PREFACE

The proposed New Dam at Mullaperiyar is a straight gravity concrete dam. The structure consists of a main dam and a small saddle dam on the right side. The spillway is located in river portion and is located +366.0m downstream of the existing old Mullaperiyar Dam.

The favourable geomorphological conditions coupled with reduced additional area of submergence (26.33Ha) of flora and fauna make the location highly technically and environmentally acceptable.

In the recent past, Mullaperiyar region has experienced floods of high magnitude flood and increased seismicity. Hence, these aspects have been studied in detail by IIT Delhi and IIT Roorkee. The recommendations of these reputed institutions have been followed in the design of the new Mullaperiyar Dam.

Hydrological studies including *Hydrological working table* of the new reservoir is included in the Detailed Project Report. Working table confirms that the state of Tamil Nadu can continue to draw water as they were doing till now.

Geological, geotechnical and foundation investigations are also discussed in detail.

The construction schedule prepared is a realistic one achievable by employing modern construction machinery and latest management techniques. The construction schedule also includes dismantling of old dam and its related activities including the removal of debris. This is included along with the schedule of progress of construction of the dam. A total of 4 years is estimated for the completion of project.

Methodology for dismantling the existing structure and to make the reservoirs as one entity has been proposed. All necessary surveys regarding topography, reservoirs, lay outs of plant and colony and

communication systems have been carried out and designed in such a way as to cause minimum adverse impact on environment and ecology. The detailed estimate fixes the total amount need for the dam as Rs.663 Crore, as per 2011 Kerala PWD schedule of rates.

A special purpose vehicle is being created to carry out the effective and efficient management of the construction of the New Mullaperiyar Dam within a period of four years after obtaining all the mandatory clearances.

The State of Kerala will faithfully commission the New Mullaperiyar Dam most expeditiously and in the minimum time frame to safeguard the lives and properties of its thousands of people and to ensure continued supply of water to the needy farmers of Tamil Nadu.

Chief Engineer, IDRB
Irrigation Department
Government of Kerala.

CONTENTS

SECTION-1

CHECK LIST

I GENERAL DATA

1 Name of the Project : New Mullaperiyar Dam

2 Location:

(a) State (s)	:	Kerala
(b) District(s)	:	Idukki
(c) Taluk(s)	:	Peerumedu
(d) Longitude	:	77° 08′ 33″ N - RB 77° 08′ 33″ N - LB
Latitude	:	09° 31′ 48″E - RB 09° 31′ 26″E - LB
(e) Survey of India Topographical Map reference No.(s)	:	58G/2
(f) Earthquake Zone number	:	III
(g) Complete address for Correspondence along with Pin code/e-mail	:	Chief Engineer, IDRB Vikas Bhavan Thiruvananthapuram Pin – 695 033 idrbtvm@gmail.com

3 Category of the project:

(a) Irrigation / multipurpose	: Multipurpose
(b) Storage / diversion	: Storage and diversion

II PLANNING

Sl. No.	Item	References
4	Has the master plan for overall development of the river basin been prepared and stages of basin development discussed?	NA

5	Have the alternative proposals (including set of smaller developments vis-à-vis a single large development) been studied and their merits and demerits discussed?	Yes
6	Does the scheme fit in the overall development of the river basin and its priority in the overall development of the basin been discussed?	NA
7	Have the other departments concerned with the development been informed?	NA
8	Is the present scheme proposed to be executed in stages? If so, are its various stages of execution and development discussed in the report?	One Stage
9	Are the effects of the scheme on the riparian rights & existing upstream and downstream projects etc. discussed?	Yes
10	Has the provision for municipal and industrial water supply been made?	NA

III INTERSTATE AND INTERNATIONAL ASPECTS

11	Are there any International/Interstate issues involved? If so, have these issues been identified and present status of agreement or tribunal decision indicated specially in respect of	
	(a) Sharing of water	Nil
	(b) Sharing of cost	Nil
	(c) Sharing of benefits(irrigation, flood control, power etc)	Yes
	(d) Acceptance of the submergence by the upstream state(s)	NA
	(e) Acceptance by the upstream state(s) of compensation of land coming under submergence	NA
	(f) Settlement of oustees	Nil
	(g) Any other	
	The benefits arising from the New Mullaperiyar Dam would be shared between the States of Kerala and Tamil Nadu as mutually agreed upon by signing an agreement or decided by the Hon'ble Supreme Court based on what is just and equitable.	

