CHAPTER – 6

DESIGN FEATURES

6.1 General:

The Ken-Betwa link project, which is a diversion cum storage scheme, comprises of:

(i) a 73.80 m high and 1468 m long earth dam across river Ken near Daudhan village;
(ii) a 326 m long side channel spillway on left flank;
{iii) an under ground power house with 3x20 MW installed capacity;
(iv) a surface power house at the end of the tunnel with 2×6 MW installed capacity; and
(v) a 231.45 km long canal for transferring water from river Ken to river Betwa.

The design features of each of these components are discussed in the subsequent paragraphs.

6.2 Type of dam

Based on the geotechnical and topographical considerations, an earth dam is proposed near Daudhan village at 2.5 km upstream of the existing Gangau weir. Exposed rocks are seen all over on the left bank of the Ken river. Geophysical investigations carried out by CSMRS have confirmed the existence of sound rock at 3 m to 5 m below natural surface level. On the other hand there is deeper overburden on the right side of the river.

The selection of a type of dam at a given site depends upon many physical factors such as topography, geological and foundation conditions, available materials, suitable site for spillway, data about earthquake etc. Keeping these factors in view earth dam is proposed at Daudhan with side channel spillway in the left flank. Small lengths of concrete non-over flow section will be there on both the sides of spillway. The abundance of availability of soil, coarse and fine aggregates nearby also makes this option economical. The axis of the dam has been given a slight turn of 5 degrees towards downstream side to facilitate easy passage of releases from spillway towards river.

6.3 Geotechnical investigations

The work of geotechnical investigations for foundation, borrow area and filter materials characterization of the proposed Ken-Betwa link project was entrusted to the Central Soil and Materials Research Station in October, 1991. Accordingly, the field party of CSMRS has carried out foundation investigations of the proposed Daudhan dam, which includes conducting in-situ permeability test in auger holes and collections of undisturbed soil samples from the auger holes as well as from the foundation trial pits excavated along the dam axis. A short description of these investigations is given in Chapter-4' Surveys and Investigations'. In addition to it, the field party of CSMRS has also collected representative soil samples from different borrow areas for conducting various test in the laboratory in order to ascertain their suitability as construction material. Three filter materials from different river bed quarries were also collected for ascertaining their suitability besides collection of a representative samples from different locations along the link canal alignment for studying their swelling properties. Recommended design parameters are given below:

6.3.1 Recommended design parameters

The CSMRS has recommended following design parameters for the proposed Daudhan dam.

Foundation materials	
Insitu Dry Density, gm/cc	
Average	1.61
Average minimum	1.52
Moisture content, %	
Average	18.7
Average minimum	15.8
Specific Gravity, G	
Average	2.69
Average minimum	2.67
Triaxial Shear test	
Total Cohesion (c), Kg/cm^2	
Average	0.32
Average minimum	0.29
Total angle of shearing resistance (q), degrees	
Average	24.4
Average minimum	22.1

Effective Cohesion (c') kg/cm^2	
Average	0.22
Average minimum	0.19
Effective angle of Shearing Resistance (q), degrees	
Average	28.6
Average minimum	26.9
Borrow area materials	
Standard Proctor Compaction Test	
Daudhan borrow area materials	
Maximum Dry Density (?d), gm/cc	
Average	1.81
Average minimum	1.79
Optimum moisture Content, %	
Average	15.6
Average minimum	14.8
Gangau borrow area materials	
Maximum Dry Density (?d), gm/cc	
Average	1.78
Average minimum	1.73
Optimum Moisture content, %	
Average	17.7
Average minimum	16.3
Palkohan borrow area material	
Maximum Dry Density (?d), gm/cc	
Average	1.86
Average minimum	1.83
Optimum moisture content, %	
Average	14.6
Average minimum	13.8
Kharyani borrow area materials	
Maximum Dry Density (?d), gm/cc	
Average	1.84
Average minimum	1.82
Optimum moisture content, %	
Average	13.9
Average minimum	13.1
Specific Gravity, G	
Average	2.72
Average minimum	2.70
Triaxial Shear test	
Total Cohesion (c), kg/cm^2	

Average	0.27
Average minimum	0.24
Total angle of shearing resistance (?), degrees	
Average	20.3
Average minimum	18.7
Effective cohesion (c'), kg/cm^2	
Average	0.17
Average Minimum	0.14
Effective angle of shearing resistance (?), degrees	
Average	25.2
Average minimum	24.0

