Chapter - 6
Design Features

6.1 General

The Parbati-Kalisindh-Chambal link project is a diversion cum storage scheme, proposed to transfer surplus water of Parbati, Newaj (a tributary of Kalisindh river) and Kalisindh rivers to Gandhi Sagar (GS) or Rana Pratap Sagar (RPS) besides providing enroute irrigation and domestic water supply. The water thus saved (i.e. water supplemented to GS or RPS) will be utilised in Upper Chambal sub- basin through proposed seven reservoirs. Either Gandhi Sagar or Rana Pratap Sagar will be used as terminal reservoir. In case of linking to Gandhi Sagar, two alternatives have been proposed.The project comprises of:

(i) Three composite dams namely Patanpur across Parbati river, Mohanpura across Newaj river and Kundaliya across Kalisindh river. In addition to these seven reservoirs in Upper Chambal sub-basin have to be constructed. The field survey of these seven reservoirs is proposed to be done at DPR stage. Features of these seven reservoirs incorporated in this report are based on toposheet study only.

(ii) A 243.62 km long canal in case of alternative-(a) linking to RPS, or a 226.63 km long water conductor system (including pumping reach of 19.74 km in three stages from Kundaliya reservoir with total head of 50.15 m) in case of alternative- (b)-I linking to GS, or 201.83 km long water conductor system (including pumping reach of 3.20 km in single stage from Akheri village with total head of 47.42 m) in case of alternative- (b)-II linking to GS for transferring water.

(iii) Three tunnels having lengths of 6.61 km, 1.29 km & 3.10 km common in all three alternatives, two additional tunnels 3.60 km & 5.96 km of length involved in case of linking to RPS or one additional tunnel of length 3.60 km in case of alternative (b)-II linking to GS.

(iv) In case of alternative (b)-I linking to GS, water will be pumped in three stages consisting of seven pumps in each stage with installed capacity of each pump 2150 HP, 1750 HP and 2000 HP or in case of alternative (b)-II linking to GS, 5000 HP will be required to lift the water in single stage. The design features of these components are discussed in the following paragraphs.

6.2 Components & type of the head works

The head works of all the three dams consist of earthen dams across the main rivers with central spillway. The length of Patanpur, Mohanpura and Kundaliya dams is 3997 m, 1900 m and 3500 m respectively with maximum height of 19.62 m, 24.50 m & 45 m respectively. The spillways length at Patanpur, Mohanpura & Kundaliya dam are 197 m, 176 m & 228.50 m and are provided with 19,17 & 22 nos. of gates respectively to pass maximum flood. The head regulators to discharge 199.30 cumec, 238.00 cumec & 49.10 cumec, at Patanpur, Mohanpura & Kundaliya dams are provided on left flanks.

6.3 Geotechnical investigations

The work of geotechnical investigations for link project was entrusted to GSI, Bhopal. Consultancy work for carrying out geotechnical investigations for foundation characterisation for head works and other link canal structures and borrow area survey for location of suitable soils for construction of canal embankment of link project has been assigned to the Central Soil & Materials Research Station (CSMRS), New Delhi. Accordingly the disturbed/ undisturbed soil samples have been collected by the NWDA under the supervision of CSMRS and logging is carried out by GSI. The laboratory test on them in order to ascertain their suitability for use in construction has been carried out by the CSMRS. A short description of these investigations has been given in Chapter-4 “Surveys and Investigations”.

6.4 Geology, seismicity and foundation conditions

6.4.1 Geology of the dam sites and project area

The Geological Survey of India has carried out the geological investigations along the dam axis of Patanpur, Mohanpura, and Kundaliya, tunnels, number of cross drainage works such as Ghorapachhar aqueduct, Ajnar aqueduct, Gharganga aqueduct, Kanthali aqueduct [alternative (b)-I] Ahu aqueduct, and some part of the canal alignment. The drilling of 28 bore holes one on the each bank of river and one in river bed in respect of 3 dams Patanpur, Mohanpura, Kundaliya & Ahu barrage, 3 on tunnel no-1, 2 each on other four tunnels, 2 aqueduct sites and one in deep cutting has been done by CWC as recommended by GSI.