IV SURVEYS

12	Have the detailed topographical surveys been carried out for the following items and maps prepared as per prescribed scales	
	(a) River surveys	Yes
	(b) Reservoir surveys	Yes
	(c) Head-works surveys(dam(s), dyke(s),barrage(s), weir(s) etc. and auxiliary components)	Yes
	(d) Plant site and Colonies sites	Yes
	(e) Canal(s), branch canal(s) and water conductor system	NA NA
	(f) Major canal structures	NA
	(g) Power house, switch-yard, surge shafts, tailrace	NA
	(h) Tunnel(s), adit(s), penstocks etc.	NA
	(i) Surveys(Detailed and sample)of areas of the command for OFD and drainage works	NA
	(j) Soil surveys	NA
	(k) Surveys for soil conservation	No
	(l) Any other surveys i.e. archeological, right of way, communication etc.	Yes

V GEOLOGICAL INVESTIGATIONS

13	Have the geographical surveys for the following items been carried out (Refer Chapter 3.4.2 and Annexure II) and report on geology of the following appended?	
	(a) Regional as a whole	Yes
	(b) Reservoir	Yes
	(c) Headwork and energy dissipation area	Yes
	(d) Power house and appurtenances	NA
	(e) Intakes and regulators	NA
	(f) Major canal structures	NA
	(g) Tunnel(s), Penstock(s), hill(s) etc.	NA
	(h) Communication routes	Yes
	(i) Any other	NIL

VI SEISMIC INVESTIGATIONS

14	Has the seismicity of the region been studied and coefficient of vertical/horizontal acceleration for the various structures discussed?	Yes
15	Has the approval of the Standing Committee for recommending design of seismic coefficient of River Valley Project been obtained?	No
16	Is there possibility of liquefaction of foundations? If so whether liquefaction studies been carried out?	NA

VII FOUNDATION INVESTIGATION

17	Have the detailed foundation investigations (including in situ tests and laboratory tests) for the following structures been carried out and detailed report(s) appended?	
	(a) Earth and rock fill dam(s)	NA
	(b) Masonry/concrete dam(s)	Yes
	(c) Barrage(s)/Weir(s)/head regulator(s) etc	NA
	(d) Canal(s) & Canal structures	NA
	(e) Power house(s), tunnel(s), transformer cavern(s), desilting chamber(s),surge tank(s) / shaft(s), intake(s)	NA
	(f) Pump house(s)	NA
	(g) Any other	NIL
18	Are there any special features affecting the designs?	No

VIII CONSTRUCTION MATERIAL SURVEYS

19	Have the surveys and laboratory tests for the following construction materials been carried out and report(s) appended?	

	(a)Soils for impervious, semi pervious and pervious zones of earth and rock-fill dam(s) (b)Sand (c)Rock and aggregate (d)Bricks and tiles (e)Pozzolana (f)Cement and limestone (g)Steel (h)Any other	 NA Yes Yes NA NA Yes NA NIL
20	Have the sources for each of the above material been identified and need etc. indicated?	Yes
21	Have the proposals for procurement of scarce materials been indicated?	NA

IX HYDROLOGICAL & METEOROLOGICAL INVESTIGATIONS

22	(a) Have the hydrological and meteorological investigations been carried out and status of data discussed in report? i. Rainfall ii. Temperature iii. Sunshine iv. Gauge & Discharge v. Sediment vi. Discharge vii. Sediment (b) Has the above data been collected & appended?	 Yes NA NA NA NA NA NA Yes

X HYDROLOGY

23	Is the hydrology dealt with in detail in a separate volume? Have its brief details been included in this Report?	Yes
24	Have an index map and bar chart showing locations of various hydro metric, climatic and rainfall stations existing/ongoing/planned water resources projects and the data availability at those stations been attached?	No
25	Have required detail note about project specific hydrometerological data observatories been attached.	NA

26	Have required detail in case of Himalayan rivers, if project being planned in upper reaches, the satellite imageries of project catchment especially one during snowmelt period(March-May) and one during monsoon (June-September) period been attached?	NA
27	Are detail notes about quality, consistency, processing and gap filling of the data included.	NA
28	Have hydrological studies been carried out for the following: (a) To establish the availability of water for the benefits envisaged? (b) To determine design flood for the various structures (spillway, weir barrage etc). (c) Sediments storage (d) Design flood for diversion during construction (e) Tail water rating curve (f) Evaporation rates from reservoirs/concerned area (g) Command area rain fall	 Yes Yes No NA No Yes No
29	Has the Ground Water Potential *(existing use and additional availability)* been indicated?	NA
30	Have the studies regarding reservoir sedimentation been carried out and revised elevation-area capacity curves been used in the simulation studies (Working Table)?	No
31	Have the ecological requirements of water such as low augmentation and water quality control etc. and water requirement for domestic, industrial use and power generation (thermal, hydel, nuclear) been considered and included in the Project Report and incorporated in the simulation studies?	NA
32	Have the details of the simulation studies (Working Tables) and conclusions arrived from the various alternatives explaining the factors and assumptions been included and discussed?	Yes
33	Have the number of failures for different aspects been indicated?	Yes
34	Have the likely desirable and undesirable changes in the hydrologic regime due to the project been brought out in the report?	NA