6.4 Geology, seismicity and foundation conditions

6.4.1 Geology of the dam site

The CSMRS has carried out detailed geophysical investigations along the dam axis. Geological Survey of India has also carried out some geotechnical investigations along the dam axis and some reaches of the link canal alignment. The investigations has revealed presence of sound rock within a depth of 3 m to 5 m on the left bank, except in small reaches, where depth may be 7 m to 8 m. Hard strata (consolidated materials) is available on the right bank of the river at about 5 m to 8 m depth in a length of about 100 m starting from the river bank. Beyond which groutable strata is available within 2 m to 8 m depth. Profile of hard rock and overburden has been given by the CSMRS. Details from the report of CSMRS on geophysical investigations at Daudhan site are furnished in Chapter-4 'Surveys and Investigations'.

6.4.2 Geology around the proposed link canal alignment

Geology around the proposed link alignment indicate the presence of ferrugineous breccia of Bijawar group sand stone, silt stone, lime stone and shales belonging to semri group (Vindhyan super group). Pink, fine to medium grained, dense granite is exposed sporadically in the reaches between 75000 m to 75400 m of the canal alignment. Good quality sand mixed with pebbles and kankars are found in some of the rivers crossed by the link canal. In the reach near the terminal point of the link canal, presence of pink, coarse grained massive granite (Bundelkhand Granite) are found. It is characterised by 3 sets of Vertical joints and 1 set of Basal joint with sub-horizontal dip. The joint openings are upto 50 m wide filled with weathered clayey material.

6.4.3 Seismicity

As per the zones given in the I.S.: 1893-1984, 'Criteria for earthquake resistant design of structures' (Fourth revision), the proposed Daudhan dam site falls in the zone 'one' indicating low seismicity of the area. However, it is recorded in the history of the existing Gangau weir, which is located at 2.5 km downstream of proposed site, that a severe earthquake shock occurred on 15th January, 1934. But there was practically no damage done except for a slight widening of the rocks in the main weir. Hence keeping in view of this fact, necessary provisions have been made in the design of the structures as per the recommendations of standing committee set up by the erstwhile Union Ministry of Irrigation and Power in 1969.

6.5 Earth dam

The earth dam proposed at Daudhan will be 73.80 m high and 1468 m long. Major length of earth dam is proposed to be located in the right flank. The total length of the earth dam in the right flank is 1224 m while length of left flank portion is 244 m. Maximum height above deepest foundation level in the right flank and left flank will be 73.80 m and 19.95 m respectively. Top width of the earth dam would be 8 m. The suitable slopes and berms at various elevations have been considered.

Quantitative assessment of various construction materials has been carried out in and around the proposed dam site. About 46.0 Mm^3 soil is available in the borrow area upstream of proposed Daudhan dam site which can be utilized in the construction of earth dam.

The top elevation of the dam will be kept at 291 m with FRL at 287 m. The geotechnical investigations of the foundation material has been carried out by CSMRS and their recommended design parameters have been used in the design.

The earth dam proposed at Daudhan site has been designed to have a zoned section comprising clay core central portion. The top width of the dam would be 8m. The side slopes would be as shown below:

Upstream side		Downstream side	
NSL -EL 235m	3.25 H:1 V	NSL -EL 230m	3 H:1 V
At EL 235m	berm of 6m	At EL 230m	berm of 6m
EL 235m -250m	3.25 H:1 V	EL 230m -245m	3 H:1 V
At EL 250m	berm of 6m	At EL 245m	berm of 6m
EL 250m -265m	3 H:1 V	EL 245m -260m	2.75 H:1 V
At EL 265m	berm of 6m	At EL 260m	berm of 6m
EL 265m -275m	3 H:1 V	EL 260m -275m	2.5 H:1 V
At EL 275m	berm of 6m	At EL 275m	berm of 6m
EL 275m -285m	2.5 H:1 V	EL 275m -285m	2.25 H:1 V
EL 285m -291m (Top of dam)	2.5 H:1 V	EL 285m -291m (Top of dam)	2 H:1 V

6.5.1 Upstream and Downstream slope protection

The upstream slope will be protected by a 600 mm thick hard packed rip-rap laid over 300 mm thick crushed stone and 300 mm thick sand layer.

The downstream slope will be protected by thick grass turfing. The 300 mm thick stone pitching rip-rap over 300 mm thick crushed stone/gravel and 200 mm thick sand layer will be provided in the toe upto 245 m elevation.

