CHAPTER – V

RESERVOIR AND POWER

5.0 General

Presently under Ken-Betwa Link Project, Phase – II, following five components are proposed:

1. Lower Orr dam across Orr river (a tributary of Betwa) located in Ashoknagar and Shivpuri district of MP.
2. Neemkheda barrage across Betwa river located in Raisen district of MP.
3. Barari barrage across Betwa river located in Vidisha district of MP.
4. Kesari barrage across Keotan (a tributary of Betwa) river located in Vidisha district of MP.
5. Kotha barrage across Betwa river located in Vidisha district of MP.

Reservoir submergence survey have been carried out for the proposed Lower Orr Dam. In case of pondage of Neemkhera barrage, Barari barrage and Kesari barrage lies in river gorge itself. For Kotha barrage, CWC has suggested for increasing pondage level from 388 m to 396 m in Novemer 2013, therefore, detailed Reservoir studies will be carried out at later stage for these barrages. The brief details in respect of these barrage projects incorporating Elevation-Area-Capacity curves have been prepared based on surveyed data/Survey of India toposheets are furnished at the end of this chapter. Further, no power generation is proposed at any of the above projects envisaged under Phase-II of Ken-Betwa link project, aspect concerning power component have not been done.

5.1 Lower Orr reservoir

An earthen dam is proposed on Orr river, a tributary of Betwa river near Didauni village in Khaniadhana tehsil of Shivpuri district at $24^0$50’50” north latitude and $78^0$05’55’’ east longitude. Based on the

topography, required storage and other relevant factors, the FRL of the proposed reservoir is kept at 380.0 m and the deepest river bed level at project site is 341.46 m. The length of dam is 2250 m (including over flow and non-over flow sectons). The gross storage capacity of the reservoir at FRL is worked out to be 371.802 MCM with corresponding submergence area of 2724 ha.

5.1.1 Fixation of Storage and Reservoir Levels Approach–Criteria

National Institute of Hydrology (NIH), Roorkee was entrusted with water balance and water yield assessment under Hydrological studies. As per these studies details are given in Chapter-V Para 5.4.10 of Volume-IV.

The net 75% dependable inflow upto Lower Orr dam site has been worked out as 362.53 MCM by the NIH, Roorkee for Ken-Betwa Link project (Phase-II) after considering u/s domestic, irrigation and industrial water requirements and regeneration thereof. Details are furnished in Para 5.4.10 of Chapter–V of Hydrological Study carried out by NIH. (Volume-IV)

The required storage to meet the given demands depends on three factors: the variability of stream flows, the size of demands and the reliability of meeting the demands. The procedure for estimating the storage capacity needed to meet given demands or the possible yield from a given project design and data constitute the storage-yield (S-Y) analysis to compute the storage capacity for various purposes, such as irrigation, municipal and industrial water supply. The techniques based on the critical period concepts are the oldest techniques of Storage-Yield analysis. The critical period is defined as the period in which an initially full reservoir, passing through various stages (without spilling), empties. One such method, known as the Mass-Curve Method is the first rational method to compute the required storage capacity of a reservoir.

Simulation method is another approach for Storage-Yield analysis. It is basically a search procedure and is one of the most widely used technique to solve a large variety of problems associated with the

design and operation of water resources systems. This approach can be realistically and conveniently be used to examine and evaluate the performance of a set of alternative options available.

The reservoir simulation study of Lower Orr reservoir has been carried out to ascertain the adequacy of the proposed live storage capacity of reservoir to meet the envisaged demands at specified reliability. The generated monthly flow data at the dam site, for a period of 108 years from 1901 to 2008 has been used for the analysis. The analysis has been done using a Simulation Programme developed by NIH, Roorkee. The analysis shows that at FRL of 380.0 m and MDDL of 360.50 m (corresponding live storage capacity of 337.806 MCM after 50 years of sedimentation), the time reliability of the project to meet the envisaged demands is 95.37% and 75% for monthly and yearly periods respectively. The volume reliability worked out from the simulation study is 97.14%.

5.1.1.1 Dead storage level (DSL)

The dead storage capacity of the Lower Orr reservoir, has been fixed on the basis of the guidelines given in "Fixing the capacities of reservoirs – Method, Part 2 Dead storage, IS 5477 (Part 2): 1994".

The new zero level of the reservoir after 100 years of operation has been worked out as 353.53 m on the basis of sedimentation studies. However, the DSL of the reservoir has been proposed as 360.50 m.

5.1.1.2 Low water level /Minimum Draw-Down level(MDDL)

The MDDL of Lower Orr reservoir has been fixed at 360.50 m which is above the new zero elevation after 100 years of operation of the reservoir, based on simulation studies carried out by NIH, Roorkee. The FSL of the off taking canal at the head is fixed as 360.50 m.

5.1.1.3 Full reservoir level (FRL)

The operation of the Lower Orr reservoir was simulated by assuming FRL at 380.0 m and MDDL at 360.5 m. It was found that if the FRL is kept at 380.0 m (corresponding storage of 371.802 MCM), the monthly and annual time reliabilities in meeting d/s irrigation demands are

94.7% and 75% respectively and the volume reliability is 97.14% when deficit up to 10% is ignored.

5.1.1.4 Maximum water level(MWL)

Reservoir routing (routing of a flood wave through a reservoir) is an important part of the reservoir analysis whose major applications are for fixing MWL during reservoir design, design of spillway and outlet works and dam-break flood wave analysis. The flood routing has also been got done through CMDD Directorate of Central Water Commission and has been fixed as 380.408 m.

Keeping this in view, spillway gates have been designed to pass design flood of 12067.67 cumecs.

Spillway with 12 nos. of radial gates has been proposed with a discharging capacity of 14593.5 cumecs.

