Chapter 6
Structure and Layout

6.1 General

The Pamba-Achankovil-Vaippar link project has been conceived as a diversion cum storage scheme with benefits like power generation facility, transfer of a part of the combined yield of Pamba Kal Ar and Achankovil Kal Ar to Vaippar basin and assured releases into the river downstream.

The proposal of the link comprises of:

i. A 150 m high and 774 m long concrete dam on Pamba Kal Ar at Punnamedu, 11 km upstream of Thekkuthodu village in Kozhenchery Taluk of Pathanamthitta district.

ii. A 160 m high and 738 m long concrete dam on Achankovil Kal Ar, 3 km upstream of the confluence of Achankovil with Achankovil Kal Ar.

iii. An interconnecting tunnel of length 8 km and 5 m diameter between Punnamedu and Achankovil Kal Ar reservoirs.

iv. A tunnel of length 9 km and 8 m diameter taking off from Achankovil Kal Ar reservoir and terminating into an open gravity canal in the eastern side of the Western Ghats.

v. A 35 m high and 216 m long concrete gravity dam on Achankovil river downstream of its confluence with Achankovil Kal Ar. This dam would function as a pumped storage structure.

vi. A power house located downstream of Achankovil Kal Ar dam with an installed capacity of 500 MW to generate peaking power for 6 hours per day round the year. During non-peaking hours the water will be pumped back into Achankovil Kal Ar reservoir.

vii. An open gravity lined canal of 50.68 km length taking off from the exit of the tunnel of 9 km. length and 8 m diameter and terminating into Alagar Odai, a tributary of Vaippar river with four number of canal falls and required number of cross drainage works.

viii. 7 numbers of power houses, one at the inlet of the interconnecting tunnel, one at the toe of Achankovil Kal Ar dam, one at the toe of Achankovil dam and one each at 4 canal drops on the main canal.

The head works, their vicinity, reasons for choice of the layout of dam, power house and tunnel are discussed briefly in the subsequent paragraphs:

6.2 Structures

All the head works are located in reserve forest of Kollam and Pathanamthitta districts of Kerala. At Punnamedu, the river flows through mountainous region and at Achankovil Kal Ar and Achankovil dam the river flows through sub-mountainous region. The bed slope of the river in the vicinity of Punnamedu dam is 1 in 143, and at Achankovil Kal Ar dam and Achankovil dam, the slopes are 1 in 128 and 1 in 252 respectively.

The sections of the rivers on which the dam sites are proposed are narrow with steep gorge and high banks. The bedrock formations are expected to be available at reasonable depths.

6.2.1 Layout of the project

At the present, the location of each dam site alongwith spillway is provided in the deep gorge portion of the river. Powerhouse is located downstream of the non-overflow block on the left side of riverbed. The interlinking tunnel between Punnamedu and Achankovil Kal Ar reservoir is located on the left bank of Pamba Kal Ar, while the tunnel taking off from Achankovil Kal Ar reservoir and run towards Tamil Nadu is located on the left bank of Achankovil Kal Ar reservoir.

The permanent stream width at Punnamedu, Achankovil Kal Ar and Achankovil dam sites are 25 m, 30 m and 40 m, respectively. Spillways are provided with a discharging capacity of 2756 m^3/sec, 2756 m^3/sec and 4134 m^3/sec at MWL at Punnamedu, Achankovil Kal Ar and Achankovil dam respectively. The length of spill way is 39 m, 39 m and 57 m respectively at the three dam sites.

Due to the non-availability of suitable materials for earth fill at reasonable lead, construction of concrete dam at these sites were suggested by GSI instead of composite dams.

The powerhouse is proposed to be located on the downstream of the non-overflow block of Achankovil Kal Ar dam on the left flank of the river. The

tailrace water will join the reservoir formed by the construction of Achankovil dam.

6.2.2 Geology, Seismicity and Foundation

a) Geology of the entire project area

The most prominent rock formations at Punnamedu and Achankovil Kal Ar dam sites are of Archaean age Charnockites. Moderately weathered to fresh Garnetiferous biotitic gneiss is exposed in the bed of Achankovil River on the right bank of dam site. Some foliation joints are also noticed along the east-west direction.

b) Geotechnical evaluation of foundation abutments, reservoirs and other major components

Drilling of bore holes, evaluation of foundation and engineering properties of foundation materials have not been done at the present stage. These investigations will be carried out in detail at DPR stage.

c) Seismicity

The project area falls under zone III as read from the map of India showing various seismic zones (IS code 1893-1984 entitled, "criteria for earthquake resistant design of structures").

