Chapter – 5
Hydrology

5.1 General climate and hydrology

The climate of the area in Parbati, Newaj and Kalisindh sub-basins is semi-arid to sub-humid, the weather being mostly dry except in the monsoon season. Summer is hot and winter is mild. About 90% of the annual rainfall is received during the monsoon i.e. from June to October. The average maximum and minimum temperatures are 41.50^{o} C and 7.9 ^{o} C respectively.

5.1.1 General hydrologic information about the region

5.1.1.1 Rainfall

Parbati sub-basin upto Patanpur dam

There are 7 rain gauge stations namely Astha, Ichhawar, Sehore, Narsinghgarh, Chachaura, Guna and Berasia in and around Parbati sub-basin upto Agra-Bombay road crossing gauge and discharge site at which the rainfall-runoff relationship equation for working out the annual yield series has been developed.

The normal annual rainfall in the catchment area of the Parbati sub-basin upto Patanpur site is assessed as 1180 mm. The monsoon rainfall contributes as much as 90% of annual rainfall. The maximum, minimum and the average monsoon weighted rainfall values are 1810 mm, 576 mm and 1118 mm respectively for the period from 1930 to 1995.

Newaj sub-basin upto Mohanpura dam site

There are 10 raingauge stations in and around the catchment area upto the Aklera gauge & discharge site at which rainfall-runoff relationship for working out the annual yield series has been developed. Out of 10 raingauge stations 6 stations, namely Biaora, Narsinghgarh, Sarangpur, Sonkatch, Astha and Shujalpur influence Newaj catchment upto the proposed Mohanpura dam site.

The normal annual rainfall of the Newaj sub-basin upto Mohanpura dam site is 1106 mm. The monsoon rainfall constitutes as much as 90% of annual rainfall. The maximum, minimum and the average monsoon weighted rainfall values are 1653 mm, 471 mm and 1005 mm respectively for the period from 1901 to 1983.

Kalisindh sub-basin upto Kundaliya dam site

There are 8 raingauge stations namely Sarangpur, Shajapur, Sonkatch, Astha, Dewas, Khilchipur, Agar and Shujalpur in and around the Kalisindh sub-basin. Out of which only 5 raingauge stations influence the catchment upto Sarangpur gauge & discharge site at which the rainfall run-off relationship for working out the annual yield series has been developed.

The normal annual rainfall of the Kalisindh sub-basin upto Kundaliya dam site is 1006 mm. The monsoon rainfall constitutes as much as 90% of annual rainfall. The maximum, minimum and the average monsoon weighted rainfall values are 1583 mm, 474 mm and 965 mm respectively for the period from 1930 to 1998.

5.1.1.2 Relative humidity

The monthly mean relative humidity data for Guna IMD station has been considered in the study of Parbati sub-basin. The average maximum and minimum values of relative humidity are 93% and 9% during the month of August in monsoon and April in summer season respectively.

The monthly mean relative humidity data for Jhalawar IMD station has been considered in the study of Newaj sub-basin as well as Kalisindh sub-basin. The average maximum and minimum values of humidity are 85% and 15% during monsoon and summer seasons respectively.

5.1.1.3 Wind velocity

The normal monthly wind velocity data for Guna IMD station has been considered in the study of Parbati sub-basin upto Patanpur dam site. The average maximum and minimum wind velocities are 13.53 km/hr and 3.78 km/hr respectively.

The normal monthly wind velocity data for Jhalawar IMD station is considered in the study of Newaj sub-basin and also in the study of Kalisindh sub-basin. The average maximum and minimum wind velocities are 11.5 km/hr and 2.1 km/hr respectively.

5.1.1.4 Cloud cover

The normal monthly cloud cover data for Guna and Jhalawar IMD stations are considered. The maximum cloud cover occurs in July or August whereas the minimum cloud cover occurs in November.

5.1.1.5 Sunshine

The monthly average coefficients of sunshine values at Guna and Jhalawar IMD stations are considered. The value varies between 0.4599 and 0.7680.

5.1.1.6 Temperature

The monthly average and monthly maximum and minimum temperatures for Guna and Jhalawar IMD stations falling in the sub-basin are considered. It is seen that the maximum and minimum temperatures vary between 41.50^{o} C and 7.90^{o} C respectively.

5.2 Drainage basins

5.2.1 General

The catchment area of Parbati sub-basin upto Patanpur dam site is 5312 sqkm which is 33.5% of the total sub-basin area. The length of Parbati upto proposed Patanpur dam site is approximately 182 km. The Parbati sub-basin upto proposed Patanpur dam site comprises of the upland areas, the eastern ranges and the western ranges. The upland areas are plain rolling land, not well defined and are discontinuous. Sub-basin is located in the major physiographic province of western India namely the Malwa plateau. This part of the sub-basin has Deccan traps as the main rock belonging to the middle series of three fold classifications with simple AA flows without tectonic imprint and dykes and pertaining to cretaccous cocene age. These rocks have their origin in the eruption of the letic magma probably in the beginning of the third era.