6.4.2 Geology of the link alignment

The link project is located in the Malwa Plateau of western M.P. and Rajasthan. In the reach Parbati (Patanpur) -Newaj (Mohanpura)- Kalisindh (Kundaliya), the region is occupied by rocks of two chronologically different geological domains. The upper most sequence comprises thick cover of basaltic lava flows and associated inter trappeans of the Deccan trap complex covering the sedimentary sequence of Vindhyan super group. Alluvium corresponding to quaternary to recent period is mainly confined along the banks of the major rivers. The area comprises soil profile ranging in thickness from 0.5 m to 6 m. At many places the elevated section of the link canal exhibits rock cover ranging 20 m to 60 m. The link crosses many major/minor rivers where CD structures are proposed. These rivers have bed rock profile at shallow depth. Since rock mass is hard, compact, fresh to slight weathered, the acceptable foundation grade is expected to be 1 m to1.5 m depth in the bed rock.

Basaltic lava flows occurring in Kundaliya-Rana Pratap Sagar alignment or Kundaliya-Gandhi Sagar alignment belong to the Mandleshwar, Kalisindh and Kan Kariya - Pirukheri formations in an ascending order of Malwa Group of Deccan trap complex which overlies the suket shale formation of Khorip group of the Vindhyan sub-group in Bhanpura-Ramganjmadi-Eklingpura section of the scheme. The 5.92 km long tunnel near Eklingpura leading to the RPS reservoir passes through the Vindhyan scarap comprising the slopes and the Chittorgarh Fort sandstone Formation of the hill top. Here the Vindhyan sequence represents the part of the south-western limb of the NW trending regional (Jhalawar) anticline. The tunneling

media all through the tunnel alignment appears to be splintery shale on existing geological conditions. The direction of dip of beds and slope angle (35^{O}) are apparently in the direction of the tunnel.

6.4.3 Seismicity

The project area falls under Zone I as given in IS 1893-1984 “Criteria for earthquake resistant design of structures (fourth revision)” indicating low seismicity of the area.

6.5 Stability analysis of earth dam

The stability analysis of earthen dam for Patanpur and Mohanpura dams has been carried out by slip circle method considering 1.01 gm/cc average submerged density, 1.70 t/sqm average cohesion and 45^{o} value of tan F. The dam section has been checked for upstream steady seepage condition and downstream seepage condition. On the basis of stability analysis of earthen dam carried out for above two dams, the side slopes for the earthen embankment in the Kundaliya dam has been assumed and no separate stability analysis has been done so far.

6.6 U/S 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 resisting and driving forces.

a) **Drawdown condition:** In the draw down condition all the zones above phreatic lines have been considered as moist for 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 driving forces. All the materials have been considered as submerged for computing resisting forces.

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

6.7 D/S steady seepage condition

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

6.8 Spillway

Patanpur dam

A centrally located ogee type spillway (over flow section) with downstream slope 1: 1 is proposed on the river gorge portion. The total length and maximum height above natural surface level (NSL) will be 197 m and 7.29 m respectively. The crest level of the spillway will be at 409.29 m. The study for probable maximum flood for the Patanpur dam site has been carried out by the unit hydrograph method. The design flood hydrograph has a peak of 10121 cumec.

Using the above design flood hydrograph, the maximum water level (MWL) was computed by carrying out flood routing for the reservoir. 18 gates of 8 m x 10.5 m are required to pass the design flood. Maximum water level thus obtained is 419.26 m whereas the FRL is 419 m. However, at the 419.62 m maximum water level 19 gates (1 standby) have been considered in the design of overflow section.