6.2.3 Design flood

The estimated maximum flood for Punnamedu, Achankovil Kal Ar and Achankovil reservoirs are 2738.55 M^3/sec., 1910.l45 M^3/sec. and 3339.72 M^3/sec. respectively. Flood routing studies have been carried out. The maximum design flood is disposed at +246.0 m, +210.829 m and +65.781 m at Punnamedu, Achankovil Kal Ar and Achankovil reservoirs with crest levels at 234.0 m, 198.0 m and 53.0 m respectively. The length of spillway at the three dams is 39 m, 39 m and 57 m respectively. The number of gates proposed is 2, 2 and 3 Nos. respectively at these dam sites and are of size 15 m x 12 m.

6.2.4 Free board for the dam

It is computed from the maximum height of wave generated on the reservoir surface because of the wind blowing over it. The backwaters of the Punnamedu, Achankovil Kal Ar and Achankovil reservoirs are expected to stretch for a distance of 11 km, 23 km and 11 km respectively. The maximum

wave height computed is 0.66 m at Punnamedu, 0.74 m at Achankovil Kal Ar and 0.65 m at Achankovil dam. The elevation of wave run up at these dams at MWL is +246.66 m, +211.569 m and +66.431 m respectively. The top of the dam is fixed as 250.0 m at Punnamedu, 215 m at Achankovil Kal Ar and 69 m at Achankovil to take care of splashing of water over the non-over flow sections and any unforeseen floods in the reservoirs.

6.2.5 River Diversion Arrangements

Cofferdams are proposed to be constructed at a location 200 m upstream of the proposed dams to take care of the river flood diversion during the construction period of the main dam. In order to facilitate diversion of river water, the cofferdams are proposed to be constructed in two stages. The selection of locations of cofferdams are made so as not to disturb the construction activities at the main dam sites. As the dams are of concrete gravity, separate structure for care and diversion is required only up to concreting of the dams to a safer height.

6.2.6 Construction Materials

The location of stone quarries which have been identified for the head works are spread over the reservoir areas, at tunnel inlet and outlets. The total quantity of stone available is assessed to be 2.3×10^7 M^3. The average lead is around 4 kms. There is scarcity of sand in the Pamba and Achankovil basins. Hence, it is proposed to use quarry dust for that purpose. The nearest cement factory is at Tirunelveli in Tamil Nadu. Steel is also to be procured from Tamil Nadu for which the nearest railway head is Shencottah.

A quantity of about 7.4×10^5 M^3 of sand is assessed to be available in the stream beds of Hanuman Nadi, Chittar Nadi, Nichibanadi, Kaka Nadi and Deviyar. The average lead is around 15 kms. Good quality of rubble to an extent of 2.24×10^8 M^3 has been assessed to be available from the quarries located in the vicinity of canal alignment. The average lead works out to about 10 km.

Qualitative assessment of the construction materials requirements and their engineering properties will be carried out at DPR stage.

6.3 Concrete dam

6.3.1 (a) Non-over flow section – Design criteria

i) Section

The length of non-overflow section at Punnamedu, Achankovil Kal Ar and Achankovil reservoirs is 735 m, 699 m and 159 m respectively. The top width of the dams is 8 m.

ii) Stresses developed

The stresses developed at the base of the non-overflow section are within the permissible limits specified in I.S code 6512-1984.

The maximum compressive stresses developed at the heel and toe are 72.171 tonnes / m^2 and 40.956 tonnes / m^2 respectively at Achankovil dam, 289.074 tonnes/ m^2 and 217.850 tonnes/m^2 at Achankovil Kal Ar and 260.253 tonnes/ m^2 and 183.789 tonnes / m^2 at Punnamedu dams.

The horizontal seismic co-efficient considered is 0.120 and hydro dynamic seismic co-efficient is 0.730.

iii) Sliding factor

The factor of safety against sliding for the conditions of reservoir empty and full and various load combinations as per IS code 6512-1984 are found to be greater than 1.00 which satisfies the condition for factor of safety as recommended in the IS code.

iv) Stability analysis.