35	Is the criteria adopted for selection of the construction diversion flood discussed?	Yes
36	Has the basis for determining the storage capacity been discussed?	Yes
37	Have integrated working tables (for more than one reservoir in the system) been prepared?	No
38	Has carry over storage been provided? If so, whether studies for most economic carry over storage been done?	No
39	Have the flood routing studies been carried out?	Yes
40	Have the back water studies been carried out?	NA

XI LAND ACQUISITION AND RESETTLEMENT OF OUSTEES

41	Have the type and quantum of land proposed to be acquired in the submerged area, project area, area coming under canal and distribution system, area required for rehabilitation of the oustees been detailed?	Yes
42	Is the basis for provision for land compensation indicated?	Yes
43	Have the rehabilitation measures, amenities and facilities to be provided to the Project Affected Persons been discussed and whether their provisions included in the report? Are those in accordance State's policy/project specific policy/draft national policy for rehabilitation and resettlement	NA
44	Are the basis of land acquisition of the submerged area up to FRL/MWL etc. discussed?	Yes

XII DESIGN

45	Does the state have established a Central Design Organization and State level multidisciplinary Advisory Committee and whether its composition has been indicated in the report?	Yes
46	Has the selection of final location of the headworks and appurtenances, in preference to the other sites investigated, been discussed?	Yes
47	Has the layout of the project viz., location of headworks, work-shop, sheds, offices, colonies, etc.	Yes

	been finalized and discussed?	
48	Has the layout of the various major components of the headworks been discussed in the light of site feature, geology, foundation characteristics etc.?	Yes
49	Have the detailed designs been prepared for the following components & got vetted by CDO?	
	(a) Earth or rock fill dam, masonry or concrete dam, spillway, barrage, weir, etc. and appurtenances.	Yes
	(b) Energy dissipation arrangements, training wells etc.	Yes
	(c) Opening through dams- galleries, head regulators, penstocks other outlets, sluices etc.	Yes
	(d) Regulators.	NA
	(e) Canal and water conductor system.	NA
	(f) Canal structures	NA
	(g) Pump house, intake structures	NA
	(h) Power House, tunnels, surge shaft.	NA
	(i) Instrumentation	Yes
	(j) Power evacuation arrangements	NA
	(k) Design of Hydro Mechanical equipments	NA
50	Have the salient features of the above components and the assumptions made in the design of above components of the project been indicated and their basis discussed?	Yes
51.	Have any model studies been carried out for location of the dam, spillway and other appurtenances & checking the design profile of the spillway, energy dissipation arrangements, location of outlets/regulators etc.?	No
52	Has the final alignment of canal(s) and branch canal(s) been discussed in the light of various alignments studied? a. Does the canal design provide for meeting requirements of rush irrigation? b. Have any intermediate storages and tail tanks been considered to reduce the canal capacities?	NA
53	Are the canals and distribution system being lined and if so what is the minimum capacity of the channel proposed to be lined?	NA

54	Is the location of canal structures on main and branch canals fixed after detailed surveys of the final alignments?	NA
55	Are the regulation arrangements of the off – taking channel both near and away from the cross regulators discussed?	NA
56	Are sufficient escapes including terminal escapes provided on the main / branch canal distributaries / minors?	NA
57	Have the basis for adopting waterway for the cross drainage works been discussed?	NA
58	Have the proposals for rating the canal section by providing standing wave flumes, rating of the falls, broad crested weirs, V- notches etc. been discussed for the canal and distribution system?	NA
59	Have any model studies for major canal structure(s) been carried out and if so are the results discussed and incorporated in the design?	NA

XIII IRRIGATION AND COMMAND AREA DEVELOPMENT

60	Have the conveyance and field irrigation efficiencies for paddy and upland crops during Kharif, Rabi, etc. been indicated, discussed and justified?	NA
61	Have the 10-daily/monthly crop water requirements at the canal head been worked out?	NA
62	Are there any proposals for introducing warabandi and if so have these proposals been discussed in the report and sample calculations for a typical distributary / minor/ sub-minor furnished?	NA
63	Has the present position of irrigation in the command through existing canals, tanks, lift schemes, wells etc. been brought out in the report?	NA
64	Are the particulars of all irrigation projects (including minor schemes) existing/ proposed in the command been indicated?	NA
65	Are there any potential areas, where ground water is available? If so, has the quality & quality of ground water been indicated?	NA
66	Has the quantum of available ground water been assessed and plan for its conjunctive use with surface water been prepared and incorporated in the report?	NA