The catchment area of Newaj sub-basin upto Mohanpura dam site is 3594 sqkm, which is 82.2% of the total sub-basin area. The length of Newaj river upto proposed Mohanpura dam site is, approximately 147 km. The sub-basin has Deccan trap as the main rock belonging to the middle series of the fold classification with simple AA flows without tectonic imprint and dykes and pertains to the creataccous cocene age. The rocks have their origin in the erruphin of theletic magma probably in the beginning of third era. The formation comprises of taped flow of varying thickness.

The catchment area of Kalisindh sub-basin upto Kundaliya dam site is 5953 sqkm, which is 24.14% of the total sub-basin area. The length of Kalisindh river upto proposed Kundaliya dam site is 170 km. The sub-basin is bounded on the South by the great Vindhyan ranges from where most southern tributaries of the Yamuna originate

5.2.2 Soil types

The soil type is mixed red and black as per the general classification. A brief description of the soil in the Parbati, Newaj and Kalisindh sub-basins are given in the following paragraphs:

(i) Soils on hill and hill ridges (Entisols)

These soils are fine loamy to coarse loamy in texture and grayish brown to dark reddish brown in colour. They are highly erodable, excessively drained, stony and gravelly in nature. These soils are of shallow depth with low nutrient status and are slightly acidic to neutral in reaction. They are low in organic matter content and have poor water retention capacity. These soils are unsuitable for normal crop husbandry. However, they may be utilised for forestry, pasture development and growing grasses.

(ii) Plateau soils (Entisols, Inceptisols and Afisols)

These soils occur of level to gently undulating terrain. They are yellowish brown to dark brown in colour. These soils are shallow to deep, coarse to fine medium textured with low nutrient status. These soils are moderately eroded. Their water retention capacity varies with the soil texture and organic matter content. In this category too the shallow soils are unfit for normal crop husbandry whereas deep soils are suitable for growing kharif crops like sorgum, millets, pulses, bajra and cowpee.

(iii) Pediment soils (Entisols and Vertisols)

These soils occur on gently to undulating gneissic terrain comprising the vast pediment and pediment plains characterised by intermittent rocky wastelands and shallow water bodies. They are shallow to deep coarse to fine medium on texture and poor in nutrient status. They are moderately eroded. The deep soils in this category are fit for cultivation of crops like sorgum, til, bajra, millets and groundnut. Shallow soils are best suited for raising pastures.

(iv) Soils of level alluvial plain and undulating flood plain (Inceptisols and Vertisols)

These soils occur on level to undulating terrain. These are deep to very deep, fine to fine loamy, well to moderately drained and contains calcium carbonate deposits. They are low in organic matter content and suited to crops like jowar, arhar, soyabean and moong under dry land and sugarcane under irrigated conditions. Wheat, gram and linseed may be grown during the Rabi season.

(v) Soils of dissected flood plain (Inceptisols)

These soils are very deep, well drained, calcareous, and gravelly with bundant lime nudules in the soils. These are fine loamy in texture, yellowish brown in colour with low organic matter content. They possess moderate water retention capacity. These soils are severely eroded during floods and need extensive conservation measures. Land situated away from the streams can be put under cultivation for kharif crops viz jowar, bajra and arhar.

5.2.3 Present land use

A. Parbati sub-basin upto Patanpur dam site

(i) Pattern

The total geographical area of Parbati sub-basin upto Patanpur is 5312 sqkm. The annual land use particulars of the basin have been worked out from available districtwise statistics of 1979-80 obtained from the Land Records and Settlements Department, Madhya Pradesh. It is seen that the areas under forest and land under non-agricultural use are 14.34% and 5.45% respectively. The net area sown is 61.75%.

An extract of the average land use statistics for the Parbati sub-basin is given in Table 5.1.

Table-5.1
Average land use in Parbati sub-basin upto Patanpur dam site (based on 1979-80 Statistics)

Type of Land	Total area in ha	Percentage of area
Forests	76146	14.34
Land under non-agricultural use	28955	5.45
Barren and uncultivable land	11819	2.22
Permanent pastures & other grazing land	46158	8.69
Land under miscellaneous, crops	19	--
Net area sown	328023	61.75
Culturable waste land	35536	6.69
Other fallows	2626	0.50
Current fallows	1918	0.36
Total	**531200**	**100.00**

Source: Land Records Office, Gwalior (M.P.)