5.1.1.5 Maximum backwater at Full Reservoir Level and MWL and its Impact, Maximum distance of such points from the axis of the Structure

The Lower Orr reservoir is expected to attain the highest water level when the flood hydrograph corresponding to the design flood passes through the reservoir. Dynamic routing of PMF through the study reach has been carried out by using MIKE-11 software. The basic objective of such a case was to determine the backwater surface profile attained when the PMF (12067.67 cumec) is routed through the reservoir when the water level at FRL i.e. 380.00 m is maintained by continuous release through all the gates. The results of dynamic routing in the upstream 21.0 km reach are presented in Table-5.1. In the table, the distance 0.0 m corresponds to first cross-section considered and 21000 m corresponds to the dam site. The presented backwater profile resembles the S1 profile. The maximum water surface elevations at different cross-sections vary from 386.323 m at upper cross-sections to 380.0 m at lower cross-section (dam site). The water level attained at every 600 m interval is presented in the table. Sediment deposition in backwater reach upstream of the reservoir could result in morphological changes including shoal formation and bed aggradations, possibly may lead to increased flood probability upstream. The computed

backwater profile of the Lower Orr dam does not account for this possibility.

Table - 5.1

Computed backwater levels at different locations, u/s of Lower Orr dam (Location 21000 m denotes dam site)

Distance along River reach (m)	Maximum Water level (m)
0	386.323
600	384.413
1200	383.133
1800	382.565
2400	382.238
3000	381.744
3600	381.571
4200	381.426
4800	381.291
5400	381.156
6000	381.074
6600	380.932
7200	380.769
7800	380.246
8400	380.000
9000	380.000
9600	380.000
10200	380.000
10800	380.000
11400	380.000
12000	380.000

12600	380.000
13200	380.000
13800	380.000
14400	380.000
15000	380.000
15600	380.000
16200	380.000
16800	380.000
17400	380.000
18000	380.000
18600	380.000
19200	380.000
19800	380.010
20400	380.000
21000	380.000

5.1.1.6 Saddles along rim of the reservoir

There is no Saddle dam proposed along the rim of the Lower Orr reservoir.

5.1.1.7 Fetch

The fetch of the reservoir was determined to fix the free board and the top of the dam. The fetch computations were done as per IS: 10635-1993, “Guidelines for Free board requirements in Embankment Dams”. The maximum and effective fetch length of 6.5 km and 2.7 km respectively has been worked out. The following factors are taken into consideration while computing the free board requirement.

(a) Wave characteristics, particularly the wave height and wave length.

(b) U/s slope of the river and roughness of the pitching.

(c) Height of wind setup above the still water level

5.1.1.8 Direction of wind - Velocity of wind - wave height - Free Board-Top of dam

The direction of wind in Lower Orr reservoir area is mostly from west to east. The Guna IMD observatory is located near to the dam site. The maximum wind velocity of 13.3 km/h is experienced in the month of June and the minimum wind velocity of 4.3 km/h is experienced in the month of November. The average velocity of wind is 7.9 km/h. However, a normal wind velocity of 39 m/s has been considered. The computed free board works out to 2.94 m. The top of the earthen portion of the Lower Orr dam has been fixed at MWL 380.408 m.

5.1.2 Sedimentation data and studies

There is no permanent Gauge, Discharge or Sedimentation site on the Lower Orr river. There is a CWC G & D site at Basoda on Betwa river, but no sediment data are recorded at this site. However, sediment measurements of a few years during the monsoon period have been taken at the Neemkheda site on Betwa and Lower Orr site on Orr river by NWDA. At the Neemkheda site, daily discharge has not been measured and only daily sediment load observations are available. No reasonable correlation between sediment load and the river flow could be established. Further, the sediment observations are given in tonnes whereas the sediment volume is required for computation of new-zero elevation and sediment profile determination. Also, for the catchment of Lower Orr reservoir, the sediment observations are available for the monsoon months (July – October) for one year only (2011), which is not adequate to estimate rate of sediment into the reservoirs. Due to the above reasons, sediment data, observed by NWDA for the catchments of Neemkheda and Lower Orr have not been utilized in the sediment study by NIH.

5.1.2.1 Rate of sedimentation

The sediment rates for some of the projects in the region, namely Tawa, Barna, Sondur, Gandhisagar, Mahanadi reservoir and Hasdeo in Madhya Pradesh and Matatila in Uttar Pradesh have been given in CBIP publication no. 137 on Major dams in India, 1979. It is found that the

designed sediment rates of these projects are in the range from 130 to 706 m^3/sq km/year. The details of sediment rate in various nearby reservoirs are furnished in Table-5.2 below**.**

Table - 5.2

Sediment rate in various reservoirs in the region

Name of dam	**Catchment Area (sq km)**	**Dead Storage (MCM)**	**Sediment Rate (m^3/sq km/year)**
Matatila (UP)	20718	269.3	130
Gandhisagar(MP)	23140	835.0	361
Sondur (MP)	512	19.0	371
Mahanadi Res.(MP)	3670	143.0	390
Tawa (MP)	5983	260.0	435
Hasdeo (MP)	6737	370.0	549
Barna (MP)	1176	83.0	706

As discussed earlier in the report, the Rajghat project is located on river Betwa at the outlet of Upper Betwa region, where four of the five projects proposed under Phase-II of the Ken-Betwa link project are located and the remaining one project viz., the Lower Orr project is located immediately on the d/s of Rajghat project. As such, the sediment volume, as used in the sedimentation analysis of Rajghat dam, has been utilized. The graph showing the original and revised EAC curves of the Rajghat reservoir is available. The Elevation-Capacity curve has been plotted on Log-scale to find out the type of reservoir using 'm' [Log(capacity)/Log(depth)] of the reservoir submergence. Value of 'm' for Rajghat reservoir works out to be 2.748 which suggest that it is Type-II reservoir (flood plain foot hill).

The Rajghat reservoir has catchment area of 16310 sq. km. From the available original and 50-year EAC graph, it is inferred that 300 MCM of sediment volume would deposit in the reservoir in span of 50

years. Using this sediment volume and the empirical area reduction method, the new-zero elevation in the reservoir after 50 years works out to be 351.0 m (which is the same as marked in the graph).

From the sediment volume of 300 MCM in a span of 50 years, sedimentation rate per unit area per year has been derived. Since, as discussed earlier, the proposed Lower Orr reservoir under Phase – II of the Ken-Betwa link project is located in the Lower Betwa region in the close vicinity of Rajghat dam, the same sedimentation rate has been assumed for this reservoir project and sedimentation volume has been estimated as shown below:

Sediment Volume	=	300 MCM
Catchment area	=	16310 sq. km
Time period	=	50 years
Sedimentation rate	=	367.872 m^3/sq. km/year

5.1.2.2 Sediment rate

As already discussed at para 5.1.2.1 above, the sedimentation rate considered for Lower Orr project is 367.872 m^3/sq. km/year.