67	Have the semi – detailed soil surveys been carried out for the entire command If not the extent of area surveyed may be indicated.	NA
68	Have soil and land irrigability classifications brought out in the report?	NA
69	Is the method used for determining the crop water requirements discussed?	NA
70	Has the pre – project cropping pattern and the proposed cropping pattern along with justification been furnished?	NA
71	Has the proposed cropping pattern been certified by Centre? State Agricultural Authorities giving the statement of having considered the soil characteristics and land irrigability characteristics of the command area in deciding the percentage of the command area falling under respective crops as suggested in DPR.	NA
72	Whether drinking water needs of the population projected for the 25-30 years after construction of the project on enroute and that in the command of the project considered.	NA
73	Whether the proposed G.W utilization is certified by CGWB and a statement furnished.	NA
74	Are the areas and percentages of the CCA that will be irrigated during kharif, rabi, two seasonal, summer and perennial been indicated?	NA
75	Is justification furnished for irrigating perennials and summer crops from the reservoir?	NA
76	Have the monthly reservoir operation studies been carried out at least for 20 years and summary on annual basis attached?	Yes
77	Have the number of blocks selected for detailed surveys for On Farm development (OFD) works including drainage and total area covered by such blocks been indicated?	NA
78	Have the existing locations of the Trial cum Demonstration Farm, inputs centers (seeds, fertilizer and insecticides) in the command been indicated and proposal to strengthen the same discussed?	NA
79	Have the arrangements for financing the OFD works and proposals, if any, for strengthening the same been discussed?	NA
80	Have the agencies responsible for execution of OFD	NA

	works been identified and simultaneous planning of execution of OFD works along with engineering works discussed?	
81	Has the year-wise phasing of irrigation development as a result of the project been discussed?	NA
82	Is the existing communication system telephone, wireless and roads within command area sufficient to meet the requirement after full development of irrigation? If not, have the new proposals been planned and discussed?	NA
83	Is the adequacy of the marketing centers in the Command Area and new proposals to meet the requirements after full development of irrigation been discussed?	NA
84	Is there any stabilization of existing irrigation proposed?	NA

XIV FLOOD CONTROL AND DRAINAGE

85	Have the various flood control components of the multipurpose project been indicated?	NA
86	Have the damage areas in pre-project & post project situations been identified and flood intensities worked out at each of the damage centre(s) which gets affected?	NA
87	Have the following aspects been discussed?	
	(a) Flood cushion in the reservoir	Yes
	(b) Maximum moderated flood out flows over the spillway etc. and its frequency	Yes
	(c) Existing and proposed safe carrying capacities of the channel below the dam after construction of flood embankment, channel improvement, river diversion etc.	NA
	(d) Synchronized moderated peak floods due to release(s) from the dam upstream and uninterested catchment up to the damage centers	NA
	(e) Average annual expenditure incurred on flood relief works	NA
	(f) Area and population affected/ likely to be affected before/ after the project	NA

	(g) Estimated saving in annual loss of life, property, cattle, crops, etc. (evaluated in terms of money) due to flood control	NA
88	Have the following drainage aspects of command area been discussed?	
	(a) Existing Surface and sub-surface drainage problems of the drainage congestion, water logging, alkalinity/salinity if any.	NA
	(b) Studies on sub soil water table(pre-monsoon, post-monsoon etc)	NA
	(c) Maximum intensity of 1, 2 and 3 day rainfall	NA
	(d) Deficiencies in farm drains	NA
	(e) Deficiencies in existing natural drains	NA
	(f) Proposal for improvement of drainage/ water logging /alkalinity/salinity of the area along with justification thereof.	NA
	(g) Identification of the area in Command which will get benefited due to execution of drainage net-work and benefits thereof in terms of relief from crop damage, increased yields etc.	NA

XV NAVIGATION

89	Is the present scheme for remodelling of the existing facilities and/ or extension of the navigable reach or establishing new navigable reach?	NA
90	Is the existing inland transport system being fully utilized? If not, have the bottlenecks in its full utilization been identified and discussed?	NA
91	Have the surveys for goods and passenger traffic been carried out and discussed?	NA
92	Is the extent of modification required in the existing system discussed and justified?	NA
93	Do design for the canal sections and structures take into account the navigation requirements?	NA
94	Have the proposals to develop the new scheme and phases of development in the different reaches been discussed?	NA
95	If the area is being served by inland water transport, have the following been discussed:	

	(a)The existing toll rates and registration fees for the crafts (size wise)	NA
	(b)Proposals for revision of tollage rates and fees, if any.	NA
	(c)Concurrence of the competent authorities for revision of rates and fees	NA
	(d)Proposal to subsidies the tariff, tollage, craft registration fee, passenger fare etc. to attract traffic	NA
96	Has the State Inland Water Authority been consulted while finalizing the scheme and its view point discussed?	NA
97	Has economic justification and viability of the Navigation component of the multipurpose project been discussed?	NA

