Chapter – 6
Design Features

6.1 General

The project comprises of 7 composite dams, 3 weirs, a tunnel interconnecting Mohankavchali reservoir with Paikhed weir, 6 power houses and a canal, the design details of which are enunciated in the following paras :

6.1.1 Structures

a) The seven dams proposed to be constructed are earthen dams with concrete spillway and some other concrete non overflow blocks. The structural details of the seven dams are furnished below in Table – 6.1.

Table – 6.1
Dams in the link

Reservoir	Total length of dam (m)	Length		Max. height		Length			No. & size of radial gate
		Ear-then portion (m)	Con-crete portion (m)	Ear-then dam (m)	Con-crete dam (m)	Spill-way (m)	Rt NOF (m)	Lt NOF (m)	
Jheri	773.5	515	258.5	76	36.5	51	125	82.5	3(15x10m)
Mohankavchali	947	600	347	70	70.6	69	155	123	4(15x10m)
Paikhed	1306	925	381	57.4	90.9	51	145	185	3(15x10m)
Chasmandva	2837	2675	162	51	35.4	33	64.5	64.5	2(15x10m)
Chikkar	1656	1444	212	60	29.9	51	78.5	82.5	3(15x10m)
Dabdar	1046	830	216	51.4	62.4	51	82.5	82.5	3(15x10m)
Kelwan	1284	955	329	50.1	62.4	69	130	130	4(15x10m)

b) Three weirs viz. Paikhed, Chasmandva and Chikkar are proposed each at the downstream of the respective dams.

c) An interconnecting tunnel, 5 km long between Mohankavchali reservoir and Paikhed weir.

d) A tunnel of 0.5 km long at R.D. 21.60 km on the canal.

e) 6 power houses, of which 4 are proposed at toes of Jheri, Paikhed, Chasmandva and Chikkar dams and the other 2 are proposed at the drops of the feeder canals originating from Dabdar and Kelwan reservoirs.

f) An open gravity lined canal 390.00 km long (including feeder canals) taking off from Paikhed weir.

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

6.1.2 Layout

Two river sluices of size 3 m x 5 m have been provided below pier gates at each of the dam to pass the required discharge at MDDL. The dam sites proposed are the narrowest portions with high banks. The bedrock levels are available at reasonable depths.

6.1.3 Geology, seismicity and foundations

a) Geology of the entire project area

The most prominent rock formations at all the seven dam sites are of Deccan trap represented by Amaygalaloidal basalt.

b) Geotechnical evaluation of foundation abutments and reservoir

The geophysical and geotechnical investigations of five dam sites namely Jheri, Chasmandva, Chikkar, Dabdar and Kelwan have been done by Geological Survey of India. The investigations in case of Mohankavchali and Paikhed dams including tunnels could not be completed due to resistance from local people. The drilling of four bore holes; two in river bed and one each on both the banks of river in respect of 3 dams viz Jheri, Dabdar and Chikkar have been done by NWDA through Engineering Geology Division, Govt. of Gujarat. The state Govt. of Gujarat had earlier carried out drilling work at 5 bore holes at the dam site at Kelwan which almost coincides with the alignment of NWDA's proposed site.

However, more drilling of bore holes along dam axis, geological investigations along the periphery of the reservoirs and engineering properties of foundation materials will be required to be done at the time of preparation of detailed project report.

c) Seismicity

The project area falls under zone III as given IS code 1893 – 1984 entitled criteria for earthquake resistant design of structures.

6.1.4 Alternative studies

The dam sites have been selected by examining alternative locations and site visits. The dam sites selected by NWDA more or less coincide with sites identified by Govt. of Gujarat and Maharashtra for these projects.