(ii) Culturable area

The culturable area of the basin comprises of culturable wasteland, land under miscellaneous crops and trees, fallow land and net area sown. Maximum culturable area of the Parbati sub-basin upto Patanpur dam is 368122 ha (69.30% of the total area).

(iii) Land holdings

The land holding in the Parbati sub-basin, as per 1990-91 statistics have been obtained from the information on land holdings in the eight districts falling in the basin and area given in Table-5.2.

Table-5.2
Land holding particulars

Land size	Number	Area in ha.
Upto 1 ha.	19668	9368
Between 1 and 2 ha.	20737	30362
Between 2 and 4 ha	21493	59706
Between 4 and 10 ha.	21882	135808
Above 10 ha.	6960	116489

Source: District Statistical Book of 1990-91.

B. Newaj sub-basin upto Mohanpura dam site

(i) Pattern

The total geographical area of Newaj catchment upto Mohanpura site is 3594 sqkm. The annual land use particulars for the basin have been worked out from available districtwise statistics of 1992-93 obtained from the Land Records office, Madhya Pradesh. It is seen that the areas under forest and land under non-agricultural use are 5.2% and 6.4% respectively. The net area sown is 66.5% and the area sown more than once is 16.9%. Thus the gross cropped area works out to be 83.4%. An extract of the average land use statistics for the Newaj catchment upto Mohanpura site is given in Table-5.3.

Table – 5.3
Average land use in Newaj sub-basin upto Mohanpura dam site
(Based on 1992-93 statistics)

Type of Land	Total area in ha	Percentage of area
Forests	18635	5.2
Land under non-agricultural use	22984	6.4
Barren and unculturable land	19294	5.4
Permanent pastures & other grazing land	42592	11.8
Land under miscellaneous crops	40	--
Net area sown	239204	66.5
Other fallows	2054	0.6
Current fallows	1013	0.3
Culturable waste land	13584	3.8
Total area	**359400**	**100.00**

Source : Land record office, Gwalior (M.P.)

(ii) Culturable area

The culturable area of the basin comprises of culturable waste land, land under miscellaneous crops and trees, fallow land and net area sown. Maximum culturable area of the Newaj catchment upto Mohanpura site is 255895 ha (71.2% of the total area).

(iii) Land holdings

The land holdings in the Newaj catchment, as per 1990-91 statistics, have been obtained from the information on land holdings in the eight districts falling in the basin and are given in Table-5.4.

Table – 5.4
Land holding particulars

Land size	Number	Area in ha
Upto 1 ha.	21215	10371
Between 1 and 2 ha	17712	25471
Between 2 and 4 ha	17329	48839
Between 4 and 10 ha	17183	106041
Above 10 ha	5047	79284

Source: District statistical book of 1992-93

C. Kalisindh sub-basin upto Kundaliya dam site

(i) Pattern

The total geographical area of Kalisindh sub-basin upto Kundaliya dam site is 5953 sqkm. The land use particulars for the basin have been worked out from available districtwise statistics of 1994-95 obtained from the Land Records Office, Madhya Pradesh. It is seen that the areas under forest and land under non-agricultural use are 11.43% and 6.07% respectively. The net area sown is 63.52% and the area sown more than once is 25.96%. Thus, the gross cropped area works out to be 89.47%.

An extract of the average land use statistics for the Kalisindh sub-basin upto Kundaliya dam site is given in Table-5.5

Table – 5.5
Average land use in Kalisindh sub-basin upto Kundaliya dam site (based on 1994-95 statistics)

Type of Land	Total area in ha	Percentage of area
Forests	68100	11.43
Land under non-agricultural use	36142	6.07
Barren and unculturable land	28025	4.71
Permanent pastures & other grazing land	66414	11.16
Land under miscellaneous crops	53	0.01
Net area sown	378144	63.52
Other fallows	2192	0.37
Current follows	3382	0.57
Culturable waste land	12889	2.16
Total area	**595341**	**100.00**

Source : Land Record Office, Gwalior (M.P.)

(ii) Culturable area

The culturable area of the basin comprises of culturable waste land, land under miscellaneous crops and trees, fallow and net area sown Maximum culturable area of the Kalisindh sub-basin upto Kundaliya dam site is 396660 ha (66.63% of the total area).

(iii) Land holdings

The land holdings in the Kalisindh sub-basin as per 1990-91 statistics have been obtained from the information on land holdings in the eight districts falling in the basin and are given in Table 5.6.

Table -5.6
Land holding particulars

Land size	Number	Area in ha
Up to 1 ha	27414	14728
Between 1 and 2 ha	23982	34684
Between 2 and 4 ha	24284	68906
Between 4 and 10 ha	26375	154690
Above 10 ha	9200	149470

Source: District statistical book of 1990-91

5.3 Availability of data

5.3.1 Availability of river flow data

There are 4 gauge and discharge measurement sites across rivers in the donor basins. Particulars of the sites are given in Table 5.7.