5.1.2.3 Sediment fraction expected

Since no power house is proposed in the Lower Orr project, hence the petrographic analysis has not been carried out.

5.1.2.4 Quantity of sediment

The catchment area of Lower Orr river up to the proposed Lower Orr dam site is 1843 sq km and the sediment volume expected in the reservoir is computed as shown in Table-5.3.

Table - 5.3

Sediment volume computation in Lower Orr reservoir

Parameters for Lower Orr reservoir	
Catchment area (sq. km.)	1843.00
Capacity at FRL (MCM) 'C'	371.8
Average annual inflow (MCM) 'I'	526.31
C/I ratio value	0.7
Trap efficiency (%) from Brune Curves	100
Sediment deposition in 50-years	33.8995
Sediment deposition in 100-years	67.799

5.1.2.5 Type and shape of Reservoir

As discussed in Chapter–II, the submergence area survey of the Lower Orr reservoir has been carried out and the original Elevation – Area – Capacity values of the proposed Lower Orr reservoir are furnished in the Table-5.4. Log values of the depth and capacity of the reservoir are also provided in the table.

Table - 5.4

Original Elevation – Area – Capacity values of Lower Orr reservoir

Elevation (m)	**Area (sq. km)**	**Capacity (MCM)**	**Depth (m)**	**Log(Depth)**	**Log(Capacity)**
1	2	3	4	5	6
340.00 (Bed)	0.004	0.000	0.00	NA	NA
341.00	0.007	0.005	1.00	0.000	-2.265
342.00	0.012	0.015	2.00	0.301	-1.829
343.00	0.018	0.030	3.00	0.477	-1.527
344.00	0.027	0.052	4.00	0.602	-1.283
345.00	0.080	0.103	5.00	0.699	-0.986

346.00	0.044	0.164	6.00	0.778	-0.784
347.00	0.055	0.214	7.00	0.845	-0.670
348.00	0.076	0.279	8.00	0.903	-0.554
349.00	0.203	0.413	9.00	0.954	-0.384
350.00	0.470	0.741	10.00	1.000	-0.130
351.00	0.748	1.344	11.00	1.041	0.128
352.00	1.186	2.303	12.00	1.079	0.362
353.00	1.930	3.846	13.00	1.114	0.585
354.00	2.876	6.233	14.00	1.146	0.795
355.00	3.900	9.608	15.00	1.176	0.983
356.00	4.456	13.783	16.00	1.204	1.139
357.00	5.447	18.726	17.00	1.230	1.272
358.00	6.302	24.596	18.00	1.255	1.391
359.00	7.420	31.449	19.00	1.279	1.498
360.00	8.264	39.287	20.00	1.301	1.594
361.00	9.111	47.971	21.00	1.322	1.681
362.00	9.877	57.463	22.00	1.342	1.759
363.00	10.600	67.699	23.00	1.362	1.831
364.00	11.415	78.704	24.00	1.380	1.896
365.00	12.036	90.428	25.00	1.398	1.956
366.00	12.974	102.930	26.00	1.415	2.013
367.00	13.994	116.411	27.00	1.431	2.066
368.00	14.693	130.753	28.00	1.447	2.116
369.00	15.334	145.766	29.00	1.462	2.164
370.00	15.879	161.371	30.00	1.477	2.208
371.00	16.419	177.520	31.00	1.491	2.249
372.00	17.094	194.275	32.00	1.505	2.288

373.00	18.211	211.924	33.00	1.519	2.326
374.00	19.463	230.758	34.00	1.531	2.363
375.00	21.187	251.077	35.00	1.544	2.400
376.00	22.413	272.874	36.00	1.556	2.436
377.00	23.493	295.825	37.00	1.568	2.471
378.00	24.721	319.929	38.00	1.580	2.505
379.00	25.899	345.237	39.00	1.591	2.538
380.00 (FRL)	27.237	371.802	40.00	1.602	2.570
380.408	27.683	383.006	40.408	1.606	2.583
381	28.330	399.585	41.00	1.613	2.602

m = [Log (Capacity at FRL) - Log (Capacity at 341 m)] / [(Log(Depth at FRL) – Log(Depth at 341 m)]

m = [2.57 – (-2.265)] / (1.602 – 0.000) = 3.018

With value of ‘m’ as 3.018, the Lower Orr reservoir is classified as Type-II reservoir (flood plain foot hill type).

5.1.2.6 Sediment studies

Taking Lower Orr as Type-II reservoir the computation for 50 year and 100 year new zero elevation and sediment profile has been made using empirical area reduction method.

The sediment volume after 50 years has been estimated as 33.956 MCM and that after 100 years is 67.911 MCM. The sedimentation computations for the reservoir have been made for 50 and 100 years. The computations for 50-year and 100-year new-zero elevation have been carried out iteratively and final value of new-zero elevations for Lower Orr reservoir after 50 years and 100 years are found out to be 351.80 m and 353.53 m respectively. Using these new-zero elevations, the sediment deposition profile computation with the empirical area reduction method for 50-years and 100-years is shown in Table-5.5 and 5.6 respectively. The elevation – area – capacity curves – original, after 50 years and after 100 years are furnished as Figures 5.1.1, 5.1.2 and 5.1.3, 5.1.4 respectively.