6.1.5 Design flood and sediment studies

a) Design flood studies

Design flood (probable maximum flood) has been estimated from synthetic unit hydrographs using the physiographical characteristics from the observed G & D data of the historical floods and PMP obtained from IMD. The probable maximum flood for Jheri, Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar, and Kelwan reservoirs are computed to be 3974 cumecs, 6783 Cumecs, 3792 Cumecs, 2303 Cumecs, 2676 Cumecs, 4181 Cumecs and 5456 Cumecs respectively.

b) Yield and sediment studies

The rate of sedimentation is considered as 715 m^3/sq km/year with additional bed load of 15% of suspended load. The sedimentation studies carried out are discussed in detail in item 7.3 in chapter -7.

c) Flood routing studies

The flood routing studies have been carried out by modified Puls method. The maximum design flood is disposed at 247.5 m, 160.5 m, 249 m, 214.5 m, 210.5 m, 170.5 m and 165 m at Jheri, Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan reservoirs with crest levels at 236 m, 148 m, 238 m, 204 m, 200 m, 159 m and 154 m respectively. The length of spillway and the number of gates proposed at the seven dam sites are already furnished in item 6.1 above.

6.2 Dams

6.2.1 Earthen dams

a) Design criteria for selection of economic zoning relating to availability of suitable materials.

Earthen dams are proposed for a length of 515 m, 600 m, 925 m, 2675 m, 1444 m, 830 m and 955 m at Jheri, Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan reservoirs respectively. The maximum height of section is 76 m, 70 m, 57.4 m, 51 m, 60 m, 51.4 m and 50.1 m above stripped level respectively. As per the explorations of borrow soils carried out, the impervious soils are proposed for formation of central core (hearting zone) and cut off trench. The casing of the dams is proposed with pervious material. The u/s slope of central core is proposed at 1:1 (H:V), whereas the d/s slope of the core is vertical. The top width of each of the dam is 10 m.

b) Cut off trench

A cut off trench is proposed at upstream base of central core in each dam in such a way that the central line of cut off trench is at a distance of 0.3 H (Height of dam) from the axis of the dam. The bottom width of 6 m and the side slopes of 1:1 (H:V) are proposed for cut off trench. The cut off trench is proposed to be taken upto 0.6 m below the rock strata and grout curtain is provided in the bottom of the trench.

c) Key arrangements with concrete/masonry abutments, interface aspects treatment at step in foundations and outlet locations etc.

Suitable key arrangements with abutment and returns at the junction of earthen dam and non-over flow masonry dam are proposed at each site.

d) Upstream impervious blanket

No upstream impervious blanket has been provided at any of the dam site.

e) Upstream rip-rap

The thickness of rip rap proposed is 0.75 m laid over 0.3 m thick crushed stone and 0.3 m thick sand layers. The upstream site rip rap starts at a level 1.5 m below MDDL to the top of the dam. However in some cases, it has been terminated at the lower end in a berm provided in the embankment as suggested in IS : 8237 – 1985.

f) Chimney filter and base filter

These filters are provided as per the present design practices. For details the drawings of designed section may be referred. These filters will collect the seepage water and will intercept foundation seepage and will lead seepage water into the down stream toe drain.

g) Rock toe and toe drain

Rock toe is proposed to be provided at the toe of the earthen dam to facilitate drainage of seepage water and to protect the lower part of the downstream slope from tail water erosion and sloughing in all reaches where the storage depth is greater than 3 m. The height of rock toe is kept at 15% of the height of storage subject to maximum and minimum heights of 4 m and 1 m respectively as per IS 9429 – 1980. The u/s and d/s side slopes of rock toe proposed are 1:1 and 2:1 respectively.

The toe drain filled with filter material is provided along downstream toe of the earthen dam to collect seepage from horizontal filter and lead into natural drain.

h) Stability analysis and factor of safety for checking the stability of the earthen dam.

Stability analysis of all the seven dams have been carried out for the following conditions as per IS 7894-1975.

Case – 1 : Construction condition without pool (for upstream and downstream slopes).

Case – 2 : Reservoir partial pool (for upstream slope).

Case – 3 : Sudden drawdown (for upstream and downstream slope).

Case – 4 : Steady seepage with reservoir full (full downstream slope).

Case – 5 : Steady seepage with sustained rainfall (for downstream slope where annual rainfall is more than 2000 mm or more).