The stability analysis of the proposed non-overflow sections has been carried out for the following conditions:

a)	Load combination – A (construction condition): Dam completed but no water in reservoir and no tail water.
b)	Load combination – B (Normal operating condition): Full reservoir elevation.
c)	Load combination – C (flood discharge condition): Reservoir at maximum flood pool elevation, all gates open, tail water at flood elevation, normal uplift and silt.
d)	Load combination – D: Combination A with earthquake.
e)	Load combination – E: Combination B with earthquake.
f)	Load combination – F: Combination C, but with extreme uplift

	(drains inoperative).
g)	Load combination – G: Combination E, but with extreme uplift (drains inoperative).

The sections are found to be safe against overturning and sliding.

6.3.1 b) Spillway section

i) Spillway profile

Downstream profile

The downstream profile has been computed using the following formula by waterways experiment status, USA (adopted by USBR)

$X^{1.85} = 2.0\ H_d\ Y^{0.85}$

Where

H_d = design head

X, Y = Co ordinates along X and Y axis.

Upstream profile

The following equation as given by U.S. Army corps of engineers has been used for finding co-ordinates for upstream face.

$$Y = [(0.724\ (x + 0.27\ H_d)^{1.85})/\ H_d^{0.85}\ ] + 0.126H_d - 0.431H_d^{0.375}(x+0.270\ H_d)^{0.625}$$

where

X, Y = Coordinates along x and y axis from the crest.

H_d = designed head over crest.

The curve extends 0.27 H_d upstream and 0.125H_d below the crest point.

ii) Capacity of spillway

The maximum flood inflows (Probable maximum flood) estimated for Achankovil, Achankovil Kal Ar and Punnamedu dams are 3339.72 m^3 / sec, 1910.45 m^3 / sec and 2738.55 m^3 / sec. respectively. To accommodate the passage of these discharges 3 gates of 15.0 x 12.0 m are proposed at Achankovil dam, while 2 gates of 15.0 x 12.0 m are proposed at Achankovil Kal Ar and Punnamedu dams respectively.

The formula adopted for calculating discharge over spillway is

$$Q = C_d \ L_e H_d^{3/2}$$

Where

C_d	=	Coefficient of discharge = 2.21.
L_e	=	effective length of overflow crest in m.
H_d	=	Head of overflow in 'm' including velocity of approach head.
Q	=	discharge in cumec.

The effective length of overflow crest has been calculated using the equation.

$$L_e = L - 2 (K_a + n K_p) H_d$$

Where

L	=	Total length of spillway in 'm'
K_a	=	abutment coefficient = 0.1
N	=	No. of piers
K_p	=	Pier contraction coefficient = 0.1

iii) Energy dissipation arrangements and protective works down stream

Flip bucket has been provided as energy dissipator, as the tail water level is insufficient for the formation of hydraulic Jump and the bed of the channel d/s comprises sound rock, which is capable of with-standing the impact of high velocity jet.

The bucket radius has been computed using Ven Te Chow formula, R.S. Varshney's formula, M.L Bajaj formula and I.S. 7365 – 1984. The minimum permissible radius has been taken as 5 times the post jump depth. The bucket radius is taken as maximum of the above values. The exit angle has been taken as 38^o.

The skijump bucket has been provided at the toe in the body of the dam at a high elevation. This will increase impact on the down stream. The bucket invert has been provided at the river bed level assuming sound rock would be available at 2.0 m below the river bed.

The radius of the bucket adopted is 23.703 m at Achankovil, 32.989 m at Achankovil Kal Ar and 30.910 m at Punnamedu dam. The lip angle is taken as 30^{o} in all the cases.

iv) Spillway gates, type, size and hoisting arrangements

For crest gates, radial gates are proposed. The size of each gate is 15 x 12 m and the total number of gates are 3 at Achankovil and 2 each at Achankovil Kal Ar and Punnamedu dam.

The hoists are proposed to be installed at RL 74 m, +220 m and +255 m at the three dams, namely at Achankovil, Achankovil Kal Ar and Punnamedu respectively.

v) Spillway bridge

The total number of spans of the bridge over the spillway are 3 nos. at Achankovil and 2 each at Achankovil Kal Ar and Punnamedu each having a clear span of 15 m. The thickness of the piers proposed is 3.0 m.

vi) Scouring / river sluices, gates, stop logs etc.