Table – 5.7
Location of gauge and discharge sites

Site	River on which located	Catchment area (sqkm)	Site maintained by
Agra-Bombay (A-B) road crossing	Parbati	6060	CWC
Shampur	Parbati	2640	CWC
Aklera	d/s of the confluence of river Newaj with Parwan	6050	CWC
Sarangpur	Kalisindh	2600	CWC

The gauge and discharge data of A-B road crossing, Aklera and Sarangpur sites have been considered while assessing the water balances in the Preliminary water balance studies of Parbati sub-basin upto Patanpur, Newaj sub-basin upto Mohanpura and Kalisindh sub-basins upto Kundaliya dam site respectively.

5.3.2 Availability of rainfall data

Rainfall data of 15 stations have been considered in Preliminary water balance studies of Parbati sub-basin upto Patanpur, Newaj sub-basin upto Mohanpura and Kalisindh sub-basin upto Kundaliya dam sites. The availability of monthly rainfall data of these stations for varying periods from 1930 to 1998 is given below in Table-5.8.

Table- 5.8
Availability of rainfall data

Name of raingauge Stations	Period of availability	PWBS study in which data used
Guna	1930-95	Parbati sub-basin
Astha	1930-98	Parbati, Newaj & Kalisindh sub-basin
Ichhawar	1930-95	Parbati sub-basin
Sehore	1930-95	Parbati sub-basin
Narsingarh	1930-95	Parbati & Newaj sub-basin
Chachaura	1930-95	Parbati sub-basin
Berasia	1930-95	Parbati sub-basin
Dewas	1930-98	Newaj & Kalisindh sub-basin
Sonkatch	1930-98	Newaj & Kalisindh sub-basin
Shujalpur	1930-98	Newaj & Kalisindh sub-basin
Shajapur	1930-98	Newaj & Kalisindh sub-basin
Sarangpur	1930-98	Newaj & Kalisindh sub-basin
Agar	1930-98	Newaj & Kalisindh sub-basin
Khilchipur	1930-98	Newaj & Kalisindh sub-basin
Biaora	1930-95	Newaj sub-basin

5.4 Yield and water balance

The National Water Development Agency has made studies of yield assessment based on gauge and discharge data of G&D sites in the respective basins. The details of surface water balance for each diversion sites are furnished in the following paras.

5.4.1 Parbati sub-basin upto Patanpur dam site

The catchment area of Parbati sub-basin is 5312 sqkm. The yield assessment of the sub-basin has been made based on the gauge and discharge data for the period from 1976-1977 to 1993-94 of Agra-Bombay road crossing G&D site maintained by CWC. The site intercepts the catchment area of 6060 sqkm. Based on the studies the 75% and 50% dependable yield has been worked out as 1934 Mm^3 and 2370 Mm^3 respectively. The water balance in Parbati sub-basin upto Patanpur dam site is given in Table-5.9.

Table-5.9
Water Balance

1	**Availability**	**Annual (Mm^3)**
a	Gross annual yield at	
	75% dependability	1934
	At 50% dependability	2370
b	Surface water import (+)	-
c	Surface water export (-)	219
d	Overall availability (a+b-c) at	
	75% dependability	1715
	50% dependability	2151
2	**Surface water requirement**	
	Irrigation by in-basin water	766
	Domestic use	78
	Industrial use	101
	Hydropower	-
	Environmental and ecology	4
	Sub-total (2)	949
3	**Regeneration (+)**	
	Irrigation	39
	Domestic use	62
	Industrial use	81
	Sub-total: (3)	182
4	**Surface water balance ((1)-(2)+(3)) at**	
	75% dependability	948
	50% dependability	1384

5.4.2 Newaj sub-basin upto Mohanpura dam site

The catchment area of Newaj sub-basin upto Mohanpura dam site is 3594 sqkm. The yield assessment of the sub-basin has been made based on the gauge and discharge data of Aklera G&D site from 1977 to 1995 maintained by CWC. The site intercepts the catchment area of 6050 sqkm. Based on the study, yield at 75% and 50% dependabilities have been worked out as 862 Mm^3 and 1266 Mm^3 respectively. The water balance in Newaj sub-basin upto Mohanpura dam site is given in Table-5.10.