Case – 6 : Earthquake condition (for upstream and downstream slope)

The computer programme adopted for the above analysis, incorporates the embankment geometry, soil strength properties and the various loading conditions.

The properties of the soil used in the analysis are based on the average soil strength criteria in absence of laboratory test data. Permissible factors of safety as per above ISI code and calculated factors of safety for different conditions for different dams have been given in Table – 6.2. These results show that all the dams are safe under various conditions.

Table – 6.2

Designed factor of safety for earthen dam

Loading condition of dam	**Slope most likely to be critical**	**Min. FOS as per IS: 7894-1975**	**Designed factor of safety**						
			Kelwan	**Dabdar**	**Chikkar**	**Chas-mandva**	**Paikhed**	**Moh-anka-vchali**	**Jheri**
1	2	3	4	5	6	7	8	9	10
Construction condition	U/S	1.0	1.544	1.522	1.381	1.604	1.596	1.929	1.558
Without pool	D/S	1.0	1.726	2.441	2.608	1.807	1.811	1.750	1.983
Reservoir partial pool	U/S	1.3	1.529	1.545	1.455	1.77	1.587	1.837	1.444
Sudden draw down									
a) Maximum head water to minimum with tail water at maximum	U/S	1.3	1.524	1.545	1.381	1.589	2.748	2.182	1.748
b) Maximum tail water to minimum with reservoir full	D/S	1.3	1.70	1.961	1.925	1.829	1.748	2.1	1.743
Steady seepage with reservoir full	D/S	1.5	1.726	2.441	2.884	2.531	1.771	2.232	2.162
Steady seepage with sustained rainfall	D/S	1.3	*	*	*	1.789	1.704	1.494	1.715
Earthquake condition									
a) Steady seepage	D/S	1.0	1.080	1.347	1.390	1.453	1.113	1.128	1.145
b) Reservoir full	U/S	1.0	1.064	1.173	1.079	1.083	1.195	1.209	1.125

** For Kelwan, Dabdar and Chikkar this condition is not required as average annual rainfall in the region is of the order of 1431 mm and 1657 mm respectively.*

6.2.2 Concrete dam

a) Design criteria for non-overflow section.

The Non-overflow section with top width as 8 m and upstream slope of 1(H) : 1(V) and downstream slope 0.85(H):1(V) from 10 m below TOD section is proposed to be provided in respect of all dams proposed in Par – Tapi – Narmada Link without considering Ukai water. Detailed analysis of the dams in Par – Tapi – Narmada Link without considering Ukai water has been carried out as per IS 6512-1984. The design has been carried out to fulfill the following requirements of stability.

i) The dam shall be safe against sliding on any plane or combination of planes within the dam, at the foundation or within the foundation.
ii) The dam shall be safe against overturning at any plane below the base.
iii) The safe unit stresses in the concrete or masonary of the dam or in the foundation material shall not be exceeded.

Further, all the forces considered in the analysis have been taken as per IS 6512 – 1984. The unit weight of concrete has been taken as 2.4 T/cum and water as 1.0 T/cum. The seismic force has been computed as per IS 1893-1984. The project area falls under zone-III of the seismic zone of India. The value of horizontal seismic coefficient has, therefore, been taken as 0.12 g. The foundation has been assumed to be granite and mass concrete (for dams) has been assumed to be of M 15. The properties of concrete have been taken as per I.S. 450 – 1982.

b) Stresses allowed

The stresses developed at the base of the non-over flow section are within the permissible limits specified in IS code 6512 -1984.

c) Grout curtain and drainage including internal drainage

The drainage gallery of size 1.5 m x 2.25 m has been provided at a distance of 10% of the head at the section subject to a minimum of 3 m. The curtain grout holes have been taken from the gallery to a depth equal to half the hydrostatic head subject to a minimum of 10 m. The depth of drainage holes has been kept as two third of curtain grout holes subjects to a minimum of 6 m. In addition to these, 200 mm dia formed concrete drain (vertical) @ 3 m c/c and inspection gallery of size 1.5 m x 2.25 m have also been provided. The diameter of the drainage hole can be kept as 75 mm dia through 100 mm dia pipe and spacing @ 6 m c/c as per IS 10135 – 1985.