Mohanpura dam

A centrally located ogee type spillway (over flow section) with downstream slope 0.9: 1 is proposed on the river gorge portion. The total length and maximum height above NSL will be 176 m and 11.0 m respectively. The crest level of the spillway will be at 389.50 m. The study for probable maximum flood for the Mohanpura dam site has been carried out by the unit hydrograph method. The design flood hydrograph has a peak of 10637.1 cumec.

Using the above design flood hydrograph, the maximum water level (MWL) was computed by carrying out flood routing for the reservoir. 16 gates of 8 m x 12 m are required to pass the design flood. Maximum water level thus obtained is 400.89 m whereas the FRL is 400 m. However, at the 401.50 m maximum water level, 17 gates (1 standby) have been considered in the design of overflow section.

Kundaliya dam

A centrally located ogee type spillway (over flow section) with downstream slope 0.9: 1 is proposed on the river gorge portion. The total length and maximum height above NSL will be 228.50 m and 32.0 m respectively. The crest level of the spillway will be at 369.0 m. The study for probable maximum flood for the Kundaliya dam site has been carried out by the unit hydrograph method. The design flood hydrograph has a peak of 11539.2 cumec.

Using the above design flood hydrograph, the maximum water level (MWL) was computed by carrying out flood routing for the reservoir, 20 gates of 8 m x 10.5 m are required to pass the design flood. Maximum water level thus obtained is 378.44 m whereas the FRL is 378 m. However, at the 379.5 m maximum water level 22 gates (2 standby) have been considered in the design of overflow section.

6.9 Stability analysis of gravity dam

The stability analysis for the non-overflow concrete dam has been carried out for different conditions.

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.

Various parameters have been assumed while carrying out the above stability analysis.

The top width, height above the NSL and side slope in the downstream of gravity dam for Patanpur, Mohanpura and Kundaliya dams are furnished in Table – 6.1.

Table – 6.1
Top width, height and side slope of dams

Name of dam	Top width (m)	Height above NSL (m)	Side slope
Patanpur	6.0	19.62	1: 1
Mohanpura	6.0	24.50	0.9: 1
Kundaliya	8.0	45.0	1: 1

6.10 Energy dissipation

In order to decide the type of energy dissipator, the jump height curve and tail water rating curve for Patanpur, Mohanpura and Kundaliya dams have been plotted. The jump height curve is found above the tail water rating curve in case of Patanpur and Mohanpura dams and hence bucket type energy dissipators are provided in the design. In case of Kundaliya dam the jump height curve is found always below the tail water rating curve. Hence, sloping apron has been provided as a dissipation device. The radius of bucket has been worked out as 1.5 m and 7.0 m in case of Patanpur and Mohanpura dams respectively, whereas the length of sloping apron is 81.0 m in case of dissipator provided in the Kundaliya dam.

6.11 Design features of pumping system

From Kundaliya reservoir in Kalisindh river while linking to Gandhisagar [alternative (b)] lift has been proposed to transfer the water. Two alternative studies have been carried out. In first alternative [alternative (b)-I] pumping is proposed in three stages upto RD 19.70 km, out of which 1.5 km pipeline and remaining canal flows in gravity. In the second alternative [alternative (b)-II] pumping is proposed in single stage. In alternative (b)-I the head in each stages is 16.65 m, 15.50 m and 18.00 m respectively, whereas in alternative (b)-II, head is 47.42 m.

Since with higher velocity, head loss due to friction increases, a velocity about 2 m/s is considered for design. The friction factor is taken as 0.01 for steel pipes. In alternative (b)-I pumping in three stages, 7 pumps with a provision of one as stand by are proposed to be installed in each stage. The diameter of each pipe is 2.40m. The installed capacities of these pumps are 2150 HP, 1750 HP and 2000 H.P. In alternative (b)-II, pumping in single stage has also 7 pumps with a provision of one as stand by are proposed having installed capacity of each pump as 5000 HP. The diameter of pipe is 2.10 m.