Table-5.10
Water Balance

1	**Availability**	**Annual (Mm^3)**
a	Gross annual yield at	
	75% dependability	862
	50% dependability	1266
b	Surface water import (+)	-
c	Surface water export (-)	-
d	Overall availability (a+b-c) at	
	75% dependability	862
	50% dependability	1266

2	**Surface water requirement**	
	Irrigation by in-basin water	179
	Additional water requirement for Enhancement of irrigation to 30% (-)	227
	Domestic use	59
	Industrial use	77
	Hydropower	-
	Environmental and ecology	2
	Sub-total (2)	544
3	**Regeneration (+)**	
	Irrigation	17
	Domestic use	47
	Industrial use	62
	Sub-total: (3)	126
4	**Surface water balance ((1)-(2)+(3)) at**	
	75% dependability	444
	50% dependability	848

5.4.3 Kalisindh sub-basin upto Kundaliya dam site

The catchment area of Kalisindh sub-basin upto Kundaliya dam site is 5953 sqkm. The yield assessment of Kalisindh sub-basin has been made based on gauge and discharge data of Sarangpur G&D site from 1976 to 1998 maintained by CWC. The Sarangpur G&D site intercepts the catchment area of 2600 sqkm. Based on the studies carried out by NWDA, the 75% and 50% dependable yield has been worked out 1278 Mm^3 and 1827 Mm^3 respectively. Water balance in Kalisindh sub-basin upto Kundaliya dam site is given in Table -5.11.

Table- 5.11
Water Balance

1	**Availability**	**Annual (Mm^3)**
a	Gross annual yield at	
	75% dependability	1278
	At 50% dependability	1827
b	Surface water import (+)	-
c	Surface water export (-)	-
d	Overall availability (a+b-c) at	
	75% dependability	1278
	50% dependability	1827
2	**Surface water requirement**	
	Irrigation by in-basin water	663
	Domestic use	96
	Industrial use	126
	Hydropower	-
	Environmental and ecology	1
	Sub-total (2)	886

3	**Regeneration (+)**	
	Irrigation	40
	Domestic use	77
	Industrial use	101
	Sub-total: (3)	218
4	**Surface water balance ((1)-(2)+(3)) at**	
	75% dependability	610
	50% dependability	1159

5.5 Surface water available for transfer

The surface water available at 75% dependability for transfer at Patanpur, Mohanpura and Kundaliya dam sites have been computed and found 948 Mm^3, 444 Mm^3 and 610 Mm^3 respectively. In order to have an equitable distribution of water in different sub-basins of Chambal basin, a criteria of attaining a minimum irrigation level of 30% both for areas upstream and downstream of diversion point in the donor sub-basin has been adopted. The level of irrigation in the Parbati sub-basin has been worked out as 35.80% in the preliminary water balance study report of Parbati sub-basin upto Patanpur considering the irrigation from existing, ongoing and proposed projects. The provision of 227 Mm^3 of water has been kept to upgrade the level of irrigation upto 30% in case of determining the balance water for diverting from Newaj sub-basin upto Mohanpura dam site. The level of irrigation in the Kalisindh sub-basin is 36.60% of the culturable area as worked out in the PWBS report of Kalisindh sub-basin upto Kundaliya dam site prepared in June 1991.

5.5.1 Simulation studies

Simulation studies have been carried out to assess the quantum of water for transfer, optimum canal capacities, capacities of destination reservoirs to accommodate bulk transfer of water etc. The studies have been carried out considering the simultaneous operation of all reservoirs namely Patanpur, Mohanpura, Kundaliya and Rana Pratap Sagar or Gandhi Sagar as the case may be, starting from downstream most reservoir. Three options have been studied for all the three alternatives.

In the first option, the quantum of water to be transferred to the destination reservoir (Rana Pratap Sagar or Gandhi Sagar) has been kept equal to the quantum of water proposed to be utilised in upper Chambal basin on substitution basis and provision of additional water for M.P. through Kota barrage after meeting the enroute demand as proposed in modified proposal of Parbati-Kalisindh-Chambal link project.

In the second option, the canal capacity has been increased to transfer the entire water available at 75% success to meet the requirement of proposed projects in upper Chambal sub-basin on substitution basis and also to compensate the loss of power generation at Gandhi Sagar upto some extent as the inflow at Gandhi Sagar will be reduced by tapping water in upper reaches by the 7 projects.

In the third option, the storage capacity of Kundaliya reservoir has been increased and releases from the Kundaliya reservoir have been regulated to transfer the equal

quantum of water to Rana Pratap Sagar throughout the year over & above the varied monthly demands in the enroute with reduced canal capacity. Under this option, the height of dam at Kundaliya is to be increased, but the canal capacity will be reduced.