Table - 5.5

Assessment of Sediment deposition profile of Lower Orr reservoir after 50 years by Empirical Area Reduction Method

Elevation (m)	Original		Relative Depth (p)	Ap	Sediment Area (sq. Km)	Cumulative Sediment Capacity (MCM)	Revised	
	Area (sq. km)	Capacity (MCM)					Area (sq. km)	Capacity (MCM)
340	0.004	0.000	0.000	0.0000	0.004	0.000	0.000	0.000
341	0.007	0.005	0.025	0.3006	0.007	0.005	0.000	0.000
342	0.012	0.015	0.050	0.4415	0.012	0.015	0.000	0.000
343	0.018	0.030	0.075	0.5503	0.018	0.030	0.000	0.000
344	0.027	0.052	0.100	0.6411	0.027	0.052	0.000	0.000
345	0.080	0.103	0.125	0.7197	0.080	0.103	0.000	0.000
346	0.044	0.164	0.150	0.7891	0.044	0.164	0.000	0.000
347	0.055	0.214	0.175	0.8510	0.055	0.214	0.000	0.000
348	0.076	0.279	0.200	0.9068	0.076	0.279	0.000	0.000
349	0.203	0.413	0.225	0.9573	0.203	0.413	0.000	0.000
350	0.470	0.741	0.250	1.0029	0.470	0.741	0.000	0.000
351	0.748	1.344	0.275	1.0443	0.748	1.344	0.000	0.000
351.80	1.098	2.111	0.295	1.0746	1.098	2.111	0.000	0.000
352	1.186	2.303	0.300	1.0817	1.106	2.332	0.080	0.008
353	1.930	3.846	0.325	1.1155	1.140	3.455	0.790	0.391
354	2.876	6.233	0.350	1.1457	1.171	4.610	1.705	1.623
355	3.900	9.608	0.375	1.1727	1.199	5.795	2.701	3.813
356	4.456	13.783	0.400	1.1964	1.223	7.006	3.233	6.777
357	5.447	18.726	0.425	1.2171	1.244	8.239	4.203	10.487
358	6.302	24.596	0.450	1.2347	1.262	9.493	5.040	15.103
359	7.420	31.449	0.475	1.2493	1.277	10.762	6.143	20.687

Elevation (m)	Original		Relative Depth (p)	Ap	Sediment Area (sq. Km)	Cumulative Sediment Capacity (MCM)	Revised	
	Area (sq. km)	Capacity (MCM)					Area (sq. km)	Capacity (MCM)
360	8.264	39.287	0.500	1.2609	1.289	12.045	6.975	27.242
361	9.111	47.971	0.525	1.2694	1.298	13.338	7.813	34.633
362	9.877	57.463	0.550	1.2750	1.303	14.639	8.574	42.824
363	10.600	67.699	0.575	1.2774	1.306	15.943	9.294	51.756
364	11.415	78.704	0.600	1.2766	1.305	17.248	10.110	61.456
365	12.036	90.428	0.625	1.2726	1.301	18.551	10.735	71.877
366	12.974	102.930	0.650	1.2650	1.293	19.848	11.681	83.082
367	13.994	116.411	0.675	1.2539	1.282	21.136	12.712	95.275
368	14.693	130.753	0.700	1.2388	1.266	22.410	13.427	108.343
369	15.334	145.766	0.725	1.2195	1.247	23.666	14.087	122.100
370	15.879	161.371	0.750	1.1957	1.222	24.900	14.657	136.471
371	16.419	177.520	0.775	1.1667	1.193	26.108	15.226	151.412
372	17.094	194.275	0.800	1.1320	1.157	27.283	15.937	166.992
373	18.211	211.924	0.825	1.0907	1.115	28.418	17.096	183.506
374	19.463	230.758	0.850	1.0415	1.065	29.508	18.398	201.250
375	21.187	251.077	0.875	0.9825	1.004	30.542	20.183	220.535
376	22.413	272.874	0.900	0.9112	0.931	31.510	21.482	241.364
377	23.493	295.825	0.925	0.8225	0.841	32.396	22.652	263.429
378	24.721	319.929	0.950	0.7072	0.723	33.177	23.998	286.752
379	25.899	345.237	0.975	0.5402	0.552	33.812	25.347	311.425
380	27.237	371.802	1.000	0.0000	0.000	33.996	27.237	337.806

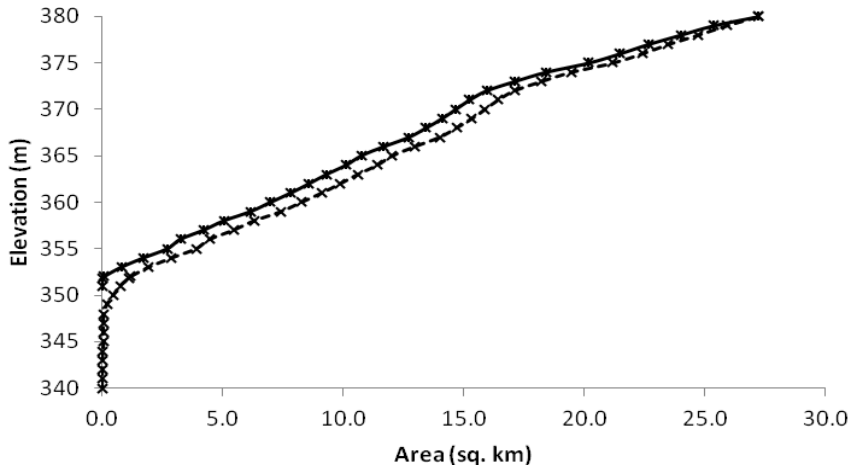

Figure – 5.1.1: Original (dotted) and 50-year revised (solid) Elevation-Area curve for Lower Orr

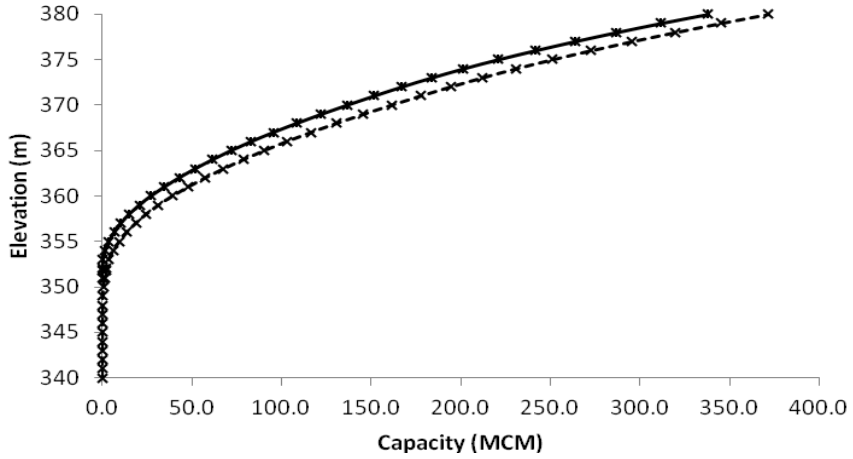

Figure – 5.1.2: Original (dotted) and 50-year revised (solid) Elevation-Capacity curve for Lower Orr

