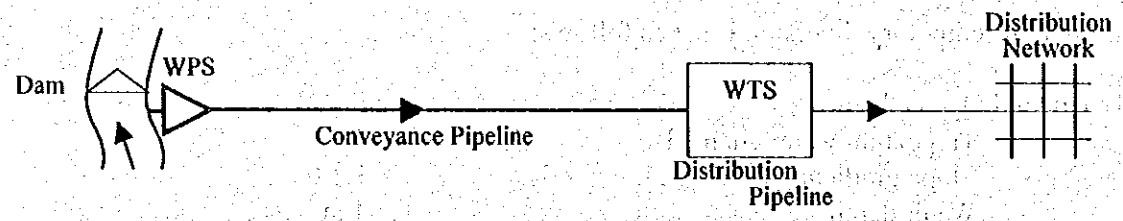


Figure-5.1 General Conceptual Sketch of Water Supply System

(2) Water Pump Station, WPS

(a) Criteria for Selection of Location of WPS

Location of WPS is selected considering the following points:

- Vicinity of Vaza Barris Dam
- Direct intake from Vaza Barris Reservoir
- Water to be conveyed by pipeline both in the right and left banks of Vaza Barris River, namely Agreste (Itabaiana) and Piauitinga (Lagarto) regions
- Existing electric power supply facility is located in the left bank near Cajaiba village
- No existing access road to construction site for WPS

(b) Criteria for Plan and Design of Pump System

Pump system is designed taking the following items into consideration:

- Length of pipeline
- Suction head
- Total head
- Required discharge capacity of pump and adaptability to fluctuation of discharge volume
- Fluctuation of intake water level
- Siphon effect
- Easy countermeasures against water hammer
- Easy operation and maintenance
- High reliability and redundancy of pump system
- Pump head-discharge curve
- Prevention of cavitation in pump
- Specific speed of pump
- Transmission system for motor to the rotating vane and type of reduction gear
- Occupied installed area of pump

(3) Connecting Reservoir

Connecting reservoir is required if one pumping system is not advantageous. Storage capacity of connecting reservoir is determined by the following items:

- Operational condition of pumps
- Frequency and condition of maintenance works of pumps
- Possibility of occurrence of electric power failure and duration of electric power outage

(4) Water Conveyance Pipeline

Diameter of pipeline is determined by life cost of water conveyance system including pump facilities. Concept of annual cost and net present value is introduced for this evaluation. Pipeline routing is planned based on the following criteria:

- Low life cost
- Easy installation and maintenance works
- Existing pump stations and pipelines
- Location of villages on the way to final destination
- Total length of pipeline as short as possible
- Topographic condition
- Hydraulic gradient in pipeline
- Effect of water hammer
- Thickness of pipes to be designed in accordance with loading conditions
- Auxiliary facility such as valves, drains, etc. where required

5.1.2 Design Criteria

(1) Codes and Standards

Facilities to be required in the Feasibility Study is designed in accordance with the Codes and Standards published and authorized by federal, regional, state, municipal and/or any other public organizations or authorities in Brazil. When applicable Codes and Standards are not specified by the related organizations mentioned above, the Codes, Standards and Regulations in Japan is used with some adjustment in accordance with the local conditions in the State of Sergipe. The following codes and standards is used for the design of water conveyance facilities:

- Brazilian Norms (NBR), Brazilian Association of Technical Norms (ABNT)
- Japan Water Works Association (JWWA)
- Japan Society of Civil Engineers (JSCE)
- Japanese Industrial Standard (JIS)
- American Water Works Association (AWWA)
- American Standard of Testing Materials (ASTM)

(2) Units of Measurements

Units of measurements used in design or specification of materials is in SI/MKS metric system.

(3) Method of Design of Facilities

In principle, allowable stress design method is applied for all structural design of the facilities.

(4) Materials to be Used

All materials to be used for construction of facilities required in the Feasibility Study is in accordance with Brazilian Technical Standards (ABNT) or equivalent Japanese Industrial Standards (JIS) or other internationally accepted standards.

(5) Loads to be Considered

In principle, the loads to be considered in the design of structures in the Water Conveyance Systems are dead weight, live loads including floor loads, equipment loads, earth pressure, groundwater pressure, hydrostatic pressure, uplift pressure and wind loads. Seismic loads such as seismic body force and hydrodynamic pressure are not considered.

(6) Design Parameters and Water Supply Volume

- Estimated population at the target year, P (person)
- Design daily water supply volume per capita :
  - Urban area q = 160 liter/capita/day
  - Large Rural area q = 120 liter/capita/day
- Coefficient of daily variation of consumption : k_1 = 1.2
- Coefficient of hourly variation of consumption : k_2 = 1.5
- Rate of water loss : r_L = 0.42 in 1,998
  = 0.25 in 2,020
- Daily maximum water supply volume, Q_{DM} (litter/day)

$$Q_{DM} = \frac{P \times q \times k_1}{1 - r_L}$$

- Hourly maximum water supply volume, Q_{HM} (litter/day)

$$Q_{HM} = Q_{DM} \times k_2 = \frac{P \times q \times k_1 \times k_2}{1 - r_L}$$

(7) Calculation of Head Loss

The head loss is the hydraulic head loss such as pipeline friction loss, shape loss and fluid friction loss. In principle, Darcy·Weisbach formula can be applied to friction loss of pipelines. Manning formula is applied to open channel, culvert, siphon, etc.

(8) Motor Power of Pumps

Motor power of pumps can be given by calculation using the following formula:

$$L = \frac{\rho \cdot g \cdot Q \cdot H \cdot (1 + \alpha)}{\eta_P \cdot \eta_G}$$

where,
- L : Motor power (kW),
- ρ : density of liquid (t/m^3),
- g : acceleration of gravity (m/s^2),
- Q : discharge capacity of pump (m^3/s),
- H : total head (m),
- α : redundancy rate,
- η_P : pump efficiency,
- η_G : transmission efficiency.