The above three options have been studied for different combination of storages at Kundaliya versus canal capacities in the different reaches from Patanpur to Rana Pratap Sagar or Gandhi Sagar to minimise the cost of project and maximise the benefits. However, due to limitations of inflow pattern and availability of storage capacity at Patanpur and Mohanpura, the storage at these two reservoir sites have been kept fixed while the capacities of the canal in different reaches i.e. from Patanpur to Mohanpura, Mohanpura to Kundaliya and Kundaliya to either Rana Pratap Sagar or Gandhi Sagar have been kept varied in all the three options. Details of various options under each alternative are furnished below:

Alternative (a): Water diverted to river Chambal at Rana Pratap Sagar

Under this alternative surplus water likely to be available at Patanpur, Mohanpura and Kundaliya storage reservoirs is proposed to be diverted to Rana Pratap Sagar through 115.08 km long gravity canal (105.52 km long open channel, and two tunnels 3.60 km & 5.96 km long).

In its first option, the maximum diversion of water from Kundaliya reservoir to Rana Pratap Sagar is proposed in the monsoon months itself in accordance with the monthly quantum of water, which will be tapped in the proposed 7 projects in upper reaches of Chambal basin to meet out the monthly demand at 75% success in the command. In this option, simulation study has been carried out keeping in view that after completion of the project, the water released from Gandhi Sagar and water transferred from the link canal could be accommodated in the Rana Pratap Sagar. The gross storage capacity at Kundaliya has been so adjusted that its live capacity at all times during the year would be sufficient to meet out the enroute requirement for the reach from Kundaliya to Rana Pratap Sagar and the quantum of water to be transferred in the lean months. Since most of the quantum of water will be diverted in monsoon months to Rana Pratap Sagar, the canal capacities in all the reaches of the link in this option will have to be enhanced which would increase the cost of the project. The enhanced canal capacities will require less storage at Kundaliya but the reduction in overall cost of the project due to low dam height at Kundaliya will be much less as compared to the increased overall cost of the project with enhanced canal capacities in all the three reaches. Keeping the low dam height and less storage at Kundaliya, the canal capacities from Patanpur to Mohanpura & Mohanpura to Kundaliya have been proposed to be enhanced to feed the reservoir at Kundaliya in monsoon months. The additional water available during monsoon, if any, after providing the required quantum of water to Kundaliya is proposed to be spilled down in rivers Parbati and Newaj at Patanpur and Mohanpura respectively.

In the second option of Alternative-(a), possibility has been explored to divert the entire quantum of balance water available at 75% dependable success at different intermediate diversion reservoirs by further enhancing the canal capacities. The storage capacities of the reservoirs are kept same as in option-I above to transfer the entire water at 75% success. It has also been kept in view that the monthly enhanced transfer of water from the link canal in conjunction with the releases from

Gandhi Sagar could be accommodated in the Rana Pratap Sagar with simultaneous generation of power at full installed capacity at Rana Pratap Sagar. The additional power generation at Rana Pratap Sagar has been observed in some months due to increased quantum of transferred water, which will compensate partially the loss of power at Gandhi Sagar. The simulation study in this option revealed that beyond optimum canal capacity the quantum of divertible water at 75% success will not be increased even adopting a canal capacity higher than the above optimum capacity. It has been observed that 277 Mm^3 additional water can be transferred to Rana Pratap Sagar as compared to option I. This additional water can further be utilised for enhancement of irrigation through Kota barrage or otherwise.

Under Option-III of alternative-(a), the storage capacity of Kundaliya reservoir is proposed to be increased by raising the FRL of reservoir at Kundaliya dam across Kalisindh river from 373.3 m to 378 m keeping the storage capacities of Mohanpura and Patanpur reservoirs the same as adopted in the previous options. The storage capacities available at Mohanpura and Patanpur reservoirs are limited due to topographical constraints. The storage at Kundaliya reservoir, thus created by raising the height of dam, is proposed to be utilised to transfer the quantum of water uniformly to Rana Pratap Sagar throughout the year in addition to cater the enroute demands from Kundaliya to Rana Pratap Sagar during lean season. In this option, the flatter slope of 1:20000 instead of 1:8000 considered in above two options is adopted in the canal between Mohanpura to Kundaliya to raise the FSL at outfall into Kundaliya reservoir.

663 Mm^3 of Chambal water is proposed to be tapped in the upper reaches of Chambal for the proposed projects. This will be supplemented by transferring 55.24 Mm^3 of water in each month at Rana Pratap Sagar through Parbati-Kalisindh-Chambal link project. Due to transfer of water on uniform basis, the canal capacities will be reduced substantially in the reach between Kundaliya to Rana Pratap Sagar. The canal capacities between Patanpur to Mohanpura and Mohanpura to Kundaliya have been so fixed that the Kundaliya reservoir could maintain its FRL in monsoon season after accounting for inflow of water from its own catchment and quantum of water received from Mohanpura and Patanpur reservoirs.