XVI POWER

98	Have the following points been discussed?	
	(a) Availability of the power generating capacity in the state as well as in the region from different sources'	NA
	(b) Total energy available and peaking capacity of the system in the state as well as in the region from different sources.	NA
	(c) Integrated operation of the system and present status of utilization in the as well as in the region.	NA
	(d) Surpluses and shortfalls in the system in the state as well as in the region.	NA
	(e) Future plans of power development from different sources in the State/region	NA
	(f) Fitment of the scheme in planning of power development of the State/region	NA
	(g) Energy generated from the project, firm power, seasonal power and total power	Yes
	(h) Proposal for transmission lines connecting to the existing system/grid.	NA
	(i) Project cost per kwh installed and per kwh generated at bus bar as compared to the different hydro-electric ,thermal generation and gas projects and different sources in the	NA

	State as well as in the region to justify the power component of the project.	
	(j) Whether the proposed addition to the transmission system has been shown on a geographical map. Whether options considered for the proposed addition have been discussed with statement of justification for the selected option after carrying out supporting studies covering load flow studies, short-circuit studies(three phase and single phase) and stability studies.	NA
	(k)# Whether sufficient surplus off peak power is available for pumping of water from lower to upper reservoir.	NA
	(l)# Actual off peak energy requirement of proposed schemes.	NA
	(m)# Cost of peak and off peak energy	NA

For pumped storage schemes only

XVII CONSTRUCTION PROGRAMME AND PLANT AND MANPOWER PLANNING

99	Are the major components of work proposed to be done departmentally or through contractor?	Contractor
100	Have the various alternative construction programme been studied and proper justification furnished for the final programme adopted?	Yes
101	Has the proposed construction programme been prepared and synchronized for timely completion of each of the major component of work including Command Area Development?	Yes
102	Have the year wise quantities of the following materials of construction been worked out for various components of the project:	
	(a) Excavation separately in soft and hard strata	Yes
	(b) Earthwork infilling impervious, semi-pervious and pervious	Yes
	(c) Rock fill for dam, toe, riprap etc.	Yes
	(d) Stone for masonry	Yes

	(e) Coarse aggregate for concrete	Yes
	(f) Sand for filter, masonry/concrete	Yes
	(g) Gravel for filter	Yes
	(h) Steel of various sizes and type	Yes
	(i) Cement – normal, quick/slow setting with or without Pozzolana , special types	Yes
	(j) Lime – surkhi – Pozzolana	No
	(k) Scarce material – special steel	No
	(l) Other material – fuel, electricity, explosive etc.	Yes
103	Have the year wise quantities to be executed by machine/labour for each of the major component been worked out for each of the above material?	Yes
104	Have the labour intensive items of the various major components of the project been identified and the quantities of such items worked out?	Yes
105	Have PERT chart or CPM diagrams for construction programme of various components been made and included in report? Has organizational set up and frequency for project monitoring been indicated in the Report?	Yes

XVIII FOREIGN EXCHANGE

106	Have the details of the plant and machinery, spares, instruments, scarce materials to be imported worked?	NA
107	Has the phasing of imports and source(s) of imports been discussed item wise?	NA
108	Are the imports to be affected under foreign grants /credits or internal resources of the country?	NA
109	Is the scheme included in the Five Year/Annual Plan? If not what is the present position regarding its inclusion in the plan?	State Sector

XIX FINANCIAL RESOURCES

110	Has the concurrence of the State Finance Department been obtained?	Yes
111	Is the scheme included in the Five Year/Annual plan? If not, what is the present position regarding its inclusion in the plan? *Rs. 5 crores has been earmarked this year for the preliminary work of the new dam proposed to be constructed in a period of 4 years*	Yes
112	Whether the scheme has already been started? If so, is the present stage of construction indicated?	No
113	Have the year wise requirement of funds been indicated?	Yes
114	Is the scheme covered or proposed to be covered under any foreign assistance/aid agreement?	No

XX ESTIMATE

115	Is the separate volume of estimate attached as appendix?	Yes
116	Is the year to which the rates adopted in the estimate relate to indicated?	Yes
117	Have the analysis of rates for various major items of work for the major components of the project been furnished and with basis for analysis described?	Yes
118	Are the provisions of the following items made on the basis of sample survey and sub-estimates:	
	a. Distributaries, minor and sub-minors	NA
	b. Water courses	NA
	c. Drainage	NA
	d. CAD works	NA

