Chapter - 7
Reservoirs

7.1 General description

There are seven storage reservoirs proposed for storing and diverting water through the Par-Tapi-Narmada link. These are Jheri, Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan. The approach to the each of the dam sites, the details of surveys carried out and the details of capacities of the reservoirs to be provided are described in the following paragraphs.

7.1.1 Jheri reservoir

The Jheri reservoir is proposed across river Par near village Jheri in Peint taluka of Nasik district of Maharashtra. The nearest railway station for this site is Nasik on Central railway. The nearest town is Peint, taluka head quarter in Nasik district. The dam site is approachable from Peint and from Dharampur a taluka in Valsad district via Dharampur-Nasik road. The reservoir survey has been carried out by NWDA. Based on this survey, a reservoir plan has been prepared to the scale of 1:10,000 with a contour interval of 5 m. The submergence area lies in the Surgana and Peint talukas of Nasik district.

7.1.2 Mohankavchali reservoir

The Mohankavchali reservoir is proposed across river Par near village Mohankavchali in Dharampur taluka of Valsad district in Gujarat state. This reservoir is in tandem with Jheri reservoir in its downstream. The nearest railway station for this site is Valsad. The nearest town is Dharampur from where the dam site is approachable. Survey for this reservoir could not be carried out either by NWDA or any other agency due to the resistance from the local people. The information furnished here is based on the toposheets of the Survey of India in the scale of 1:50,000 with a contour interval of 20 m. The submergence area lies in Surgana taluka of Nasik district in Maharashtra state and in Dharampur taluka of Valsad district in Gujarat state.

7.1.3 Paikhed reservoir

The Paikhed reservoir is proposed across river Nar, the main tributary of river Par near village Paikhed in Dharampur taluka of Valsad district. The nearest town is Dharampur and the nearest railway station is Valsad. The reservoir survey has been carried out by the NWDA. Based on this survey, the reservoir plan is prepared to a scale of 1:10,000 with a contour interval of 5

m. The submergence area lies in the Surgana taluka of Nasik district and in the Dharampur taluka of Valsad district.

7.1.4 Chasmandva reservoir

The Chasmandva reservoir is proposed across river Tan a tributary of river Auranga near Chasmandva village in Dharampur taluka of Vaslad district. The nearest town is Dharampur and the nearest railway station is Valsad. The reservoir survey has been carried out by NWDA through Survey of India and the reservoir plan is prepared to a scale of 1:10,000 with a contour interval of 5 m. The submergence area lies in Surgana taluka of Nasik district and in Dharampur of Valsad district and Vansda taluka of Navsari district in Gujarat.

7.1.5 Chikkar reservoir

The Chikkar reservoir is proposed across river Ambica near village Chikkar in Ahwa taluka of Dang district in Gujarat State. The nearest town and the railway station is Waghai. The Govt. of Gujarat has carried out the survey through Survey of India and its own staff. Based on the survey, the reservoir plan is prepared to a scale of 1:15,000 with contour intervals of 2.5 m and 5 m. The entire submergence area lies in Ahwa taluka of Dang district in Gujarat.

7.1.6 Dabdar reservoir

The Dabdar reservoir is proposed across river Kapri, a tributary of river Ambica near village Dabdar in Ahwa taluka of Dang district in Gujarat. The nearest town and the railway station is Waghai. The reservoir survey has been carried out by Govt. of Gujarat through Survey of India and its own staff. Based on the survey, the reservoir plan is prepared to a scale of 1:15,000 with a contour interval of 5 m. The submergence area lies entirely in Ahwa taluka, of Dang district in Gujarat.

7.1.7 Kelwan reservoir

The Kelwan reservoir is proposed across river Purna near village Kelwan and Kakarda in Ahwa taluka of Dang district in Gujarat State. The nearest railway station is Vyara, a taluka head quarter in Surat district. The Govt. of Gujarat has conducted the reservoir survey through Survey of India and its own staff. Based on the survey, the reservoir plan is prepared to a scale of 1:25,000 with a contour interval of 5 m. The reservoir area lies entirely in Ahwa taluka of Dang district in Gujarat.

7.2 Fixation of storage and reservoir levels

Reservoir capacity and related levels depend on many interrelated parameters. The major factors are quantities and distribution of inflows, demand pattern, reliability of fulfillment of demands, sediment distribution, operational criteria and design flood. Inflow into the reservoirs and design flood have already been discussed in Chapter–5 "Hydrology". Other factors have been described in the following paragraphs.