d) Uplift

Uplift pressures are assumed to act over the entire base width and vary from maximum at heel on upstream side to one third of its value at the drainage gallery and to zero at toe on downstream side where no tail water is assumed.

e) Joints and seals

Metal sealing strips conforming to I.S. specifications will be placed across the transverse joints and around the galleries.

f) Keying arrangements

The guide walls and training walls at the junctions of NOF Section with spillway are provided with adequate anchoring arrangements. Keying arrangement of concrete dam with earthen dam has already been discussed in preceding paragraph.

g) Mean shear friction factor and sliding factor

The stability analysis for each dam for various load conditions has been carried out. It is found that the factor of safety against sliding and overturning worked out for different cases are within permissible limits.

h) Sliding factor

The factor of safety against sliding for the conditions of reservoirs empty and full (FRL and MWL) and various load combinations as per IS code 6512 – 1984 are found to be greater than 1.00 as recommended in IS code.

Various conditions of MWL and TWL, uplift and earthquake forces for 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, with extreme uplift (drains inoperative).

The sections are found to be safe against overturning.

6.2.2.1 Spillway section – design criteria

a) Spillway profile

The sharp crested ogee spillway has been provided for all the seven dams for discharging the flood water in the downstream alongwith ski jump bucket (Flip bucket) and energy dissipaters etc. due to presence of sound rock. The design flood adopted for each spillway, its length, number of gates provided etc. have already been discussed in para 6.1.1 and 6.1.5. In case of Kelwan, Dabdar, Paikhed and Mohankavchali, the spillway has been provided in the river gorge whereas in case of Chikkar it is on extreme left side of dam. Similarly, in case of Chasmandva and Jheri it is on right side of the dam. These locations have been selected as per the preliminary geological report of Govt. of Gujarat and recommendations received from geologists of GSI, Jaipur.

The ogee profile of the spillway has been designed as per IS 6934 – 1973. The upstream slope provided is 0.1:1 (H:V) upto certain height below MDDL whereas downstream slope provided is 0.9:1 (H:V).

b) Downstream profile

The downstream profile has been computed using the following equation as given in IS code 6934 – 1973.

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

Where :

Hd = Design head

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

c) Upstream profile

The following equation as given in IS code 6934 – 1973

$$Y = \frac{0.724\ (X+0.270Hd)^{1.85}}{0.85} + 0.126Hd - 0.431Hd^{0.375}(x+0.270\ Hd)^{0.625}$$

Hd

Where :

x, y = Co-ordinates along X and Y axis from the crest

Hd = Designed head over crest

Plate 6.10.1 to 6.10.7 showing spillway section of each dam. The curve extends to 0.27 Hd upstream and 0.125 Hd below the crest point.

d) Capacity of spillway

The capacity of spillway for each dam has been worked out on the basis of following equations :

$Q = Cd\ Le\ Hd^{3/2}$

Where Q = Discharge over ogee crest in cumecs Cd = Coefficient of discharge which has been taken as 2.21

Le = Effective length of overflow crest in metre

= L – 2 (ka + n Kp) Hd

L = Total length of spillway in metre

Ka = Abutment coefficient taken as 0.1

Kp = Pier contraction coefficient taken as 0.01

n = No. of piers

Hd = Head of overflow in metre including velocity of approach head.

To accommodate the passage of maximum flood discharge (probable maximum flood), two to four gates of 15 x 10 m size are proposed at the dam spillway.

e) Energy dissipation arrangement

Since foundation rock is good and tail water level is lower than the post jump depth, ski jump bucket is considered as an ideal and economic option. The ski

jump bucket has been provided at the toe in the body of the dam. This will increase the impact on the downstream. The bucket invert has been provided at the river bed level assuming sound rock to be 2.0 m below the river bed. The bucket radius has been computed using Ven Te Chow formula. R.S. Varshney formula, M.L.Bajaj formula and IS 7365 -1984. Finally the radius worked out by IS code was adopted and the same is given in the spillway drawings of individual dams.

f) River sluices, gates, stop logs etc.