The releases from the power house of Gandhi Sagar has been adjusted in such a manner so that the total quantum of water received at Rana Pratap Sagar i.e. from power house of Gandhi Sagar and Kundaliya reservoir of Parbati-Kalisindh-Chambal link could together be accommodated. The size of canal is more dominating factor as compared to size of the reservoir in controlling the cost of the project. Therefore, the reduction in canal size has resulted in the reduction of the overall cost of the project. Considering the reservoir operation table of existing Rana Pratap Sagar and Gandhi Sagar reservoir and inflow pattern at proposed Patanpur, Mohanpura and Kundaliya reservoirs for the concurrent period, the average annual power loss at Gandhi Sagar has been worked out as 5.79 MW. However, due to supplementation of flows to the Chambal river at Rana Pratap Sagar through Parbati-Kalisindh-Chambal link, negligible change in power generation at Rana Pratap Sagar is seen.

Water diverted to river Chambal at Gandhi Sagar

Alternative-(b)-I:

In this alternative, the entire water is proposed to be lifted in three stages from Kundaliya reservoir at an off-take level of 368.35 m (average suction level) through pumping reach of 19.74 km with a lift of about 50.15 m followed by 78.35 km long gravity canal upto Gandhisagar. The simulation study carried out at Patanpur, Mohanpura and Kundaliya under alternative (a) for its all the three options will be applicable to this alternative also. The only difference is that the diversion of water under this alternative involves pumping while it was through gravity flow in case of water to be diverted to Rana Pratap Sagar. The entire quantum of water required at Gandhi Sagar including enroute demands between Kundaliya to Gandhi Sagar is proposed to be lifted from Kundaliya reservoir itself.

In option-I, the maximum quantum of water is proposed to be lifted during monsoon months itself in order to substitute the quantum of water at Gandhi Sagar in the same fashion as tapped in the upper reaches projects of Chambal basin. Since pumping of most of the waters is confined to the monsoon period only, large size of pumping station will have to be installed, thereby increasing overall cost of the project. Moreover, during lean season most of the pumping units will remain unutilised as the limited quantum of the water is to be lifted to meet the enroute requirement only.

In the second option, the entire balance water available at 75% dependability at each intermediate reservoir is proposed to be diverted by lifting water from Kundaliya reservoir to Gandhi Sagar. In this option also, most of the quantum of water is proposed to be pumped during monsoon season itself while during lean season only the quantum of water required to meet out the enroute demand is proposed to be lifted from Kundaliya reservoir. The quantum of water as received at Gandhi Sagar by pumping from Kundaliya is further regulated through existing power houses installed at Gandhi Sagar keeping in view the inflow received at Gandhi Sagar after tapping of water in the projects proposed in the upstream of Gandhi Sagar of Chambal basin, storage capacity at Rana Pratap Sagar accounting for power generation at Rana Pratap Sagar and demands at Kota barrage.

Since the quantum of water proposed to be lifted in this option is more in comparison to the first option, the installation capacity of the pumping station will further be enhanced, which in turn will increase the cost of the project. However, the quantum of water diverted from Kundaliya to Gandhi Sagar in this option is more than the water tapped in the upper reaches proposed projects of Chambal basin, the additional power at Gandhi Sagar as well as at Rana Pratap Sagar can be generated during monsoon months through existing power houses itself.

In the option-III of alternative (b)-I, the quantum of water diverted during monsoon months from Patanpur and Mohanpura reservoirs has been proposed to be stored at Kundaliya reservoir including its own catchment inflow by raising the height of the dam. The stored water at Kundaliya is proposed to be further diverted to Gandhi Sagar by lifting the quantum of water directly from Kundaliya. The quantum of divertible water after catering the enroute demand between Kundaliya to Gandhi Sagar is proposed to be transferred in equal amounts uniformly to Gandhi Sagar

reservoir throughout the year. As the transferred quantum of water received at Gandhi Sagar is on uniform basis, the releases from Gandhi Sagar accounting for its own inflow is proposed to be diverted to Rana Pratap Sagar from its power houses uniformly throughout the year. The uniform regulation of releases from Gandhi Sagar will be beneficial to firm up the power generation on regular basis at Gandhi Sagar and Rana Pratap Sagar throughout the year. It is also imperative to mention that the installation capacity required for pumping in this case will be reduced substantially due to uniform transfer of water throughout the year.