7.3 Sedimentation studies

Reservoir sedimentation study for the seven reservoirs has been carried out using Empirical area reduction method as per IS : 5477 (part-ii) 1969, 'Method for fixing the capacities of reservoirs'. In this method, rate of sedimentation and type of reservoir, are the main inputs. These are therefore discussed below.

7.3.1 Rate of sedimentation

The catchment area upto the dam site for each of the dams is given in Table – 7.1.

Table – 7.1

1.	Jheri	425 Sq km
2.	Mohankavchali (Below Jheri site)	206 Sq km
3.	Paikhed	315 Sq km
4.	Chasmandva	89 Sq km
5.	Chikkar	323 Sq km
6.	Dabdar	482 Sq km
7.	Kelwan	733 Sq km

The sediment rate for all the reservoirs has been considered as 715 Cum/sq km/year. While examining some of the reservoir studies related to Par-Tapi-Narmada link, it was pointed out by Govt. of Gujarat that the observed silt rate for South Gujarat is in the range of 1.2 to 2.0 acre-ft/sq mile/year. It was further suggested that a silt rate of 1.5 acre-ft/sq mile/year (715 Cum/sq km/year) may be adopted for the reservoirs of the link. The sediment rate for other similar reservoirs has been found and given in Table – 7.2.

Table – 7.2

Reservoir	Catchment area (Sq km)	Sediment rate (cu .m/sq km/year)
1. Bhatsa	386	595
2. Dantiwada	2862	698
3. Kanhar	N. A.	699
4. Attaria-II	544	726
5. Machrewa-II	471	726

Thus, the sediment rate of 715 Cu m/sq km/year adopted for the reservoirs of Par-Tapi-Narmada link is reasonable. Further it is assumed that the bed load of sediment is 15% of suspended load.

7.3.2 Type of reservoirs

The type of the reservoir has been classified according to the classifications of types of reservoirs provided by Borland and Miller. The capacity inflow ratio has been calculated for each of the reservoirs and the trap efficiency corresponding to this ratio has been computed from the Brune's curve. The value of trap efficiency and parameters 'n' and 'm' are obtained from the plot of reservoir depth and reservoir capacity. The details are furnished in Table – 7.3.

Table – 7.3
Trap efficiency and type of reservoirs

Sl. No.	Reservoir	Trap efficiency adopted	Value of 'n'	Value of 'm'	Type of reservoir
1.	Jheri	0.98	0.412	2.43	III
2.	Mohankavchali	0.98	0.397	2.52	II
3.	Paikhed	0.98	0.397	2.52	II
4.	Chasmandva	0.98	0.360	2.78	II
5.	Chikkar	0.98	0.333	3.00	II
6.	Dabdar	0.98	0.333	3.00	II
7.	Kelwan	0.98	0.382	2.62	II

7.3.3 Sedimentation in the reservoir after 50 and 100 years

The total quantity of sediment that would deposit in the reservoir and new zero elevations for 50 years and 100 years have been worked out and furnished in Table – 7.4. The table also contains the dead storage levels or the MDDLs adopted. Dead storage is provided for 100 years of sedimentation and revised area-capacity curve after 50 years of sedimentation has been considered for simulation study for estimating the regulated yield from the reservoirs.

Table – 7.4
Sediment volume in 50 years and 100 years period

Sl. No	Reservoir	In 50 years		In 100 years		Dead storage level / M.D.DL. adopted (m)
		Sediment volume (Mm^3)	New zero elevation (m)	Sediment volume (Mm^3)	New zero elevation (m)	
1.	Jheri	17.117	185.120	34.246	197.900	203.70
2.	Mohankavchali	20.400	94.750	50.800	97.251	143.00
3.	Paikhed	12.702	164.510	25.355	172.061	190.22
4.	Chasmandva	3.598	172.050	7.188	175.920	189.92
5.	Chikkar	12.998	162.456	26.001	169.670	178.15
6.	Dabdar	19.423	120.380	38.863	127.150	137.06
7.	Kelwan	29.521	117.935	59.017	128.020	136.06

Dead storage levels above these new zero elevations have been adopted from the outlet level considerations. The DSL in case of Mohankavchali reservoir, however, have been fixed at much higher elevation to allow gravity flow in the tunnel off-taking from Mohankavchali.

7.3.4 Life of the reservoirs

The life of all the reservoirs of Par-Tapi-Narmada link project without considering Ukai water is considered as 100 years for the purpose of sediment distribution and working out the B.C. ratio.

7.4 Capacities

The capacity of each of the seven reservoirs have been worked out by simulation studies. The factors affecting the reservoir capacities have been

described earlier in this Chapter, Para-7.2 and in Chapter-5. The other factors like demands and reliability of their fulfillment and their utilisation in simulation are discussed in simulation studies.