XXI REVENUES

119	Is the basis for the following sources of revenues furnished?	
	a. Betterment levy and proposal for its recovery	NA
	b. Irrigation cess	NA
	c. Flood protection cess	NA
	d. Crop wise water rates	NA

	e. Sale of water for village/city/industrial/power/ water supply	NA
	f. Miscellaneous	NA
120	Have these rates been compared with the existing rates at the other projects in the State/region?	NA
121	In case the rates are being enhanced, has the concurrence of the concerned department(s) been obtained?	NA
122	Have the organizational setup for the collection of revenue been indicated?	NA

XXII B.C. RATIO

123	Is the allocated cost for the following components of the multipurpose project worked out and basis therein furnished?	
	a. Irrigation	NA
	b. Power	NA
	c. Flood Control	NA
	d. Navigation	NA
	e. Water Supply	NA
	f. Any other	NA
124	Have the various departments of the State/Centre agreed to the sharing of the above allocated cost?	NA
125	Have the crop wise benefits been worked out for irrigated and unirrigated crops being grown before project in consultation with the agriculture department and statement furnished?	NA
126	Have the crop wise benefits been worked out for proposed cropping pattern after the introduction of irrigation in consultation with the agriculture department and statement furnished?	NA
127	Is the B.C. ratio of Irrigation Projects acceptable or otherwise justified?	NA
128	Is the B.C. Ratio for Flood control Projects acceptable or otherwise justified?	NA
129	Is the B.C. Ratio for power component of the Project acceptable or otherwise justified?	NA
130	Have the financial and economic return statements been furnished keeping in view the phasing of development?	NA
131	Are the benefits other than those considered in the B.C. Ratio and financial return statement been identified?	NA
132	Is the benefit from Galloper land, if proposed, based on lease rates admissible and statement from concerned	NA

	Central/State authorities furnished?	
133	Are the benefit from fisheries, horticulture, if proposed, based on lease rates admissible and statement from concerned Central/State authorities furnished.	NA

XXIII ECOLOGICAL ASPECT

134	(a) Is the area likely to have any of the following environmental and ecological problems due to altered surface water pattern? If yes, whether preventive measures have been discussed?	
	i. Excessive sedimentation of the reservoir and the upper reaches of the river and its tributaries tailing in to reservoir.	No
	ii. Water Logging, salinity/alkalinity.	No
	iii. Quality of surface and ground water	No
	iv. Ground water recharge	No
	v. Health hazards – water borne diseases, industrial pollution etc.	No
	vi. Submergence of important minerals deposits	No
	vii. Submergence of monuments/archeological sites	No
	viii. Fish culture and aquatic life	No
	ix. Plant life (flora)	Yes
	x. Wild life	Yes
	xi. Migratory birds	No
	xii. National parks and sanctuaries.	Yes
	xiii. Seismicity due to filling of reservoir	No
	xiv.Likely change in the regime of the river	No
	xv. Any other	No
	(b)Have the environmental and forest clearances from MoE &F been obtained? If not what is status thereof?	&&

&& Permission has been obtained from MoE&F for surveying in the proposed area. EIA studies are initiated for obtaining the clearances.

XXIV COLONIES AND BUILDINGS

135	Has the planning of the colony/building been done keeping in view the ultimate use for optimum utilization of investment?	Yes
136	Has an estimate of the extent of higher cost involved been made and details discussed?	Yes
137	Are the permanent buildings being constructed required for maintenance of the project only?	Yes
138	Can the buildings other than required for maintenance of the project being constructed be put to some other use after the completion of the project by the department or any other agencies?	NA
139	Have the interested agencies been consulted in planning of the buildings to suit their requirements later on?	NA
140	Have the proposals for disposal of temporary buildings been discussed?	Yes

XXV PUBLIC PARTICIPATION AND COOPERATION

141	Are the possibilities of these been discussed in :	
	a. Planning	NA
	b. Construction	NA
	c. Improved agricultural practices	NA
	d. Any other	NA
142	Have public debates about utility of projects been held and the response thereof outlined in the Report?	No

XXVI SOIL CONSERVATION

143	Is the need for soil conservation measures in the catchment of the project discussed?	No

SECTION-2

SALIENT FEATURES

1. Name of the Project : New Mullaperiyar dam

2. Type of Project : Multi Purpose

3. Location

3.1 River Basin

a) Name : Periyar

b) Located in

i. State : Kerala

ii. Country : India

3.2 River/Tributary : Periyar

3.3 State(s)/District(s)/Taluka(s) or Tehsils in which following are located:

a) Reservoir : Idukki

b) Headwork : Idukki

c) Command Area : Tamil Nadu

d) Power house : Kambam

3.4 Name of village near

the Head works : Kumili

3.5 Location of Head-works

Longitude : 77° 08′ 33″N - RB
77° 08′ 33″N - LB

Latitude : 9° 31′ 48″E - RB
9° 31′ 26″E - LB

c) Lies in Earthquake Zone No: III

3.6 Project area reference to:

a) Degree Sheets : 58 G/2

3.7 Access to the project

	Place	*Distance from the Project Site*
Airport	Nedumbassery	180 km
Rail head	Kottayam	110 km
Road head	VandiPeriyar	13 km
Sea port	Cochin	177 km