Rectangular river sluices of size 3 m x 5 m are proposed to be provided in spillways. Radial gates of 14 m radius are proposed in the spillways. Arrangement for stoplog and gate lifting has also been made.

g) By pass arrangements

No bypass arrangements are provided

h) Section

Spillways are proposed for a length of 51 m, 69 m, 51 m, 33 m, 51 m, 51 m, and 69 m at Jheri, Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan dams.

The hydraulic design of spillway including energy dissipaters and crest gates is based on the relevant IS code 6934-1973, IS 6512-1984 and IS 7365-1974.

(i) Stresses allowed and stability analysis

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

The factor of safety against sliding on the basis of partial factor of safety in respect of friction (FO) and partial factor of safety in respect of cohesion (Fc) has been computed for various load combinations as per IS code 6512-1984 and are found to be greater than the recommended values. The following are the various load combinations adopted for calculation of stresses and partial factors of safety against sliding for stability analysis of proposed overflow section.

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 normal dry weather tail water, normal uplift, ice, silt (if applicable)
c)	Load combination- C(Flow discharge condition)	Reservoir at maximum flood pool elevation, all gates open tail water at flood elevation, normal uplift and silt (if applicable)
d)	Load combination- D	Combination A with earthquake
e)	Load combination – E	Combination B with earthquake but no ice.
f)	Load combination - F(drains inoperative)	Combination C but with extreme uplift
g)	Load combination G(drains in operative)	Combination E, but with extreme uplift

The sections adopted are safe for all the above loading conditions.

(j) Other

Description regarding grout curtain and drainage including internal drainage, uplift, joints and seals and keying arrangements given in para 6.2.2.(c) to (f) non-overflow section will remain same for spillway section.

6.2.3 Intake works and power houses

Jheri, Paikhed, Chasmandva and Chikkar dams are having toe power houses. The intake provision in the Paikhed dam is proposed from 5th non-overflow block on left side of spillway and at RL 199.13 m. In case of Jheri dam, a bell mouth entry in Penstock is proposed through the earthen dam on left side of spillway. Intake well of 4 m dia with intake level of penstock at 202.45 m has been provided. In case of Chikkar dam, intake of power house is provided through the right side of spillway by intake well of 4 m dia at a level of 177.48 m through the body of earthen dam. In case of Chasmandva dam, the provision of intake is through the left side of earthen dam by a 4 m dia intake well with level of 189.5 m.

Chikkar Power House, having installed capacity of 4.5 MW is located at the toe of the dam. The Power house is located in the river portion while spillway is located away from the river. The size of the power house is 12 m x 8 m and its height is 21 m. The level of EOT cranes and generators floor level are also fixed. Size of service bay is 8 m x 8 m where as size of tail water channel is 20 m x 8 m. However the civil works of all the power houses are similar to those provided in Chikkar power house.

6.2.4 Weirs

Paikhed, Chasmandva and Chikkar weirs have been designed as per IS code 7365-1985, IS 11527-1985 and design of small dams by USBR.

6.2.5 Tunnels

Two tunnels are proposed in Par-Tapi portion of the link canal. The first tunnel connecting Mohankavchali reservoir and Paikhed weir has a length of 5 km and the second tunnel is on the main canal has a length of 500 m at RD 21.60 km. The first tunnel will offtake Mohankavchali reservoir at RL 143.00 m and after crossing the ridge between the Par and the Nar rivers, it will out fall at Paikhed weir at RL 141.33 m. The slope of the first and second tunnels has been kept as 1 in 3000 and 4000 respectively. The diameter of the two tunnels are 5.5 and 8.0 m respectively. At the beginning of the tunnels an intake structure has been provided to regulate the flow of water in tunnels. The intake structure is in the form of rectangular well of size 6.5 m x 3 m.