7.5 Simulation studies

7.5.1 General

Simulation studies were carried out for each of the reservoir separately for estimating the annual regulated yield that can be obtained at the specified reliability and the storage capacity required for that value of yield. For this purpose a curve relating yield from the reservoirs with the storage capacity was developed for each reservoir by carrying out simulation for different capacities and estimating the yield from the reservoir for those capacities considering 75% level of success in irrigation supplies. Simulation were carried out with the help of the computer programme CAPYIELD, developed in NWDA.

7.5.2 Data used in simulation study

The data used in the simulation study are inflow, demand, evaporation, elevation area capacity table, dead storage capacity of reservoir or capacity at the minimum draw down level and values of storage capacities for which yields are required to be estimated. Some of these have been discussed earlier and the rest are described below.

7.5.2.1 Elevation area capacity relationship and dead storage levels

Original elevation area capacity relationship of the reservoirs has been derived from the actual survey data of each of the reservoirs. The revised elevation area capacity relationship after 50 years of sedimentation by Moody's method have been worked out for use in simulation.

7.5.2.2 Pattern of demands

The simulation process assumes open or unlimited demand which is restricted only by the yield from the reservoir of a specified capacity. Therefore in the input, only the pattern or the monthly distribution of the demand needs to be specified. Thus instead of actual demand or requirement, only the percentage of annual requirements is needed in each of the months. The monthly requirement percentage was worked out based on cropping pattern and water requirements as described in Chapter 'Irrigation Planning'. These monthly demands in percentage are as given below.

Month	Percentage of annual demand
January	12.67
February	10.14
March	5.16
April	2.16
May	2.18
June	4.59
July	3.39
August	4.75
September	15.49
October	14.45
November	15.18
December	9.84
Total	**100.00**

7.5.2.3 Evaporation

The average monthly evaporations in terms of depth observed at Madhuban reservoir have been used to work out the evaporations in each of the monthly periods from these reservoirs. The monthly evaporation data used in simulation are given below.

Month	Evaporation depth (mm)
January	116
February	135
March	206
April	205
May	236
June	150
July	48
August	48
September	97
October	119
November	108
December	119

The evaporation is calculated on the basis of mean of the water spread area at the beginning and at the end of the period. The programme carries out the necessary iterations required for this purpose three times.

7.5.3 Reliability criterion and operation policy

The simulation of reservoir operation was carried out without any special rule curve of operation. Full release equal to demand were made as long as the

reservoir was sufficiently above the dead storage level to make full releases, otherwise releases were curtailed or even stopped. No releases were made when reservoir was at or below the dead storage level but uncontrolled evaporation from the reservoir often brought the reservoir levels slightly lower than the dead storage level.

The programme takes up one value of capacity at a time out of the many storage capacity values given as input. For that capacity it tries to adjust the yield values in such a way that the number of permitted failures or shortfall years are equal to the number of permitted failures, which is normally 25% of the years under consideration. For this purpose failure of any amount and in any month of a year designates that year as a failure year. After estimating the yield for that capacity the programme picks up another value of storage capacity and repeats the process. At the end, a set of annual yield corresponding to the specified set of storage capacity is evolved. From this set, a yield capacity curve is drawn to estimate the capacity that should be adopted for the reservoir to provide a desired yield at 75% reliability of fulfillment of demands.

7.5.4 Results of simulation studies

The capacity yield relationship for each reservoir in the Par-tapi-Narmada link is given in Table - 7.5.

Table - 7.5
Capacity-yield relationship of Par-Tapi-Narmada Link reservoir
(regulated yield from reservoirs)

Unit : Mm^3

Capacity	Jheri	Mohan-Kavchali	Paikhed	Chasmandva	Chikkar	Dabdar	Kelwan
20				30			
40	57		40	55	52		
60	83		68	77	77	87	
80	110		95	94	103	113	
100	137		122	99	128	139	121
120	162		146	108	142	164	145
140	188		172	116	152	185	170
160	211		193		156	211	195
180	235		215		163	236	221
200	252		235			262	240
220	273	60	254			285	256
240	289	86	264			295	265
260		111	276			302	273
280		136					282
300		160					290
320		178					298
340		195					306
360		204					
380		210					
400		219					

Considering the slope of the yield capacity curve, the capacity has been kept in the neighborhood of the highest value of the steeper part (more additional yield per unit of additional storage capacity) of the curve. These values have been shown in Table – 7.6.