2 Nos. of river sluices of square shape of size 2.5 x 2.5 m, 2.0 x 2.0 m and 2.5 x 2.5 m are proposed at Achankovil, Achankovil Kal Ar and Punnamedu dams respectively. Necessary gates and stop log arrangements have also been provided.

vii) Spillway
a) Section

The spillway is proposed for a length of 57 m, 39 m and 39 m at Achankovil, Achankovil Kal Ar and Punnamedu dams respectively and the percentages of the spillway with respect to total length of the dam sections are respectively at 24.35%, 5.27% and 5.00%.

i) Achankvoil Dam

The maximum section of the spillway dam has upstream face vertical from EL +52.171 m to +48.81 m and 0.2:1 (H:V) slope from EL +48.81 m to EL + 43.85 m and 0.5:1 (H:V) slope from EL +43.85 m to +34.3 m. The downstream face has a Ogee profile with slope of 0.9:1 (H:V).

ii) Achankvoil Kal Ar dam

The maximum section of the spillway has upstream face vertical from +196.96 m to +150 m and 0.2:1 slope from +150.0 m to +56.31 m. The downstream face has an Ogee profile with slope of 0.9:1.

iii) Punnamedu dam

The maximum section of the spillway has upstream face vertical from EL +233.14 m to 222.964 m and 0.2:1 slope from EL +222.964 to foundation level. The downstream face has a Ogee profile with slope of 0.9:1.

The salient features of the spillway section of all the three dams are given below:

Salient Features of Spillway Section

Sl. No	Particulars	Achankovil	Achankovil Kal Ar	Punnamedu
1)	Maximum flood discharge (m^3 /sec)	3339.92	1910.45	2738.55
2)	Crest level (m)	+53.0	+198.0	+234.0
3)	FRL (m)	+65.0	+210.0	+246.0
4)	MWL (m)	+66.0	+215.0	+250.0
5)	Number of gates	3	2	2
6)	Size of the crest gate (m)	15 x 12	15 x 12	15 x 12
7)	Thickness of the pier (m)	3.0	3.0	3.0
8)	Deepest river bed level (m)	+39.39	+66.31	+116.22
9)	Foundation level (m)	34.0	55.0	100.0

6.3.2 Opening through dams

a) Galleries, adits, shaft, stairs, wells etc.

i) Location, layout and purpose

Foundation cum drainage galleries are proposed at a distance of 10% of the head at the section subject to a minimum of 3.0 m and are connected to foundation rock by drain pipes to relieve the uplift pressure. Vertical shafts are provided to the left of spillway to make access to inspection galleries.

ii) Shape and size

The proposed galleries are rectangular in shape with size 1.5 x 2.25 m at Achankovil, Punnamedu and at Achankovil Kal Ar dams. Inspection gallery of size 1.5 x 2.25 m has been provided at all the three dams.

iii) Stresses around the openings and design criteria

Detailed designs and stress analysis around the openings are not done at the present stage and will be incorporated at DPR stage.

6.4 Tunnels and Intake

Two tunnels are proposed for the diversion of water to irrigation purposes. The tunnel connecting Punnamedu and Achankovil Kal Ar reservoir has a diameter of 5 m and a length of 8 km and is of horseshoe shape. The maximum capacity of tunnel is 28.8 m^3 /sec. The tunnel taking off from Achankovil Kal Ar reservoir and terminating into an open gravity canal in Tamil Nadu has a length of 9 km. The tunnel is of horseshoe shape with a diameter of 8.0 m. The maximum capacity of tunnel is 72 m^3 /sec.

6.4.1 (a) Tunnel Intake

The design of the tunnel intake has been carried out as per I.S 11570-1985 with the following design criteria.

i. The high head reservoir type intake has been provided considering the topography, geology and availability of sufficient water depth at the entrance.

ii. The centerline of intake has been kept at +212.70 m for the tunnel taking off from Punnamedu and +192.18 m for the tunnel taking off from Achankovil Kal Ar.

iii. Type I trash rack has been provided as per IS 11388-1985.