4. Interstate aspects of the project

a) Catchment area of the basin : 5398 Sq.Km

b) State-wise details

of catchment area : 5284 Sq.Km (Kerala)

114 Sq.Km (Tamil Nadu)

c) Submergence due to projects : 4733.35 acres (Kerala)

c) Water Allocation for other states : As per the working table and subject to availability

h) Minimum agreed/proposed flow

in the river for maintaining ecology : 2.5 cumecs during summer months of January to May

5. Hydrology

5.1 Catchments : Periyar

5.1.1 Catchments area at headwork site

(sq.km) : 624.5

5.1.2 Catchment area classification

according to mode precipitation(sq.km)

a)Rain fed : 624.5

b)Snow fed : Nil

5.2 Precipitation : 2204 mm (1985-2010)

5.2.1 Catchment

	Rainfall (weighted mm)	
	Annual	Monsoon(Jun-Oct)
Average	2204 mm	1680mm
Maximum	3652mm	3035mm
Minimum	1338 mm	921mm

5.3 Annual yield calculated at the proposed site (MCM) –

(1960-2009 – last 50 years)

Maximum	1581.96
Minimum	270.20
Average	665.24
50% Dependable	628.22
75% Dependable	523.04
90% Dependable	398.22
98% Dependable	270.20

5.4 Seismic coefficients

a)Horizontal : 0.21g

b)Vertical : 0.105g

5.5 Utilisation within the State (MCM) : 32.62 during Jan-May

5.6 Floods near the head work site

Maximum water level	+873.14m	+872.68m
Maximum discharge estimated	7164 cumecs	4417cumecs
Date of occurrence	Jan 2 to 4, 1943	July 15 to 16, 1924

5.7.1 Probable Maximum flood : 8676.25 cumecs (Peak)

6. Reservoir

6.1 Water levels (El-m)

a) Maximum Water Level (MWL) : +873.20

b) Full Reservoir Level (FRL) : +867.41

c) Minimum Draw Down Level (MDDL) : +857.66

e) Dead Storage Level : +857.66

6.2 Free board (m) : 1.50

6.3 Live storage (MCM) : 175.02

6.4 Capacity (MCM) at:

a) Maximum Water Level(MWL) : 475.95

b) Full Reservoir Level(FRL) : 321.48

c) Minimum Draw Down Level(MDDL) : 146.46

d) Dead Storage Level : 146.46

6.5 Flood absorption capacity (Mm^3)

Between FRL& MWL : 154.57

6.6 Average monthly evaporation losses from the reservoir (MCM)

Month	Average Evaporation Loss
January	1.428
February	1.352
March	1.372
April	1.125
May	1.255
June	1.090
July	0.544
August	0.992
September	0.613
October	0.476
November	0.775
December	1.316

7. Submergence

7.1 Land and property submerged

a) Villages affected (No.) - 1

	MWL	FRL
b) Land affected (ha)		
i.Gross	25.67	21.79
ii.Culturable	Nil	Nil
iii.Irrigated	Nil	Nil
iv.Forest	25.67	21.79

	c)Buildings/houses(No)	Nil	Nil
	d)Wells(No)	Nil	Nil
	e)Road/Rail(km)	Nil	Nil
	f)Transmission lines(km)	Nil	Nil
7.2	Number of families/persons affected -		Nil

8. Head works

8.1 Dam

8.1.1 Concrete Dam (Non-over flow section)

	Left side	Right side
	Main	Saddle
a) Type of Dam	Concrete	Concrete
b) EL of top(m)	874.69	874.69
c) EL of deepest foundation(m)	820.53	850.00
d) Length at top(m)	370.10	137.00
e) Length at the river bed(m)		
f) Width at top(m)	6.0	6.0
g) Width at the deepest bed level(m)	42.25	26.0
h) Maximum height above deepest foundation level(m)	54.16	24.69