Table – 7.6
Reservoir capacities and corresponding yields

Unit : Mm^3

Reservoir	Gross capacity	Live Storage	Regulated yield	Downstream committed utilization	Diver-table yield
Jheri	186	178	242	--	242
Mohankavchali	347	175	201	64	137
Paikhed	217	209	252	40	212
Chasmandva	79	73	92	16	76
Chikkar	129	122	146	--	146
Dabdar	204	193	267	--	267
Kelwan	255	240	270	--	270
Total	1417	1190	1470	120	1350

The final MDDL, FRL and storage capacities adopted are given in Table - 7.7.

7.5.5 Assumption made in the simulation study

I) Upstream utilisation figures available are on annual basis. The monthly inflows into the reservoirs are assumed to be in proportion to the reduced river flows due to upstream utilisations.

II) Simulation has been carried out on the basis of limited available data of 16 to 22 years upto 1983.

III) The demands used in the simulation studies are assumed to be constant. They do not vary from year to year.

Table – 7.7
Final FRL, MDDL and storage capacities of reservoirs

Reservoir	F. R. L.	M. D. D. L.	At the time of construction of dam			After 50 years of operation		
			Storage at F.R.L.	Storage at MDDL	Live Storage	Storage at F.R.L.	Storage at MDDL	Live Storage
	(m)	(m)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)
Jheri	246	203.70	202.76	15.42	187.34	185.643	7.433	178.210
Mohankavchali	158	143.00	371.65	191.71	179.94	346.250	171.102	175.16

Paikhed	248	190.22	229.43	11.43	218.00	216.728	8.167	208.561
Chasmandva	214	189.92	82.00	6.92	75.08	78.402	5.414	72.988
Chikkar	210	178.15	141.91	11.91	130.00	128.912	7.036	121.876
Dabdar	169	137.06	223.00	17.58	205.42	203.577	10.294	193.283
Kelwan	164	136.06	284.33	26.51	257.82	254.809	15.308	239.501
Total			1535.08	281.48	1253.60	1414.321	224.754	1189.567

7.6 Annual losses

a) Evaporation losses in reservoir area

The average monthly evaporation losses in terms of depth observed at Madhuban reservoir have been used for simulation studies of all the seven reservoirs. The data is given earlier in Para 7.5.2.3.

b) Seepage in the reservoirs

No adverse features like buried channels, topography sub-terrain channels, fault plane of unconformities which promote leakage of reservoir have been reported by the geologist. No seepage losses therefore have been considered in the studies.

7.7 Effect on sub-soil water table

Detailed studies for the above have not been carried out. However as the reservoirs are situated in hilly terrain, the effect on the sub-soil water table may not be significant.

7.8 Area of submergence

The area of submergence at FRL, consequent on the construction of reservoirs is as furnished in Table-7.8.

Table – 7.8
Submergence area at F.R.L.

Unit : ha

Sl. No.	Reservoir	Maharashtra		Gujarat			Total
		Peint taluka	Surgana taluka	Dharam-pur taluka	Ahwa taluka	Vansda taluka	
1.	Jheri	618	218	--	--	--	836
2.	Mohankavchali	--	1372	122	--	--	1494
3.	Paikhed	--	894	100	--	--	994
4.	Chasmandva	--	32	320	--	263	615
5.	Chikkar	--	--	--	742	--	742
6.	Dabdar	--	--	--	1249	--	1249
7.	Kelwan	--	--	--	1629	--	1629
	Total	**618**	**2516**	**542**	**3620**	**263**	**7559**

7.9 Submergence Ratio

The total quantity of 1350 Mm^3 would be available annually at these seven reservoirs for diversion through Par-Tapi-Narmada link. The culturable command area under this link project is 1,88,414 ha and the total submergence area of all the seven reservoirs is 7559 ha, therefore, the submergence ratio works out to 0.04. This ratio will be still lower if cultivated submerged area is considered instead of total submerged area.

7.10 Land acquisition, property submerged and rehabilitation

a) Extent of land

The submergence particulars of all the seven reservoirs upto their F.R.L.s are furnished in the Para 7.8 for acquisition of lands and properties coming under submergence. The acquisition of land has been considered upto M.W.L. of the reservoir.

b) Classification of lands

The details of classification of lands coming under submergence of the reservoirs upto these F.R.L.s. are furnished in Table - 7.9.