The total power requirement for lifting of water in alternative (b)-I and alternative (b)-II works out as 22.38 MW and 18.10 MW based on average of 16 years data.

6.12 Design features of tunnels

There are five tunnels proposed along the link canal to cross the high ridges. The first tunnel has a length of 6.61 km from RD 6.764 km to 13.372 km from Patanpur to Mohanpura dam reach, second and third tunnels are between Mohanpura to Kundaliya dam reach having lengths of 1.29 km and 3.100 km from RD 33.315 km to 34.600 km and RD 50.264 km to 53.364 km respectively, and fourth & fifth tunnels are in the reach from Kundaliya to Rana Pratap Sagar dam from RD 16.915 km to 20.515 km and at the tail end of the canal from RD 107.100 km to RD 113.060 km having length of 3.60 km and 5.96 km respectively. Tunnels are designed as free flowing tunnels providing free board of 0.75 m. The maximum velocity in the tunnel has been kept as 2.70 m/second as per IS 10430:2000 for concrete lining. The rugosity coefficient for tunnel is considered as 0.014. It is assumed that the inner surface finish will be achieved at the time of construction. The shape of tunnels is modified horseshoe. The radii of tunnels are 5.10 m, 5.50 m & 2.90 m respectively.

6.13 Canals

The canals of proposed P-K-C link can be described in three parts as follows:

i) Reach from Patanpur to Mohanpura dam
ii) Reach from Mohanpura to Kundaliya dam
iii) Reach from Kalisindh to Chambal River
   (a) Reach from Kundaliya to Rana Pratap Sagar [alt-(a)]
   (b) Reach from Kundaliya to Gandhi Sagar [alt-(b)-I]
   (c) Reach from Kundaliya to Gandhi Sagar (via Ahu barrage) [alt-(b)-II]

Details of the link canal are summerised in Table-6.2.

Table-6.2
Details of the Link Canal

Canal Reach	Length (Km)	Design Discharge (cumec)	Bed Width (m)	FSL (m)	Bed Slope	Velocity (m/sec)
Patanpura-Mohanpura	55.37	199.30	19.5	411	1:10,000	1.331
Mohanpura-Kundaliya	73.17	238.00	21.3	392.5	1:8,000	1.502
Kundaliya-Ranapratap Sagar (Alt.-a)	115.08	49.10	8.00	368.7	1:20,000	0.752
Kundaliya-Gandhisagar (Alt.-b-I)	98.092	49.10	7.00	412.0	1:10,000	1.07
Kundaliya-Gandhisagar (Alt.-b-II)	73.29	49.10	9.00	368.7	1:13,500	0.8621

6.13.1 Lining

Lining with precast in M-10 C.C 1:4:8 is proposed in canal bed as well as in side slope for the entire length of the canal. The thickness of lining shall be according to canal capacity as per IS code 3875-1978.

6.13.2 Transmission losses

The transmission losses are assumed as 0.60 cumecs per million sqm of wetted area as per IS code 10430-2000

6.14 Cross drainage works

As the link is aligned as a contour canal, it shall cross several streams and minor rivers. It shall also cross several roads and railway tracks. The type of cross drainage work depends upon the catchment area of the stream and its bed level with reference to full supply level and bed level of the canal at the crossing. In general, aqueducts are proposed across major streams and hume pipe culvert across small streams. Super passages are proposed when the bed level of the streams is much higher than the full supply level of the canal at crossing. In view of the large size of the canal, canal syphons shall be avoided. Detailed laboratory tests for finding the suitability of rock for foundation of the two major aqueducts across Ajnar and Gharganga river have been carried out. Whereas for other major CD structures, DRB, railway bridges, CR/escapes etc auger hole/trial pit + auger holes have been carried out. Based on the soil samples collected, it is inferred that hard rock can be met with at reasonable depth below the stream bed level/NSL.