Table - 5.6

Assessment of Sediment deposition profile of

Lower Orr reservoir after 100 years by Empirical Area Reduction Method

Elevation (m)	Original		Relative Depth (p)	Ap	Sediment Area (sq. Km)	Cumulative Sediment Capacity (MCM)	Revised	
	Area (sq. km)	Capacity (MCM)					Area (sq. km)	Capacity (MCM)
340	0.004	0.000	0.000	0.0000	0.004	0.000	0.000	0.000
341	0.007	0.005	0.025	0.3006	0.007	0.005	0.000	0.000
342	0.012	0.015	0.050	0.4415	0.012	0.015	0.000	0.000
343	0.018	0.030	0.075	0.5503	0.018	0.030	0.000	0.000
344	0.027	0.052	0.100	0.6411	0.027	0.052	0.000	0.000
345	0.080	0.103	0.125	0.7197	0.080	0.103	0.000	0.000
346	0.044	0.164	0.150	0.7891	0.044	0.164	0.000	0.000
347	0.055	0.214	0.175	0.8510	0.055	0.214	0.000	0.000
348	0.076	0.279	0.200	0.9068	0.076	0.279	0.000	0.000
349	0.203	0.413	0.225	0.9573	0.203	0.413	0.000	0.000
350	0.470	0.741	0.250	1.0029	0.470	0.741	0.000	0.000
351	0.748	1.344	0.275	1.0443	0.748	1.344	0.000	0.000
352	1.186	2.303	0.300	1.0817	1.186	2.303	0.000	0.000
353	1.930	3.846	0.325	1.1155	1.930	3.846	0.000	0.000
353.530	2.414	5.068	0.338	1.1314	2.431	5.111	0.000	0.000
354	2.876	6.233	0.350	1.1457	2.461	6.261	0.415	0.000
355	3.900	9.608	0.375	1.1727	2.519	8.751	1.381	0.857
356	4.456	13.783	0.400	1.1964	2.570	11.295	1.886	2.488
357	5.447	18.726	0.425	1.2171	2.614	13.887	2.833	4.839
358	6.302	24.596	0.450	1.2347	2.652	16.520	3.650	8.076
359	7.420	31.449	0.475	1.2493	2.683	19.188	4.737	12.261
360	8.264	39.287	0.500	1.2609	2.708	21.884	5.556	17.403
361	9.111	47.971	0.525	1.2694	2.727	24.601	6.384	23.370
362	9.877	57.463	0.550	1.2750	2.739	27.334	7.138	30.129
363	10.600	67.699	0.575	1.2774	2.744	30.075	7.856	37.624
364	11.415	78.704	0.600	1.2766	2.742	32.618	8.673	45.886
365	12.036	90.428	0.625	1.2726	2.733	35.556	9.303	54.872
366	12.974	102.930	0.650	1.2650	2.717	38.281	10.257	64.649
367	13.994	116.411	0.675	1.2539	2.693	40.986	11.301	75.425
368	14.693	130.753	0.700	1.2388	2.661	43.664	12.032	87.089
369	15.334	145.766	0.725	1.2195	2.620	46.304	12.714	99.462
370	15.879	161.371	0.750	1.1957	2.568	48.898	13.311	112.473
371	16.419	177.520	0.775	1.1667	2.506	51.435	13.913	126.085
372	17.094	194.275	0.800	1.1320	2.432	53.903	14.662	140.372
373	18.211	211.924	0.825	1.0907	2.343	56.290	15.868	155.634

Elevation (m)	Original		Relative Depth (p)	Ap	Sediment Area (sq. Km)	Cumulative Sediment Capacity (MCM)	Revised	
	Area (sq. km)	Capacity (MCM)					Area (sq. km)	Capacity (MCM)
374	19.463	230.758	0.850	1.0415	2.237	58.580	17.226	172.178
375	21.187	251.077	0.875	0.9825	2.110	60.754	19.077	190.323
376	22.413	272.874	0.900	0.9112	1.957	62.787	20.456	210.087
377	23.493	295.825	0.925	0.8225	1.767	64.648	21.726	231.177
378	24.721	319.929	0.950	0.7072	1.519	65.289	23.202	253.640
379	25.899	345.237	0.975	0.5402	1.160	67.625	24.739	277.612
380	27.237	371.802	1.000	0.0000	1.000	68.012	27.237	303.790

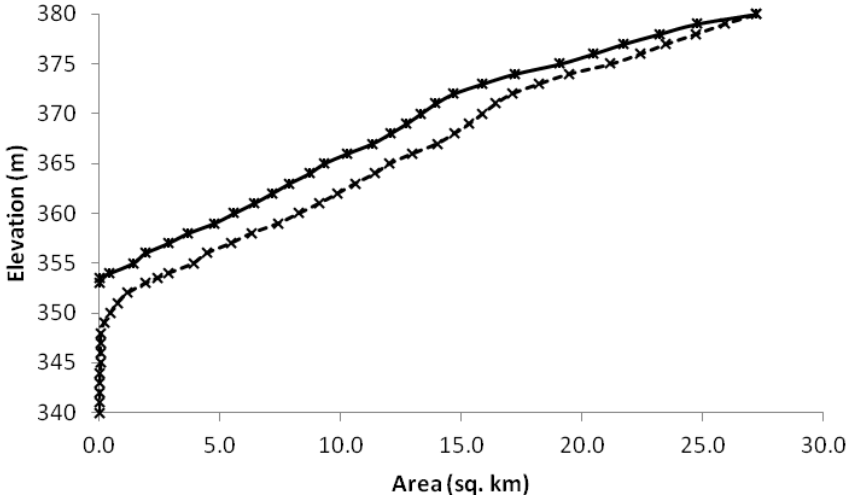

Figure – 5.1.3: Original (dotted) and 100-year revised (solid) Elevation-Area curve for Lower Orr reservoir