Semi-circular trash racks have been proposed at the head of both the tunnels. The invert level of the tunnel taking off from Punnamedu is 211.25 m and that of the tunnel taking off from Achankovil Kal Ar is 196.80 m. While a vertical trash rack support is proposed at Achankovil Kal Ar reservoir, the trash rack support at Punnamedu is proposed at 10^o slope. The top of the trash rack structure is proposed at +228.0 m at Punnamedu and +210.3 m at Achankovil Kal Ar dams. The radius of

trash rack is 5.43 m at Punnamedu and 6.78 m at Achankovil Kal Ar. The velocity through the rack is 1.0 m/sec.

iv. Coefficient of contraction has been taken as 0.6.
v. Conduit has been placed horizontally.
vi. Elliptical entrance curve has been adopted to satisfy the stream lining requirement.
vii. The air demand has been computed on the basis of full discharging condition of the tunnel.
viii. The bell mouth entry has been designed as per B.I.S. recommendation.

The section of the tunnel has been provided as per I.S 4880 (Part II) – 1976, criteria for geometric design of tunnels. Modified horseshoe sections of dia 5.0 m and 8.0 m are provided for the interconnecting tunnel and Achankovil Kal Ar – Tamil Nadu tunnel.

6.4.1 (b) Tunnel exit

At the exit of the interconnecting tunnel, good quality rock out crop extending to the sides is noticed. Hence, no separate structure is envisaged at the exit of interconnecting tunnel.

At the exit of Achankovil Kal Ar – Tamil Nadu tunnel, hydraulic jump type stilling basin with horizontal apron has been provided as energy dissipation device, as the water depth at the exit will match the hydraulic jump curve. The design of the stilling basin has been carried out as per USBR and IS 4997 – 1968 to determine:

1) Type of stilling basin
2) Basin length and depth
3) Basin appurtenants

Type III stilling basin (USBR type-II) has been provided with basin length of 10.0 m and depth of 4.537 m. The height of chute block is 0.750m with a spacing of 0.750m. The height of basin block is 0.950 m at a spacing of 0.70 m with a top width of 0.20 m.

6.5 Canals

6.5.1 Description of canal system, capacity and alignment

The main canal off taking from the exit of Achankovil Kal Ar – Tamil Nadu tunnel will irrigate the area enroute. The FSL of the canal at off take is 187.00 m. The canal is designed to carry a discharge of 72 m^3 /sec. with 13.8

m bed width. The canal is a contour canal running for a length of 50.68 km before terminating into Alagar Odai, a tributary of Vaippar river. In order to irrigate maximum command and to reduce seepage losses, the canal is proposed to be lined.

The alignment of main canal runs in cutting in the head reaches and has a bed slope of 1 in 10,000 upto RD 14.40 km. The canal in this reach crosses major streams like Hanuma Nadi, Karuppa Nadi at RD 1.09 km and 12.248 km where a super passage and aqueduct respectively are proposed. In addition to these two major streams, the canal crosses 12 nos. of minor streams / channels where suitable aqueduct / super passages / siphon aqueducts / sluices are proposed. Seven road bridges are proposed in this reach at road crossings. There is no irrigation in this reach of the link canal. The bed width of canal in this reach is 13.8 m with full supply depth of 3.6 m.

The second reach of the link from RD 14.40 km to 24.13 km runs almost entirely in cutting, with a bed slope of 1:7500 and bed width of 13.8 m and full supply depth of 3.60 m. There are no major streams crossing the canal in this reach. Four super passages and one siphon aqueduct are proposed at minor stream/channel crossings. In addition, 4 nos. of road bridges and one railway bridge are provided in this reach to negotiate road and railway crossings.

The third reach of canal runs only for a short distance of about 0.5 km from RD 24.130 km to 24.677 km at the end of which a branch canal is proposed to irrigate 50192 ha. The bed slope of the canal in this reach is 1 in 10,000 with full supply depth of 3.60 m and Bed width 13.80 m. The branch canal is 15.680 km long with designed discharge of 31.905 m^3 / sec. A cross regulator is proposed at the off take point of the branch canal. Three outlets are provided for taking off distributaries at RD 5.402 km, 8.287 km and 14.537 km of branch canal with discharge capacities of 2.5 m^3 / sec, 2.84 m^3 / sec and 7.22 m^3 / sec to cover 4500 ha, 4553 ha and 12240 ha respectively. The branch canal will run for a further distance of 1.143 km beyond the third outlet upto RD 15.680 km and outfall into Nichibanadi, a tributary of Vaippar for irrigating 28,899 ha enroute through a tail end branch canal with suitable network of distributary system. The canal in this reach crosses a surplus channel of Kulayampuram tank, where a siphon aqueduct is proposed.