6.3 Canals

The proposed Par – Tapi – Narmada link project can be described in two parts as follows :

i) Par – Tapi link starting from proposed weir across river Nar, and terminating in the existing Ukai reservoir across river Tapi. The length of the main canal is 172 km whereas the length of feeders i.e. Chasmandva, Chikkar, Dabdar and Kelwan are 3 km, 8.3 km, 14.2 km and 7.8 km respectively.

ii) Tapi – Narmada link of 190.14 km length starting from Ukai reservoir and terminating at Miyagam branch canal of Narmada Main Canal system after crossing Narmada river.

6.3.1 Description of canal system

6.3.1.1 Par – Tapi link

a) Canal capacity

The 172 km long Par – Tapi link canal, takes off from upstream of Paikhed weir with the F.S.L of 140.70 m. The water into Paikhed weir will be fed from two

sources, one from Mohankavchali reservoir on the river Par through a tunnel (5 km long) with FSL of 143.00 m and the other through Paikhed reservoir which is about 10 km upstream of Paikhed weir on the same river Nar. In the initial reaches starting from Paikhed weir, the canal has a carrying capacity of 44.13 Cumecs. As the canal moves northwards, water from other reservoirs is added through the feeder canals. The gross surplus water available from all seven reservoirs is 1470 Mm^3. After sparing the state's requirement of 120 Mm^3, the net surplus water available from diversion is 1350 Mm^3. With these additions the capacity of the canal becomes 90.90 Cumecs at the tail before falling in Ukai. The water, reaching at Ukai will be 1077.50 Mm^3 and conveyance losses of 78.80 Mm^3.

b) Canal alignment

The alignment of the proposed Par – Tapi link canal and feeders, finalized on the basis of field surveys have been marked on topo sheets. As indicated in the preceding para, the canal offtake at FSL of 140.70 m. Further the Chasmandva feeder which offtake from Chasmandva weir at FSL of 130.95 m joins the main canal at RD 55.40 km at FSL of 130.37 m. Again after 43 km, Chikkar feeder which off-takes from Chikkar weir at FSL of 124.55 m joins the main canal at RD 98.53 km at FSL of 120 m. Similarly, the Dabdar feeder which off takes from the main dam at FSL 136.960 m joins the main canal at RD 102.30 km at FSL of 119.82 m and Kelwan feeder, also off taking from main dam at FSL 135.46 m joins the main canal at RD 124.20 km at FSL of 115.55 m. The FRL of Ukai reservoir is 105.125 m. The Par-Tapi canal is proposed to outfall into the Ukai reservoir at FSL of 108.31 m after traversing a distance of 172 km. The bed gradient of the canal from Par to Tapi is different from reach to reach and it varies from 1 in 7,000 to 1 in 10,000.

Further, the link canal is essentially a contour canal. However, the main canal has to cross the ridges between various basins and sub-basins where in deep cuts are involved and also to cross many rivers and streams requiring construction of cross drainage works. A tunnel of 500 m length at R.D. 21.6 km has been proposed to avoid circuitous route, C.D. works and deep cutting.

In view of the fact that the F.R.L. of the terminal reservoir at Ukai is R.L. 105.15 m and that the length of the canal is about 172.07 km, the offtake level at Mohankavchali has been kept at R.L.143.00 m. For feeders the offtake levels are considered keeping in view the corresponding F.S.L. of main canal where the feeder joins the link. Economy in case of feeders from weirs of Chikkar & Chasmandva diversion points and M.D.D.L. at offtake diversion point for feeders from Kelwan and Dabdar has been kept in view.