6.14.1 Details of canal structures

In case of alternative-(a), linking to Rana Pratap Sagar, the link canal shall cross 12 major rivers, 2 National highways, 2 railway lines, across which aqueducts/canal siphon and bridges have been proposed. Apart from these 53 small streams & nallas and 50 roads shall come across the link canal. In case of linking to Gandhi Sagar Alt-(b)-I, the link canal shall cross 7 major rivers, 2 National highways, 2 railway lines, across which aqueducts and bridges have been proposed. In addition to these, 47 small streams & nallas and 50 roads shall come across the link canal in this alternative. Whereas in the second alternative of Gandhi Sagar named as Alt-(b)-II, the link canal shall cross 8 major rivers, 2 National highways, 2 railway lines, across which aqueducts and bridges respectively have been proposed. Apart from these, 45 small streams & nallas and 41 roads shall come across the link canal in this alternative. The reach wise drainage works are described as follows:

6.14.1.1 Reach from Patanpur to Mohanpura dam

There are 2 aqueducts, 6 super passages, 2 drainage syphons, 10 DRB and 6 VRB and 1 railway bridge, 1 CR cum escape, 1 escape, 6 HR, 1 tunnel and 3 hume pipe culvert are proposed along the alignment in this reach.

6.14.1.2 Reach from Mohanpura to Kundaliya dam

There are 3 aqueducts, 2 super passages, 5 drainage syphons, 13 DRB & 4 VRB, 1 CR cum escape, 1 escape, 6 HR and 8 hume pipe culvert are proposed along the alignment in this reach.

6.14.1.3 Reach from Kundaliya to RPS dam [Alt-(a)]

There are 5 aqueducts, 5 super passages, 11 drainage syphons, 14DRB & 7 VRB, 2 CR cum escapes, 3 escapes, 12 HR, 13 hume pipe culvert and 1 canal syphon across railway track (BG) are proposed along the alignment in this reach.

6.14.1.4 Reach from Kundaliya to Gandhi Sagar dam [Alt-(b)-I]

There are 2 aqueducts, 1 super passages, 12 drainage syphons, 1 barrage, 9 DRB & 12 VRB, 1 railway bridge, 2 CR cum escapes, 2 escapes, 12 HR and 7 hume pipe culvert are proposed along the alignment in this reach.

6.14.1.5 Reach from Kundaliya to Gandhi Sagar dam [Alt-(b)-II]

There are 2 aqueducts, 3 super passages, 7 drainage syphons, 5 DRB & 7 VRB, 1 railway bridge, 1 CR cum escapes, 1 escape, 12 HR and 9 hume pipe culvert are proposed along the alignment in this reach.

6.14.2 Percentage of fluming proposed

The canal is flumed at the site of structures like aqueducts, bridges, super passages, and syphons with a view to minimise the cost of structure. At the site of aqueduct the canal is flumed upto an extent of 25%.

6.14.3 Transition in canal section and head losses

Head loss of 0.15 m is provided in each aqueduct and head loss of 0.05 m is provided in each DRB, Railway bridges and Super passages whereas head loss of about 0.23 m is provided at canal syphon across railway line at RD 67.100 Km.

The losses of head due to contraction is computed as = $0.2 (v_2^2 – v_1^2) /2g$
The losses of head due to expansion is computed as = $0.3 (v_2^2 – v_1^2) /2g$

Where v_1 = Velocity of the canal before contraction

v_2 = Velocity of the canal at exit of contraction

6.14.4 Cross regulators

Cross regulators are provided at regular interval in order to ensure effective water regulation and safety of major structures. Regulators are provided whenever the discharge of the distributary /branch canal is about 10% or more than the main canal discharge. Head loss of 0.15 m is provided at each regulator.

6.14.5 Escapes

Escapes are proposed especially to take care of the vulnerable embankment reaches to divert the canal flows into nearby streams in case of breach in embankment. The escapes are designed for 50% discharge of the parent canal in order to minimise the cost.