6.5.2 Filter

It is proposed to provide 3 m thick vertical chimney filter from elevation 287 m. It will comprise 1 m thick gravel/crushed stone sandwiched by 1 m thick sand layers. It will join the 1.5 m thick horizontal filter comprising of 0.5 m thick crushed stone/gravel layer sandwitched by 0.5 m thick sand layers. The downstream filter shall be extended further to join the open drain. Filter material shall be compacted to an average density of 70% with a minimum relative density of 65%. Filter material shall satisfy following criteria:

I. $$\frac{D_{15} \text{ of filter material}}{D_{15} \text{ of base material}} > 5$$

II. $$\frac{D_{15} \text{ of filter material}}{D_{85} \text{ of base material}} < 5$$

Where D_{15} and D_{85} represent the sizes of which 15% and 85% of the total soil particles are finer than these sizes respectively. Filter shall not contain more than 5% of the material finer than 0.74 mm (Sieve No.200).

The CSMRS has carried out Geotechnical investigations regarding suitability of filter material available there. Representative filter materials samples were collected from different locations of river bed sand quarries i.e. from Daudhan borrow area, Gangau, Palkohan and Kharyani borrow areas. These have been examined for arriving at the suitability criteria. The analysis indicates that these materials do not satisfy all the three filter criteria except satisfying the piping ratio criteria. CSMRS has indicated that decision in this regard may be taken in consultation with the designers. This may be looked into at the time of construction.

6.5.3 Stability analysis of the earth dam

The stability analysis of the earth dam has been carried out on Computer using CWC package for stability analysis of earth dams. Following foundation soil parameters have been used for carrying out the study.

a	Insitu average dry density	1.61 gm/cc
b	Average submerged density	1.01 gm/cc
c	Average moist density	1.91 gm/cc
d	Average saturated density	2.01 gm/cc
e	Average angle of shearing resistance	24.4º
f	Average cohesion	2.2 t/sqm

The dam section has been checked for the following conditions of stability as per I.S. code 7894.

6.5.3.1 Upstream steady seepage condition:

All the zones above the phreatic line (drawn for upstream water level consideration) have been considered as moist for working out resisting and driving forces and zones below it have been considered with their submerged weights for working out both the resisting and driving forces.

(a) Draw-down condition: In the draw down condition all the zones above the phreatic lines have been considered as moist for the computation of both the driving and resisting forces.

(b) Zones in the draw-down range: Core material and non-free draining material have been considered as saturated and free draining material have been considered as moist for computing the driving forces. All the materials have been considered as submerged for computing the resisting forces.

(c) Zones below draw-down level: All the zones including foundation zones below the draw-down level have been considered as submerged for computing both the driving and resisting forces.

6.5.3.2 Downstream steady seepage condition

The stability analysis of earth dam has been carried out assuming that the dam is fully saturated below the phreatic line.

Material below tail water level has been considered as submerged for all the conditions of stability. The analysis for upstream slope has been done for the condition of the draw-down from the full reservoir level.

The results of stability analysis of the earth dam as obtained through the computer package for all the above mentioned conditions were obtained. The section is found to be safe. The factors of safety obtained in the analysis are given in Table 6.1.

Table 6.1
Factor of safety for various conditions of stability for earth dam

Elevation	u/s steady seepage condition		d/s steady seepage condition		u/s draw down (Without earthquake condition)
	Without earthquake	With earthquake	Without earthquake	With earthquake	
217m	1.982	1.604	1.672	1.520	1.700
230m	2.010	1.632	1.670	1.516	1.623
245m	1.977	1.631	1.688	1.531	1.474
260m	1.994	1.681	1.722	1.572	1.421
275m	1.983	1.750	1.823	1.687	1.416

Critical slip circle for different conditions were drawn.

6.6 Concrete dam

The geological investigations carried out by CSMRS indicate existence of sound rock at 3 m to 5 m below natural surface level and also seen

exposed in the left side of Ken river. On the other hand, there is a deeper overburden on the right side of river. Keeping these geological features in view, concrete gravity dam is proposed on the left flank.