6.3.1.2 Tapi – Narmada Link

a) Canal capacity

The Tapi – Narmada link canal will carry 1,077.50 Mm^3 of water from Ukai reservoir, out of which 266.30 Mm^3 is irrigation requirement for the 23,940 ha (CCA) area to be irrigated enroute. After allowing conveyance losses of 70.02 Mm^3. The water likely to reach at Miyagam branch canal of Narmada canal system is 741.18 Mm^3 . The canal capacity at offtake from Ukai reservoir is 70.83 cumecs and after meeting enroute and target area requirements, the canal capacity at the tail end will be 46.66 cumecs.

b) Canal alignment

The alignment of the proposed Tapi – Narmada link canal has been finalized on the basis of field surveys and investigations carried out by NWDA. The canal off-takes from the saddle portion of Ukai dam at FSL 81.79 m which is below the MDDL of Ukai reservoir (i.e. RL 82.296 m). It is aligned as contour canal with bed slope of 1:10,000 throughout its length. The canal is in low to medium cutting for about 100 km length in different reaches of canal. Partial cutting and filling is required to be done in another 90 km length of canal. Lower to high banking is needed mostly at river crossing for about 22 km length of canal. Rest of the canal is passing through deep cutting. The canal crosses a number of rivers, roads, canals, distributaries, railway lines, requiring construction of CD works. For enroute command, two outlets as cross regulator / head regulator are provided at RD 51.90 kms. Escapes have been provided along the canal, in various reaches, wherever it is felt necessary for safety of canal. The Tapi-Narmada canal finally joins the Miyagam branch canal at RD 16.7 km after traversing a length of 190.14 km. The F.S.L of link canal is 54.38 m at the terminal point, whereas FSL of Miyagam branch canal is 53.36 m.

6.3.2 Details of lining provided

Lining is provided for the entire length of main and branch canals to minimise seepage. Lining with C.C. 1:4:8 is proposed in canal bed as well as in side slopes. The thickness of lining vary according to canal capacity as per IS code 3873-1978. In the cutting reaches where rock is available porous concrete is proposed below bed lining.

6.3.2.1 Transmission losses

Transmission losses are considered at the rate of 0.6 cumecs per million sq m of wetted perimeter area as per IS code 10430-1982.

6.3.3 Sections and reaches

As the length of canal increases from the starting point, more reservoirs and the command area are added and so the section of the canal needs change. It is not practical to change the section of the canal at each and every offtake point. Hence, the canal is divided into suitable reaches and canal sections are designed to carry the required discharges in the particular reaches.

a) Design calculation for adequacy of canal section

The canal section in various reaches is 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 in m
S = Bed slope of canal

b) Side slope

Side slopes are assumed as 1.5:1 (H:V) throughout the main canal.

c) Velocity allowed

The velocity ranges between 0.69 m/sec to 1.14 m/sec, which is below 2.7 m/sec the limiting velocity as per IS code 10430-1982 for C.C. lining.

d) Critical velocity ratio

The critical velocity ratio is found to be ranging from 0.85 to 0.95 in main canal and from 0.97 to 1.08 in feeder canals.

e) Full supply depth and free board

The full supply depth of main canal is ranging from 3.12 m to 3.72 m in Par-Tapi reach and 3.3 m to 3.5 m in Tapi – Narmada reach. The free board is provided in as per IS code 10430-1982

f) Ratio of bed width to depth

B/D ratio is not important as this is a lined canal

g) Loss of head provided at canal structures

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

1.	Aqueducts and cross regulators	0.15 m
2.	Road & railway bridges	0.03 m
3.	Cross regulator cum escape	0.20 m

In Par – Tapi reach the section of canal at head is 6.60 x 3.12 m and at tail end is 14.60 x 3.72 m, while in Tapi – Narmada reach the section at head is 12.5 x 3.5 m and at tail end is 7.5 x 3.3 m.

6.3.4 Canal operation

The main and feeder canals will be in operation throughout the year with a peak discharge of 64.39 Cumecs during September. However for design purposes a discharge of 70.83 Cumecs is assumed.