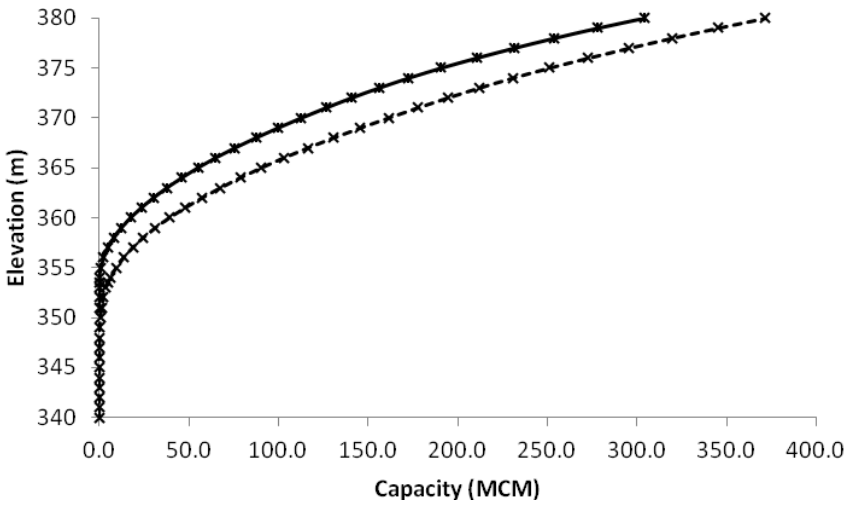

Figure – 5.1.4: Original (dotted) and 100-year revised (solid) Elevation-Capacity curve for Lower Orr reservoir

Source: Para 7.4 Chapter-VII of Hydrological studies done by NIH September 2013, Volume-IV.

5.1.3 Life of Reservoir in years with basis

The MDDL has been kept as 360.5 m which is sufficiently above new zero elevation 348 m as computed for 100 years time span and 351.5 m as computed for 50 year. Therefore MDDL of 360.5 m can be safely adopted for Lower Orr reservoir and the life of the Lower Orr dam has been considered as 100 years.

5.1.4 Capacity

The storage capacity of the Lower Orr reservoir at various levels is furnished below:

		Capacity (MCM)		
	Level	**Original**	**After 50 years**	**After 100 years**
1	FRL (380.0 m)	371.802	337.806	303.790
2	LWL/MDDL (360.5 m)	43.629	30.938	20.387

5.1.4.1 Water tightness of the reservoir

Water tightness of the reservoir is to be dealt mainly by two angles viz., (i) through the bed of the reservoir and or (ii) through the foundation of the dam with special attention in case of earth and rockfill dams. As per GSI report in-situ permeability tests (WPT) have shown impervious to locally semi pervious nature of the foundation rockmass requiring no systematic grouting for reservoir tightness in general. As most of the test sections of drill holes suggest impervious nature of rockmass which are not corroborating with the results of the core recovery and RQD, a few test holes for rechecking the permeability are necessary during the construction stage of the dam. The necessity of curtain grouting or otherwise would be decided on the result of these test holes. Since the upstream part of the dam is covered with black cotton soil of fairly good thickness, no clay blanket is required as an additional for reservoir tightness the above inference are tentative based on interpretation of limited exploration. The revision/modification is subject to improvement in

rockmass quality when the foundation is exposed to the designed levels and geological mapping is carried out for the COT by GSI prior to refilling to ensure it to be free from geological surprises.

5.1.4.2 Annual losses

In the simulation analysis, the evaporation loss from the reservoir surface is estimated by using the initial and final water spread areas during the month and multiplying the average area with the normal monthly evaporation depth in the month (refer Hydrology chapter). The monthly evaporation losses from the reservoir during the simulation period of 1901 to 2008 are furnished at Annexure 8.3 (page A-474 of Hydrological studies and Multi-reservoir Simulation Studies for DPR of Ken-Betwa Link Project (Phase-II) - September 2013 by NIH, Roorkee) of Volume:IV. The average monthly evaporation loss from the Lower Orr reservoir is presented in Table-5.7.

Table - 5.7

Average Monthly evaporation Losses (MCM) from Lower Orr reservoir

Month	**Average Evaporation losses (MCM)**
January	2.962
February	1.886
March	2.105
April	3.235
May	3.560
June	2.490
July	1.906
August	1.804
September	1.849
October	2.594
November	3.136
December	3.864
Total	**31.390**

The maximum value of monthly evaporation occurs in December and the minimum occurs in August.

5.1.4.3 Flood absorption

No flood storage is earmarked for this project. However, reservoir routing studies have been done by NIH, Roorkee. The estimated Design flood (PMF) is 12067.67 cumec.

5.1.5 Effects on sub-soil water table in the adjoining areas particularly d/s of the dam

The sub-soil water table will improve due to the impoundment of water in the Lower Orr reservoir. In addition, the regulated releases from the Lower Orr dam for irrigation of command area in Shivpuri and Datia districts will increase the sub- soil water level in the areas.

5.1.6 Reservoir rim stability

No reservoir rim stability survey has been carried out.

5.1.7 Area of submergence

5.1.7.1 Maximum Water Level

Submergence area of Lower Orr reservoir at MWL is worked out as 2768.3 ha.

5.1.7.2 Full Reservoir Level

Since the FRL is kept as 380 m, the submergence area at FRL is 2723.70 ha.

5.1.7.3 Submergence Ratio : submerged (Cultivated) area/CCA

The land use classification of the submergence area is furnished below:

Forest	:	968.243 ha
Culturable area	:	853.287 ha
Unculturable area	:	556.605 ha
Built up area	:	19.614 ha
Other lands	:	325.951 ha

The submergence Ratio = Submerged (Cultivated) area/CCA

= 853.287 /53573 =0.016

5.1.8 Land Acquisition-Property submerged-Rehabilitation

5.1.8.1 Land acquisition (ha)

Acquisition to be made on about 2723.70 ha for construction works and that coming under submergence upto FRL only. For colony area, approach road and store yard, etc. about 53.5 ha of additional land has to be acquired.