A 247 m long concrete dam has been proposed. Out of which 146 m non-overflow section is proposed on the left side and 101 m on the right side of spillway. The top elevation of dam and deepest foundation level will be 291 m and 232 m respectively. The width of dam at the top is 8 m. The maximum height above foundation level will be 55 m. An inspection gallery of 1.5 m x 2.25 m size is proposed at an elevation of 260 m, 3.25 m away from the upstream face. The foundation gallery of size 2 m x 2.5 m will also be provided 4 m away from the upstream face. The curtain grout holes shall be taken to a depth equal to half the hydrostatic head subject to minimum of 10 m. The depth of drainage holes shall be kept as two-thirds of curtain grout holes to a minimum of 6 m at 3 m centre to centre. The acceptable foundation grade shall be at least 1 m below sound rock level. The horizontal seismic co-efficient of 0.03 g has been adopted for the design.

6.6.1 Qualitative and quantitative assessment of availability of construction materials

Qualitative assessment

The CSMRS has carried out construction materials survey for Ken Betwa link project during December, 1993. The CSMRS team had identified three rock quarries and two fine aggregate quarries. The rocks from the major quarries, which are likely to be available, are Daudhan village rock quarries, Palkohan rock quarry and down-stream of dam axis quarry. Extensive field survey was carried out on the upstream and downstream of the dam axis.

Following conclusions and recommendations about construction materials have been made by the CSMRS:

(a) Coarse aggregate

The rock materials available from Daudhan village quarry and Palkohan Road rock quarry are found to be suitable for use as coarse aggregate in concrete for non-bearing surfaces. The rock from downstream of dam axis quarries was found unsuitable for use as coarse aggregate in concrete.

(b) Fine aggregate

The two sand samples, collected from Banne river shoal and Barne river shoal are found to be suitable for use as fine aggregate in concrete. However, in view of the higher percentage of silt content, the sand has to be washed before using in concrete.

Details of the report on construction materials survey and laboratory testing of rock and sand samples for use as coarse aggregate and fine aggregates in concrete are given in Chapter-4 'Surveys and Investigations'.

Quantitative assessment

Study has been carried out regarding quantitative assessment of various construction materials. Following quantities are assessed approximately which are given in table 6.2.

Table 6.2
Quantities of construction materials

Type of material	Source	Quantity (approximate)
Fine aggregate	Banne & Barne Nadi shoal	2.0 Mm^3
Coarse aggregate	Daudhan & Palkohan Road rock quarry	8.0 Mm^3

6.6.2 Stability analysis for gravity dam

The stability analysis for the non-overflow concrete dam has been carried out as per I.S. 6512-1984.

The design has been carried out to fulfill the following conditions / criterion of stability:

(a) The dam shall be safe against sliding at any plane or combination of planes within the dam, at the foundation and within the foundation.

(b) The dam shall be safe against overturning at any plane within the dam at the base and at any plane below the base.

(c) The safe unit stresses in the concrete of the dam and in the foundation material shall not be exceeded.

Assumptions:

The following assumptions have been made:

(i) Forces considered in the stability analysis:

All the forces considered in the analysis have been taken as per I.S. 6512-1984. The unit weight of concrete and water have been taken as 2.4 t/cum and 1.0 t/cum respectively. The seismic force has been computed as per I.S. 1893-1984. The project area falls under zone-1 of the seismic zones of India. The values of horizontal and vertical seismic coefficients are considered to be as 0.03 g and 0.015 g respectively.

(ii) Load combinations:

The section has been checked for all the following seven conditions:
(a) Construction condition: Weight of dam but no water in reservoir and no tail water without earthquake.
(b) Normal operating condition: Full reservoir elevation, normal dry weather tail water, normal uplift and silt and without earthquake.
(c) Flood discharge condition: Reservoir at maximum flood pool elevation, all gates open, tail water at flood elevation, normal uplift and silt and without earthquake.
(d) Condition 'a' with earthquake.
(e) Condition 'b' with earthquake.
(f) Condition 'c' with extreme uplift (drains inoperative)
(g) Condition 'e' with extreme uplift (drains inoperative)

Result

The dam section is found to be safe in all the conditions.

6.7 Spillway

A side channel ski-jump bucket type spillway (over flow section) with downstream slope 0.9: 1 is proposed on the left flank of the dam. The total length and maximum height above the deepest foundation level will be 326 m and 28 m respectively. The crest level of the spillway will be at 269 m. The study for probable maximum flood for Daudhan dam site has been

carried out by the unit hydrograph method. The design flood hydrograph has a peak of 45104 cumec.