Table – 7.9
Classification of lands

Unit : ha

Sl. No.	Reservoir	Forest land	Cultivable land	River portion	Total
1.	Jheri	408	256	172	836
2.	Mohankavchali	743	486	265	1494
3.	Paikhed	317	589	88	994
4.	Chasmandva	300	255	60	615
5.	Chikkar	300	332	110	742
6.	Dabdar	614	482	153	1249
7.	Kelwan	890	450	289	1629
	Total	**3572**	**2850**	**1137**	**7559**

7.11 Details of property submerged

a) Details of villages, houses and population

The number of villages, houses and population to be affected due to submergence of reservoirs are given in Table - 7.10

Table – 7.10
Submergence details of properties

Sl. No.	Reservoir	No. of villages			No.of houses	Population	
		Full	Part	Total		Human	Live stock
1.	Jheri	--	7	7	140	1122	685
2.	Mohankavchali	5	8	13	423	3194	1764
3.	Paikhed	2	9	11	363	2266	1570
4.	Chasmandva	--	7	7	206	1434	612
5.	Chikkar	2	7	9	174	1016	682
6.	Dabdar	4	7	11	331	1780	1176
7.	Kelwan	11	6	17	610	4020	2540
	Total	**24**	**51**	**75**	**2247**	**14832**	**9029**

It can be seen from the above table that a total of 75 villages either fully or partially will get affected. Out of these, the habitation and land will be affected in 41 villages and only land will be affected in the remaining 34 villages. The total number of houses to be affected as a result of submergence in these 7 reservoirs will be 2247. A human population of 14832 and live stock of 9029 would also be affected.

b) Details of communication (railways, roads, telegraph lines and power lines etc).

Under Jheri reservoir, 6.7 km length of water bound macadam road connecting Kayare to Ambe will come under submergence. Three cart tracks connecting Kahandolpada-Khokarvihir, Khokarvihir-Modalpada and Kayare-Ambe villages will also be affected due to submergence. Under Mohankavchali reservoir, two cart tracks connecting Dhamni-Bhati and mani-Piproti villages will be affected. Under Paikhed reservoir, end portion of an important road connecting Sidumber-Tutarkhed and eight cart tracks connecting Paikhed, Khapatiya, Gundiya (main)-Gundiya (Shisumal), Khapatiya-Gundiya (Kiloipada). Khapatiya-Barbe via Karanjul, Khadaki – Karanjul, Khadaki-Rakshasbhuwan, Madhuri-Rakshasbhuwan and Charva-Khadoki villages will get submerged. Under Chasmandva reservoir, three cart tracks connecting Chasmndva-Khikarpaliya, Behadpada-Chorwani and Chasmandva-Nadagdhari will be coming under submergence. Under Chikkar reservoir, 8 km length of state highway connecting Waghai-Saputara and a kachcha road meeting the state highway at Km stone 77.3 km from Kunda will be affected. Under Dabdar reservoir, about 8.5 km length of state highway connecting Bilimora-Ahwa, two kachcha roads connecting villages Dhadra-Waghai-Ahwa, and Dabdar-Waghai-Ahwa and one cart track connecting Bhavad-Waghai-Ahwa will be affected due to submergence of reservoir. Under Kelwan reservoir about 10 km length of state highway connecting Vyara-Ahwa, three Kachcha road connecting villages Karlipada-Kolban, Kalibel-Tekpada and Bhalket-Vyara-Ahwa and one track connecting Patli-Wankan will be affected due t2o submergence. All the above affected roads required realignment.

No power and telegraph lines will be coming under submergence of Jheri, Mohakavchali, Paikhed and Chasmandva reservoirs. The power and telegraph lines of about 10 km length from Baj-Lahen-Dabdar villages in Chikkar reservoir, about 12 km length from Waghai-Pimpri in Dabdar reservoir and about 14 km length from Karlipada-Khatal villages in Kelwan reservoir will have to be shifted and realigned.

c) Details of valuable mineral deposits/mines

It is indicated that no valuable mineral deposits would be submerged under any of the above seven reservoirs.

d) Details of historical archaeological monuments

It is also indicated that the submergence area of any of the above reservoirs is not having any historical or archaeological monument.

7.12 Rehabilitation of project displaced persons

In the rehabilitation package worked out for the displaced persons, land for land rehabilitation grant and maintenance allowances have been provided as per the norms. Adequate irrigation facilities will be proposed by the irrigation authority. Rehabilitation committee consisting of senior officers of concerned departments is proposed to look into the problems of the project affected persons.

For compensation of houses, built up houses of EWS (Economically weaker sections), LIG & MIG category having plinth area of 30, 50 and 70 Sqm on a plot area of 150, 250 and 350 Sqm respectively shall be provided to these categories free of cost in lieu of the houses acquired. Larger properties acquired shall be compensated over and above the provisions under MIG. Similarly all Civic amenities such as Roads, Electrification, Water supply, Health Centres, Schools, Post offices, Community Centre, Panchayat Ghar, Police Stations, Rural Banks and Temples etc. are proposed for the newly established villages. More details are furnished in the chapter 'Environmental and Ecological aspects of the project.