6.4 Canal structures

a) Cross drainage works / regulators

There are 58 aqueducts, 30 cross regulators, 18 head regulators, 95 drainage syphons, 4 canal syphons, 10 escapes, 2 canal drops and 94 road and railway bridges proposed along the alignment of the main and feeder canals.

b & c) Layout and foundation

Detailed laboratory tests for finding the suitability of soils for foundations of cross drainage works are not carried out for the present. However, based on the soil samples collected it is inferred that hard rock can be met with at reasonable depths below the stream bed levels.

d) Transition in canal section and head losses

The loss of head due to contraction is computed as

$0.2 (V_2^2 - V_1^2)/2g$

Where V_2 = Velocity of the section at the exit of contraction

V_1 = Velocity of section before contraction

The loss of head due to expansion is considered as

$0.3 (V_2^2 - V_1^2)/2g$

The loss due to difference in velocity heads is considered as

$(V_2^2 - V_1^2)/2g$

e) Cross drainage

The type of cross drainage structure to be provided depends on the physical features of the stream crossed such as position of bed level of stream in relation to canal bed level. Canal syphons are proposed when canal bed level is little below the stream bed level. A typical design of each of the following cross drainage works has been carried out.

1. Aqueduct 2. Cross regulator 3. head regulator 4. Drainage syphon 5. Canal syphon 6. Escape 7. Road bridge 8. Canal falls.

f) Aqueducts

Aqueducts have been proposed along the link canal at the crossings of major streams where the bed level of the link canal is much above the highest flood level of the drain. 41 aqueducts are proposed in Par-Tapi portion and 17 aqueducts are proposed in Tapi-Narmada portion. Loss of head of 0.15 m is provided at each aqueduct. The typical design of aqueduct at RD 2.075 km on Serula Khadi in Tapi-Narmada portion has been carried out. The safe bearing capacity of foundation is assumed as 30 t/m^2.

g) Cross regulators

Cross regulators are provided at regular intervals in order to ensure effective water regulation. There are 19 cross regulators in Par-Tapi portion and 11 cross regulators in Tapi-Narmada portion proposed along the link canal. The loss of head of 0.15 m is considered at each regulator. One typical design of cross regulator at RD 164.4 km in Par-Tapi portion has been carried out.

h) Head regulators

i) Head regulators on main canal

There are 12 head regulators proposed on main and feeder canals of Par-Tapi portion and 6 head regulators proposed in Tapi-Narmada portion.

ii) Head regulator at Ukai reservoir

Head regulator as offtake structure has been proposed on saddle portion of Ukai dam to offtake Tapi-Narmada canal at FSL 81.79 m. The saddle dam is located on the right flank of Ukai dam. The canal discharge required is 90.90 m^3/sec. Two nos. of sluice gates of size 2.6 x 3.9 m have been provided to pass the required discharge.

i) Drainage syphons

21 drainage syphons are proposed in Par-Tapi portion and 74 drainage syphons are proposed in Tapi-Narmada portion of link canal. A typical design of drainage siphon at RD 51.2 km in Par-Tapi portion has been carried out.

j) Canal syphons

There are 4 canal syphons proposed in Par-Tapi portion. A typical design of canal syphon at RD 74.6 km has been carried out. The canal discharge at this location is 48.37 m^3/sec.

k) Escapes

There are 6 escapes proposed in Par-Tapi portion whereas 4 escapes are proposed in Tapi-Narmada portion. The escapes are provided to take care of the vulnerable embankment reaches, to divert the canal flows into the nearby stream in case of any danger of breach in embankment. The typical design of escape at RD 102.27 km in Par-Tapi portion is carried out. The discharge of canal and escape at this location are 54.88 m^3/sec and 47.64 m^3/sec respectively.

l) Bridges

90 road bridges and 4 railway bridges are proposed along the length of the canal. Loss of head of 0.03 m is considered at each bridge. A typical design of road bridge at RD 54.4 km in Par-Tapi portion has been carried out where the canal

discharge and bed width are 44.13 m^3/sec and 3.12 m respectively. The water way is estimated using the formula.

Water way = b+2 [s (d+d1+ Afflux) + bearing of abutment]

Where b = Bed width of canal
s = Side slopes of canal
d = Full supply depth of canal
d_1 = Free board

m) Falls

Two canal drops one each on the feeder canals of Chikkar and Dabdar have been provided with power stations for generation of power. A typical design of cross regulator cum fall at chainage 14.10 km of Dabdar feeder has been carried out.