Alternative (b)-II:

Under this alternative, instead of lifting the water from Kundaliya itself to Gandhi Sagar as proposed in alternative (b)-I, the link canal is proposed to run for a distance of about 45 km upto Ahu barrage (open channel 41.4 km and 3.6 km tunnel) by gravity traversing the same alignment as in alternative-(a) i.e. the alignment from Kundaliya to Rana Pratap Sagar. Thereafter, beyond the proposed barrage at river Ahu, the canal after providing irrigation in the enroute command between Kundaliya and river Ahu shall run for a length of 5 km in the North-Westerly direction to feed the sump well located near village Mogra. The water is proposed to be pumped in single stage lift of about 47.42 m to RL 404.00 m. The lifted water will be carried through a 3.2 km long pipe line followed by 4.55 km long gravity canal to join the alignment as proposed in alternative (b)-I. Thereafter, the link canal followed same path for 15.54 km as proposed in alternative (b)-I upto Rupania nalla which ultimately falls into Gandhi Sagar reservoir. The total length of the link canal in this alternative from Patanpur to Gandhi Sagar comes out to about 201.83 km including pumping reach. The simulation studies carried out at Patanpur, Mohanpura and Kundaliya reservoirs under alternative (b)-I, has been adopted as such in this alternative also the quantum of water proposed for diversion and monthly release pattern from Kundaliya to Gandhi Sagar reservoir in each option is kept same as per the previous alternative. The remarkable difference in this alternative is that the substantial quantum of diverted water from Kundaliya is utilised by gravity in the enroute command prior its lifting to Gandhi Sagar whereas in alternative (b)-I the entire water is proposed to be lifted from Kundaliya reservoir itself. However, the pumping reach in this alternative in comparison to alternative (b)-I is less and quantum of water lifted will also be less due to enroute irrigation in the command of the link canal between Kundaliya to Ahu river. The options tried under this alternative are same as in alternative (b)-I. However, the salient points under each option are discussed below.

Since both these alternatives i.e. alternative (b)-I & (b)-II involve lifting of water therefore, in addition to the quantum of water to be transferred, installation of pumping stations and duration of the pumping will have an impact on the capital cost of the project. Shorter is the duration of the pumping more will be the cost of installation of the pumping station. Therefore, the cost of the pumping as worked out in the alternative (b)-I & II of the study will be maximum for option-II and minimum for option-III. The details of gross and live storage capacities of each proposed reservoirs, reach wise canal capacities, power required for lifting the water, additional power generated and net loss of power generation at Gandhisagar and Rana Pratap Sagar are given below in Table-5.12.

Table – 5.12
Details of storage and canal capacities

Particulars	Alternative-(a) (Patanpur to RPS)			Alternative-(b)-I (Patanpur to G.S., lift from Kundaliya			Alternative-(b)-II (Patanpur to G.S., lift after river Ahu)		
	Opt.I	Opt.II	Opt.III	Opt.I	Opt.II	Opt.III	Opt.I	Opt.II	Opt.III
1. Gross storage capacity in Mm^3									
Patanpur dam	156	156	156	156	156	156	156	156	156
Mohanpura dam	140	140	140	140	140	140	140	140	140
Kundaliya dam	867	687	1234	718	538	1085	867	687	1234
2.Canal capacity in cumecs (reach wise)									
Patanpur to Mohanpura	129	265.4	199.3	129	265.4	199.3	129	265.4	199.3
Mohanpura to Kundaliya	187.1	305.3	238	187.1	305.3	238	187.1	305.3	238
Kundaliya to destination reservoir	263.6	442.2	49.1	263.6	442.2	49.1	263.6	442.2	49.1
3.Average annual power (MW)									
A. Linkage to RPS									
a) Loss of power generation to GS	5.72	5.17	5.79	-	-	-	-	-	-
Additional power generation due to transferred water	0.43	6.48	0.09	-	-	-	-	-	-
Overall loss/ gain of	(-) 5.29	1.31	(-) 5.70	-	-	-	-	-	-
B.Linkage to GS									
Power required for lifting the water	-	-	-	40.11	60.57	22.38	25.60	40.67	18.10
Power generated by transferred water	-	-	-	9.23	13.11	9.07	9.23	13.11	9.07
Overall loss of power	-	-	-	30.88	47.46	13.31	16.37	27.56	9.03

5.6 Flood studies for Patanpur, Mohanpura and Kundaliya dams

Studies for probable maximum flood for proposed Patanpur, Mohanpura and Kundaliya dams under P-K-C link have been carried out by developing synthetic unit hydrograph for each of the above site. The Synthetic Hydrographs for above sites have been prepared on the basis of "Flood Estimation Report for Chambal Sub-Zone-1(b)" published by the Directorate of Hydrology (Small catchment, Central Water Commission, New Delhi). The probable maximum flood for Patanpur, Mohanpura and Kundaliya dams has been worked out as 10120.86 cumec, 10637.1 cumec and 11539.2 cumec respectively.