Using the above design flood hydrograph, the maximum water level (MWL) was computed by carrying out flood routing for Daudhan reservoir. 14 gates of 18 m x 18 m are required to pass the design flood. Maximum water level thus obtained is 288 m whereas the FRL is 287 m. Maximum outflow from the reservoir routing is 43993 cumec which has been used for the design of spillway.

The spillway consists of 14 blocks of 22 m width each (pier thickness 4 m) and two overflow /non-overflow blocks of 20 m width at either end. Fifteen radial gates of size 18 m × 18 m are proposed to be provided.

Parameters of the spillway have been worked out after carrying out the detailed design of spillway.

6.8 Energy dissipation

Keeping in view the low tail water level, it is not possible to provide either stilling basin or roller bucket for energy dissipation. Therefore, Ski-jump bucket has been provided. The lip elevation of bucket is kept at RL 244 m and bucket radius as 20 m. The jet from this bucket would touch NSL at a maximum distance of about 75 m from the bucket lip. However, the initial length of spillway channel has been kept straight for a length of 100 m. Beyond this point the spill channel takes smooth turn towards the river. The detailed design of energy dissipator is carried out and tail water rating curve has been drawn.

6.9 Junction of earth/gravity dams

In accordance with the modern trend in designs, no core wall is proposed at the junction of earth and gravity dams. Instead, the face of NOF block normal to dam axis is given a slight turn in plan and also in elevation so as to ensure a very firm contact with earth dam at the interface. As a result of this feature, the width of NOF block at its downstream end becomes slightly more than its normal width. The exact details are to be worked out at the time of preparation of Detailed Project Report (DPR) of the project.

6.10 Tunnel section

A 1.95 km long tunnel from RD 175 m to RD 2125 m is proposed to cross a high ridge and to take water from the approach channel of Daudhan dam to Power House No.2. The tunnel has been designed with bed slope of 1 in 2000 and design discharge of 79 cumec. A round shaped tunnel with 5.0 m diameter has been proposed. Detailed design of the tunnel has been carried out.

6.11 Surge tank

A simple surge tank of 23.5 m diameter has been proposed in the head race tunnel of Power House No.2 at RD 1980 m to take care of pressure fluctuations in the penstock and to prevent additional water hammer pressures from being exerted upon the walls of the tunnel. The hydraulic design of surge tank has been carried as per I.S. 7396 (Part-I) -1985 recommendations and using Charles Jaegar's equation for computing the maximum upsurge.

6.12 Power House

While planning Ken-Betwa link irrigation cum power project, it was decided to utilize the storage of Daudhan dam as well as the pondage between the proposed Daudhan dam and existing Gangau weir for generation of power. The power will be generated at two locations. The first power house which will be a pumped storage scheme shall be located on the downstream of gravity dam, while the second power house shall be located at the end of the tunnel that carries the water from the reservoir to the link canal.

6.12.1 Power House No.1

The power house No.1 which is also named as dam power house shall be of underground type. The installed capacity of this power house is 3x20 MW. Vertical shaft reversible type of Francis turbines are proposed to be installed for utilizing this power house as a pumped storage scheme. Preliminary dimensions of the power house have been designed by using the standard hand book of Hydro-Electric Engineering and also the I.S.: 12800 (Part-I & II) -1989.

6.12.2 Power House No.2

The power house no.2, which is named as Canal Power House, is located at the end of a 2.0 km long tunnel. The installed capacity of this power house is 2X6 MW. The releases are allowed to pass into K-B link canal for carrying water to Betwa basin. This power house is designed as surface power house with a bye pass tunnel and a surge tank on the main tunnel. Preliminary design for fixing the dimensions of various components of the power house have been carried out. Design of intake structure, trash rack and air vent for this power house are also done.

6.13 Canal section

The water balance studies of Ken and Betwa basins carried out by NWDA reveal that 1020 Mm^3 of surplus water will be available in Ken basin upto Daudhan dam, which can be diverted through the link canal for enroute utilization and to water short Betwa basin. The reservoir operation studies carried out for Daudhan dam show that the link canal from Daudhan dam will carry a maximum monthly flow of 185 Mm^3 in the month of August and September. As per the present proposal, surplus water transfer from Ken to Betwa basin is confined to 8 months (243 days) from July to February. The design discharge of Ken-Betwa link canal will be 72 cumec from RD 0 kms to RD 134 kms, 62 cumec from RD 134 km to RD 195 km. and 57 cumec from RD 195 onwards. The section changes because of the withdrawal of water in the enroute command. The length of K-B link canal will be 231.45 km with FSL at head 259 m. A freeboard of 0.75 m has been provided in the link canal. The side slope of the canal and bed slope will be 1.5 (H) : 1 (V) and 1:10,000 respectively. The link canal will be lined completely with plain cement concrete.