The canal in its fourth reach, from RD 24.677 km to 26.314 km has a bed slope of 1 in 10,000 with full supply depth of 3.40 m and bed width 7.6 m. The canal in this reach crosses two roads, where suitable road bridges are provided. A drop of 11.5 m is available at the end of this reach, where a

power station is proposed to utilise the head available at the drop for power generation.

The canal in the fifth reach from RD 26.314 km to 29.4 km runs in cutting. The bed slope of canal in this reach is 1 in 10,000 with full supply depth of 3.0 m and bed width is 12.50 m. The canal crosses a local stream at RD 27.813 km., where a siphon aqueduct is proposed. The canal crosses 3 roads in this reach where road bridges are proposed.

The sixth reach of link canal extends from RD 29.4 km to 35.1 km. The canal in this reach has a bed slope of 1 in 10,000 will full supply depth of 2.75 m and bed width is 12.50 m. The canal runs in cutting and do not come across any cross drainage works. 3 road bridges are proposed at road crossings.

The seventh reach of canal from RD 35.1 km to 44.98 km also runs in cutting. The canal has a bed width of 12.5 m, full supply depth of 2.5 m with a bed slope of 1 in 10,000 and an outlet is proposed on main canal at RD 35.28 km with discharge capacity of 6.16 cumec to irrigate 9796 ha. Three canal drops at RD 35.28 km, RD 38.03 km and RD 44.93 km and are proposed with power stations to utilise the head available for power generation. The canal crosses 4 roads where road bridges are proposed.

The last reach of the main canal from RD 44.98 km to 50.68 km runs entirely in cutting with a bed slope of 1 in 7500 and FSD of 2.50 m and bed width 12.50 m crossing four streams where super passages are proposed. Two road bridges are also provided in this reach. The capacity of the reach is 18.5 m^3 /sec. to cover irrigation to 31412 ha enroute through suitable distributary system before its outfall into Alagar Odai, a tributary of Vaippar river. Adequate provision has been made in the estimate for covering the distributary system under both main and branch canals.

6.5.2 Study of integrated network of canal system and its operation to utilise the water potential of streams crossed by the main canal

The canal on its way crosses two major streams namely Hanumanadi and Karuppa Nadi and other minor streams. These streams are not perennial. These originate in nearby hills and floods are flashy. These streams are very small without the possibility of storages.

6.5.3 Description of soil profile along the canal alignment based on pit / Auger holes

Auger holes are driven at every 6 km along the alignment of the main canal and samples are collected. Based on the analysis of these samples, the topsoil comprises yellow, grey and reddish laterite soils of depth ranging from 1 to 4 m followed by soft weathered rock of depth ranging from 1 to 3 m. Hard rock is met at the bottom of soft rock.

6.5.4 Evaluation of design parameter and treatment of problematic reaches

The canal alignment mostly runs in cutting except in small reaches where it runs in banking. Detailed laboratory tests to ascertain the characteristics of the soils for firming up the design of embankments, foundations etc, have not been carried out at present. Detailed survey and investigation in this regard will be incorporated in DPR stage. Hydraulic design of canal and cross drainage works have only been carried out for estimating the cost.

6.5.5 Details of lining provided

Lining is provided for the entire length of main and branch canals to minimize seepage. Lining with CC 1:4:8 is proposed in the canal bed as well as in side slopes.

6.5.6 Transmission losses

Transmission losses are considered at the rate of 0.6 m^3 /sec. per Mm^2 of wetted area as per IS code 10430 – 1982.

6.5.7 Sections and reaches

Due to changes in soil profile, bed slope, side slope of the canal and the command area to be served, the section of the canal changes. It is not practicable to change the section of the canal at every point. Hence the canal is divided into suitable reaches and is designed to carry the required discharge by considering the other prevailing parameters especially in respect to soil type, bed slope and side slope.

a) Design of canal section

The canal sections in various reaches are designed using Manning's formula

$V = 1/n \; R^{2/3} \; S^{1/2}$

Where

V = Velocity in m/sec.

n = Rugosity coefficient, 0.018 for lined canal.

R = Hydraulic radius = Area / wetted perimeter.