5.1.8.2 Details of property submerged

As per the submergence area Plan, the villages likely to be affected were identified upto M.W.L. 380.408 m. It is assessed that at M.W.L, 9 revenue villages of Ashok Nagar District and 3 villages of Shivpuri district are likely to affected under submergence of the project.

The culturable area under submergence is 853.287 ha at F.R.L.380.0 m. The entire submergence lies in Madhya Pradesh State only. Seven villages will be fully submerged at F.R.L/M.W.L. In addition, lands of 5 villages will also be affected due to the submergence.

5.1.8.3 Rehabilitation of oustees

As per the studies carried out by Mrs. Asha Singh, Professor, Hamidia Government Arts and Commerce College, Bhopal, 2939 PAPs of 870 families are likely to be affected by the submergence due to Lower Orr reservoir.

The rehabilitation of oustees/project affected persons will be governed by the State/Central policy on R&R. Ministry of Rural Development, Government of India has finalised the National Policy on R&R for project Affected Families (NPRR-2007). The policy addresses the R&R issues of the PAF (being displaced) in case of compulsory acquisition of land for public purpose including infrastructure projects. The central objective of the whole exercise is to ensure PAP's to regain their previous standard of living, if not better, within a reasonable transition period. Keeping in view the social dimensions of the project, some measures have been envisaged for the project and described below:

- Census socio-economic survey of PAF's
- Compensation for land

- Compensation for house building
- Compensation for loss of business
- Maintenance allowance for PAF's
- Ex-gratia payment
- Shifting allowance
- Infrastructure development
- Direct and indirect employment opportunities in project
- Training of PAP's
- Institutional arrangement
- Monitoring and evaluation
- Public information system and grievance redressal.

5.1.9 Recreation facilities

As proposed Lower Orr dam is near the historical town Chanderi, following recreational facilities are proposed to be developed.

- Development of parks/gardens in d/s of dam.
- Development of Children parks in the township.
- Development of Tourist spot with boating facilities
- Development of Guest house, inspection bungalow and dormitory accommodation.
- Development of aviary.

These facilities in the area will ensure tourism development in the area.

5.1.10 Pisciculture

There are some existing irrigation projects namely Rajghat, Matatila, Samrat Ashok Sagar, Barwa sagar, Dukwan reservoir etc. in the vicinity of project area, where pisciculture is being developed to generate revenue from fisheries. There is scope for developing fisheries in Lower Orr reservoir also. The submergence area of Lower Orr reservoir is 2723.70 ha

from which about 3592 tonnes of fishes can be produced annually which will increase the revenue from the project.

5.1.11 Need and recommendation for soil conservation measure in the catchment

The chances of soil erosion, if any can be prevented/minimized by adopting following measures.

- Avoid the creation of cut slopes and embankments which are of an angle greater than the natural angle of repose for local soil type.
- Implanting Shrubs and trees in the area.
- Vegetation alone may not be enough to prevent soil erosion, hence, few engineering measures may be adopted to complement the vegetation such as CAT, stone-pitching of vulnerable locations, etc.

Appropriate financial provisions have been provided for soil conservation measures in the catchment area.

5.1.12 Any other relevant information

Nil

5.2 Neemkheda barrage

The Neemkheda barrage site is proposed across Betwa River near village Neemkheda in Goharganj Tehsil of Raisen district at north latitude $23^0$16’40” and east longitude $77^0$40’49”. The Pond level of the barrage is decided as per the topography and toe level of the barrage and pond level of the down stream of proposed barrage (Parariya) i.e., at 426.0 m and capacity of the barrage is 11.06 MCM. The deepest bed level at barrage site is 415.0 m. The length of barrage is 138.0 m. The project envisages irrigation in a CCA of 3066 ha. NIH, Roorkee has assessed the net 75% dependable inflow up to Neemkheda barrage site as 328.61 MCM by the NIH, Roorkee in Hydrological studies for Ken-Betwa Link project (Phase-II after considering u/s domestic, irrigation and industrial water requirements and regeneration thereof. Details are furnished in Chapter – V of Hydrological Study (Volume-IV).

At pond level of 426.00m, Neemkheda barrage is likely to submerge an area of 484 ha. As the barrage is proposed within the gorge portion of the river, therefore no village is coming under submergence. Hence, human population and livestock population will not be affected. The Gross storage capacity at pond level of 426.0m works out to 11.062 MCM. The elevation-area-capacity table of Neemkheda barrage is furnished in Table-5.8.

Table - 5.8

Elevation-Area-Capacity table for the Neemkheda barrage

Elevation(m)	Area(sq.km)	Capacity(MCM)
417	0.00	0.000
418	0.06	0.020
419	0.10	0.099
420	0.21	0.251
421	0.42	0.560
422	0.85	1.182
423	1.22	2.212
424	2.15	3.385
425	3.74	6.783
426	4.84	11.062

The simulation analysis was carried out for the period from June, 1901 to May, 2009. From the simulation analysis, it is inferred that more demands (in comparison to the design demands) can be met from the project with annual reliability of 75%. A number of iterations have been made and it is found that 2.75 times the design demands can be met from the project with annual reliability of 75.93 %

5.3 Barari barrage

The proposed barrage site is located on Betwa river near the village Barrighat in the district and tehsil of Vidisha of Madhya Pradesh. The latitude and longitude of the barrage site is $23^0$40’30” N and $77^0$50’30” E respectively. The proposed barrage site is about 28 km from Vidisha – Lashkarpur- Barrighat Road. Vidisha is the nearest town. The nearest

railway station is Vidisha. Bhopal is the nearest airport, which is about 80 km from the site. The total catchment area of Betwa river upto Barari barrage is 5474 sq.km which is about 32.47% of the total catchment area (w.r.t 16861 sqkm) of upper Betwa sub-basin. The net 75% dependable inflow up to Barari barrage site has been worked out as 1078.32 MCM by the NIH, Roorkee in Hydrological studies for Ken-Betwa Link project (Phase-II after considering u/s domestic, irrigation and industrial water requirements and regeneration thereof. Details are furnished in Chapter – V of Hydrological Study (Volume - IV).