The design of canal sections has been checked for passing 25% additional design discharge. It is seen that it is possible to pass this additional discharge with about 0.40 m encroachment in the 0.75 m free board available in the canal.

The design computations of canal sections for different design discharges are carried out. The simulation studies for Daudhan dam will be carried out afresh at the time of preparation DPR of this project considering the exact monthly requirements downstream of Daudhan dam and monthly water requirement of Betwa basin down to the existing Parichha weir on Betwa river. The details of the link canal sections are given in the Table-6.3.

Table 6.3
Details of canal sections

Canal reach	Design discharge (cumec)	Bed width width	Full supply depth (m)	Bed slope	Velocity (m/sec)
From RD 0 to RD 134 kms	72.0	12	3.56	1 in 10,000	1.04
From RD 134 to RD 195 kms	62.0	9.7	3.56	1 in 10,000	1.01
From RD 195 kms to Terminal point	57.0	8.5	3.56	1 in 10,000	1.00

The existing outlet i.e. waste weir on the extreme right side of Barwa Sagar shall be used to drop link canal water at RL 220.62 m into Betwa river through Barwa river.

There is a fall of 8.56 m at R.D. 224.3 km of link canal, which can be used for micro-power generation.

6.14 Cross drainage works

The Ken-Betwa link canal is predominantly contour canal except in small reaches where it is aligned as a ridge canal. It crosses several streams, minor/major rivers and several roads. The type of cross drainage works depend upon the catchment area of the streams and its bed level with reference to the bed level of the canal it crosses. In general, if the bed level of canal is well above the HFL of a drain, an Aqueduct is the obvious choice. Super passage are proposed when the bed level of the stream is much higher than the full supply level (FSL) of the canal at the crossing. Syphon aqueduct has been provided if the HFL of the drain is higher than the canal bed. Canal syphon has been provided if the FSL of the canal is sufficiently above the bed level of the drainage trough, so that the canal can flow under symphonic action under the trough.

In the entire length of 231.45 km of the link canal, seven Aqueducts, six-Super passages, four-Syphon aqueducts, thirteen-canal syphons, ten-pipe culverts and eighteen road bridges and one railway crossing are required to be constructed.

The detailed design of the cross drainage works such as Aqueduct at Pukhraha Nalla, Syphon Aqueduct at Tendua Nalla, Canal Syphon at Dhasan river, Super passage at Biyalpur Nalla and pipe culvert at Kumer Nalla have been carried out as per relevant IS Code of Practice and sections of typical cross drainage works are drawn.

6.15 Design of dam sluice

A rectangular sluice of 1.5m x 1.25m size has been proposed at 240 m elevation in the non-overflow section of dam to pass the discharge during non-operation period of power house no. 1 to fulfill the irrigation requirements downstream of Ken river. Detailed design of dam sluice has been carried out.

6.16 Canal out fall structure

The K-B link canal terminates near Barwa Sagar at R.D. 231.45 km. A cross regulator at R.D. 231.15 km has been designed to fill Barwa Sagar as per requirements. A regulator gate, is also designed to allow the water from the link canal to spillover a broad crested Ogee-type weir to Barwa Sagar Tal.

The crest level of the regulator is kept at 221.14 m elevation while the crest level of the escape channel is kept at 220.64 m elevation. The water way of the escape channel is so designed that it can pass a discharge of 57 cumecs by using the following formula:

$$Q = B\sqrt{h}(1.69h+3.54h_1)$$

Where, Q = Discharge in cumecs
B = Clear water way
h = Difference of water level u/s and d/s of the crest
h_l = Depth of d/s water level in the escape channel above the crest

The downstream floor of the escape channel is kept 1.0 m below the main canal bed and its length is kept equal to the two-thirds of the total floor length. Suitable transition to the side slopes have been provided to both the main canal as well as the escape channel.

A regulator type sluice gate is provided in the main canal to control the flow. The sill of the regulator is kept 0.3 m below the canal bed level. A plate form and a bridge is provided to operate the gate from top.