S = Bed slope of canal 1 in 10000 in soil and
1 in 7500 in rock strata.

Side slopes of the canal sections are assumed as 1.5:1 in soils and 0.75: 1 in rock.

b) Velocity allowed

The velocity is ranging between 0.849 m / sec to 1.215 m / sec which is below 1.5 m / sec limiting velocity as per IS 10430-1982.

c) Critical velocity ratio

The critical velocity ratio is found to be ranging from 0.78 to 1.00.

d) Free board

Free board provided is 0.75 m above FSL throughout as per IS code 10430-1982.

6.5.8 Canal operation

The main and branch canals will be in operation through out the year. The main canal will have to carry a peak discharge of 59.6 m^3 / sec during June to fulfill the enroute requirement. For design purpose, a discharge of 72 m^3 / sec is considered for the initial reach.

Hydraulic particulars of the main canal considered and arrived at are given below:

Sl. No.	Canal reach	Designed discharge M^3/sec	Bed width m	Full supply depth m	Bed slope	Velocity m/sec
1.	00.00–14.40	72.0	13.8	3.60	1/10000	1.045
2.	14.40–24.13	72.0	13.8	3.60	1/7500	1.215
3.	24.13–24.68	72.0	13.8	3.60	1/10000	1.045
4.	24.68–26.31	40.1	7.6	3.40	1/10000	0.937
5.	26.31–29.40	40.1	12.5	3.00	1/10000	0.943
6.	29.40–35.10	40.1	12.5	2.75	1/10000	0.894
7.	35.10–45.00	33.9	12.5	2.50	1/10000	0.849
8.	45.00–50.68	33.9	12.5	2.50	1/7500	0.991

6.5.9 Canal structures (cross drainage works / regulators)

a) There are two head regulators, three cross regulators, four canal drops, 35 cross drainage works and 27 road bridges and one railway bridge along the alignment of the main and branch canals.

In order to facilitate free flow of traffic on these roads and railway line, double lane bridges and single lane bridges are provided depending upon type and importance of road crossing.

The loss of head provided at canal structure is as follows:

a) Head regulator & Cross drainage works 0.15 m
b) Road & railway bridges 0.05 m

(b) Criteria for maximum flood discharge and HFL of the drainage

The maximum flood discharge of the streams at canal crossing has been computed using Ryve's formula.

$$Q = CA^{2/3}$$

Where Q = design flood discharge in m^3 / sec
C = constant
A = catchment / drainage area in km^2.

The observed maximum flood level in the stream or the computed MFL from the flood discharges calculated using the cross section of the stream at the crossing of canal, whichever is higher is taken as HFL of the river.

(c) Choice of structure

The type of cross drainage structure to be provided depends on the physical and hydrological features of the stream to be crossed such as position of bed/ high flood levels of stream in relation to canal bed/full supply levels. Siphon aqueduct is proposed when canal full supply level is little below the stream bed level. Wherever the stream bed is sufficiently above the canal full supply level, a super passage is provided. An aqueduct is proposed when the canal bed level is higher than maximum flood level of the stream.

(d) Falls

Four canal drops each with a drop of 11.5 m are provided at RD 26.314 km, 35.280 km, 38.03 km and 44.93 km with power stations for generation of power.

6.6 Power house

There are seven power houses envisaged under the project as shown in the table below:

Sl. No.	Location	Installed capacity	No. of units
1.	At the toe of Achankovil Kal Ar dam	500 MW	5 x 100 MW (3 units reversible)
2.	At the outlet of Punnamedu-Achankovil Kal Ar tunnel	3.0 MW	-
3.	At the toe of Achankovil dam	1.50 MW	-
4.	At RD 26.314 km of main canal (Canal Drop No.1)	1.125 MW	3 x 375 KW
5.	At RD 35.480 km of main canal (Canal Drop No.2)	1.125 MW	3 x 375 MW
6.	At RD 38.030 km of main canal (Canal Drop No.3)	0.810 MW	2 x 405 KW
7.	At RD 44.930 km of main canal (Canal Drop No.4)	0.810 MW	2 x 405 KW

However, for the purpose of feasibility report, preliminary designs were carried out only for the 500 MW capacity powerhouse located at the toe of Achankovil Kal Ar dam. Designs have not been attempted for other powerhouses at this stage and will be incorporated in DPR stage.