At pond level of 407.72m, Barari barrage is likely to submerge an area of 597 ha. As the barrage is proposed within the gorge portion of the river, therefore no village is coming under submergence. Hence human population and livestock population will not be affected. The gross storage capacity at pond level of 407.72m works out to 14.02 MCM. The elevation-area-capacity table of Barari barrage is furnished in Table-5.9.

Table - 5.9

Elevation-Area-Capacity table for the Barari barrage

Elevation(m)	Area(sq.km)	Capacity(MCM)
397	0.00	0.000
398	0.01	0.003
399	0.05	0.029
400	0.14	0.119
401	0.32	0.341
402	0.54	0.766
403	0.81	1.439
404	1.31	2.491
405	1.59	3.937
406	2.35	5.893
407	5.68	9.789
408	6.08	15.670
409	9.53	23.413
410	13.57	34.905

The simulation analysis was carried out for the period from June, 1901 to May, 2009. From the simulation analysis, it is inferred that more demands (in comparison to the design demands) can be met from the project with annual reliability of 75%. A number of iterations have been made and it is found that 3 times the design demands can be met from the project with annual reliability of 79.63 %

5.4 Kesari barrage

The proposed barrage site is located on Keotan river, a tributary of Betwa, near village Didholi in the Basoda tehsil of district Vidisha of Madhya Pradesh. The latitude and longitude of the dam site is $23^0$52'32" N and $78^0$01'34" E respectively. The proposed dam site is about 11 km from Basoda. Basoda is the nearest town. The nearest railway station is Basoda about 11 km from the site. Bhopal is the nearest airport, which is about 110 km from the site. The catchment area of Kesari barrage is 506 sq.km. This is 3.02% of the total catchment area (w.r.t, 16861 sq.km.) of upper Betwa sub-basin. The net 75% dependable inflow upto Kesari barrage site has been worked out as 120.66 MCM by the NIH, Roorkee in Hydrological studies for Ken-Betwa Link project (Phase-II after considering u/s domestic, irrigation and industrial water requirements and regeneration thereof. Details are furnished in Chapter – V of Hydrological Study. (Volume - IV)

Keeping in view the topographical features and the pattern of the submergence vis-à-vis storage, pond level of 403.90 m is considered more appropriate. The Gross storage capacity at pond level of 403.90 m works out to 10.0 MCM . The deepest bed level at barrage site is 395.0 m. The elevation-area-capacity table of Kesari barrage is furnished in Table-5.10.

Table - 5.10

Elevation-Area-Capacity table for the Kesari barrage

Elevation(m)	Area(sq.km)	Capacity(MCM)
395	0.00	0.00
396	0.06	0.02
397	0.17	0.13
398	0.39	0.41
399	0.79	0.99
400	1.20	1.98
401	1.45	3.30
402	1.89	4.97
403	2.55	7.18
404	3.74	10.31
405	5.14	14.73
406	6.99	20.76
407	11.51	29.92

The barrage can also been used as storage. Due to topographical constraints, sufficient command will only be possible after proposing lift upto 410m. Therefore, MDDL of Barrage has been fixed tentatively as 401 m. The project envisages irrigation in a CCA of 1479 ha. The results of simulation studies show that the time and volume reliabilities in meeting irrigation demands were 80.7% and 92.7% when FRL is kept at 403.90 m (corresponding storage 10.0 MCM). The annual irrigation reliability when ignoring deficit upto 10% is 79.3%.

At pond level of 403.90 m, Kesari barrage is likely to submerge an area of 362(255) ha. As the barrage is proposed within the gorge portion of the river, therefore no village is coming under submergence. Hence, human population and livestock population will not be affected.

5.5 Kotha Barrage

The Kotha barrage site is proposed across Betwa River near village Near kotha village in Vidisha district. The pond level of the barrage

is decided as per the topography i.e. 396 m and capacity of the barrage is 104.6 MCM. The deepest bed level at barrage site is 384.0 m. The length of barrage is 579.0 m. The project envisages irrigation to a CCA of 17357 ha.

The net 75% dependable inflow upto Kotha barrage site has been worked out as 1652.23 MCM by the NIH, Roorkee in Hydrological studies for Ken-Betwa Link project (Phase-II after considering u/s domestic, irrigation and industrial water requirements and regeneration thereof. Details are furnished in Chapter – V of Hydrological Study (Volume - IV).

The Elevation-Area-Capacity table for the Kotha barrage is given below in Table-5.11.

Table - 5.11

Elevation-Area-Capacity table for the Kotha barrage

Elevation(m)	Area(sq.km)	Capacity(MCM)	Cumulative Capacity(MCM)
384	0.0	0.0	0.0
385	1.5	0.5	0.5
386	2.8	2.1	2.6
387	4.0	3.4	6.0
388	4.7	4.3	10.3
389	5.3	5.0	15.3
390	6.9	6.1	21.4
391	8.3	7.6	29.0
392	10.0	9.2	38.2
393	13.8	11.9	50.0
394	16.8	15.3	65.3
395	19.9	18.3	83.6
396	22.1	21.0	104.6
397	23.9	23.0	127.6

The simulation analysis was carried out for the period from June, 1901 to May, 2009. Assuming the revised inflow series, revised demand pattern, and revised EAC table. A number of scenarios have been

analyzed with different levels of demands and Pond levels so as to achieve a minimum annual reliability of 75% for meeting various demands from the project. The results of simulation analysis are summarized in Table–5.12.

Table – 5.12

Results of simulation analysis under different scenarios for Kotha barrage

Description of Scenarios and Variables	**Values**
Scenario – 1 (Demands as 72 MCM and Pond level as 396.00 m)	
Annual reliability for meeting full demands (%)	100
Monthly reliability for meeting full demands (%)	100
Volume reliability (%)	100
Scenario – 2 (Demands as 136.803 MCM and Pond level as 396.00 m)	
Annual reliability for meeting full demands (%)	75.93
Monthly reliability for meeting full demands (%)	94.91
Volume reliability (%)	99.37
Scenario – 3 (Demands as 72 MCM and Pond level as 392.00 m)	
Annual reliability for meeting full demands (%)	75.00
Monthly reliability for meeting full demands (%)	93.67
Volume reliability (%)	99.19