8.1.2 Spillway (over flow section)

a) Type of spillway	:	Ogee
b) Full reservoir level(EL-m)	:	+867.405
c) Maximum water level(EL-m)	:	+873.19
d) Length(m)	:	305.90 *(incl. pier width)*
e) Maximum height above the deepest foundation(m)	:	54.16

f) Crest level(El-m) : +867.405

g) Number of gates : 14 nos (7 nos ungated)

h) Type of gate : radial

i) Size of gate (m x m) : 12 X 6.40

j) Maximum discharge capacity : 3454.66 cumecs

i) Type of energy dissipation arrangement : Type II as per IS

8.1.3 River sluice(s), Irrigation/Power outlet(s)

a) Purpose : Scour, Outlet

b) Number : 1 , 1

c) Size(m) : 1 m diameter

d) Sill level(El-m) : +828.530, + 835.530

9. Cost

9.1 Allocated cost (Rs.Lakh) : Rs.663 crores

SECTION – 3

REPORT

1. INTRODUCTION

1.1 Aim of the Project and Description of the Work

The old Mullaperiyar Dam is a composite gravity structure having a height of 47.24m above the river bed level (datum) and a length of 366m. The front and rear faces of the dam are built with uncoursed rubble masonry in lime surkhi combination mortar. The hearting, which accounts for more than 60% of the volume of the dam is constructed of lime surkhi concrete. As the dam was built during a time when the dam engineering was at its infancy, many of the major technical and construction requirements applicable to modern gravity dams were not followed in its design and construction. Effects of uplift and seismic forces were not considered in the design. No drainage gallery and scour sluices were provided. The dam is constructed as one long continuous monolith without any construction joints. No instruments were embedded in the body of the dam to monitor its behavior and performance over the years. Heavy and continuous seepage of water started appearing right from the first filling of the reservoir. Measures like guniting the upstream face of the dam and grouting the body of the dam were resorted to check the seepages during 1935 and 1961. During 1980s further strengthening measures like cable anchoring, adding weight at top by reinforced concrete capping, plain cement concrete backing, etc were carried out in the old dam to apparently improve the structural stability of the old dam. In the meantime, the spillway capacity was increased to negotiate the floods. The Full Reservoir Level (FRL) was also reduced to +136 ft in 1979 to reduce the load on the dam as well as for giving more room for flood storage. This reduced FRL is being maintained even today. In spite of the above strengthening measures, the dam has not gained adequate strength to function further.

Genuine apprehension regarding the safety of the dam persists in the minds of the people residing downstream and becomes aggravated during the rainy season.

The century old Mullaperiyar Dam has already outlived its useful life. The consequence of any failure of this dam could be catastrophic and its outcome beyond all human imagination. In this background, State of Kerala decided to ascertain the safety of this century old dam as per modern standards. For this purpose, IIT, Delhi was entrusted with the task of evaluating the hydrological safety. IIT, Delhi after detailed evaluation of PMF and flood routing study, concluded that the present Mullaperiyar Dam is hydrologically unsafe. The studies carried out by IIT, Roorkee have found out that the present dam is structurally unsafe to withstand the impact of the probable earthquakes that can reasonably be expected to occur in the vicinity of the dam.

Idukki Hydro Electric Project with a gross storage of about 2000 MCM is existing just downstream of the Mullaperiyar Dam. Collapse of the Mullaperiyar Dam will trigger a cascading failure of the Idukki group of dams resulting in an unimaginable degree of devastation in the thickly populated districts of central Kerala. Studies have brought out the fact that Idukki reservoir cannot accommodate the water retained by the Mullaperiyar dam even up to +136 ft in an unfortunate event of its collapse. The gross storage capacity of Idukki reservoir at MWL is 74.4 TMC and at FRL is 70.5 TMC. The MWL of Idukki reservoir would have exceeded if failure of Mullaperiyar dam had occurred on 13/11/1981, 18/11/1992, 09/11/1994, 15/11/1998, 17/09/2005 and 28/09/2007, as combined storage of Idukki reservoir and Mullaperiyar would have surpassed its gross storage capacity on those days. The threat frequency of

concurrent filling of Idukki has thus happened in 6 out of 32 years after 1979, when the water level in Mullaperiyar reservoir was lowered to 136 ft on safety considerations.

There is a limit to the number of years one can keep dams in service through maintenance and strengthening measures. In the case of Mullaperiyar dam, the dam has to be there for another 884 years for diverting water to Tamil Nadu as per Lease Deed. This is an impossible proposition. All over the world, safety of dams are being reviewed as per modern standards and hundreds of dams have already been dismantled considering the safety aspects of human life and property. In developed countries like USA, UK, Canada and Australia it has become common practice to replace old unsafe dams by new dams designed and constructed as per modern standards. Rebuilding of a new dam upstream side of the old Victoria Dam in Australia in 1991 is one such example.

In view of the definite conclusions of the scientific studies conducted by National Institutions of repute and the persistent threat which the dam poses, it is imperative that the present old Mullaperiyar Dam demands urgent decommissioning for discharging the responsibility of the State to protect the lives and properties of its citizens. From 1895 onwards, State of Tamil Nadu is utilizing the waters of Mullaperiyar Dam for irrigation and drinking water requirements. State of Kerala does not desire to deprive Tamil Nadu of the Mullaperiyar waters on which their needy farmers are greatly dependent. Hence, State of Kerala has taken a decision to build a new dam downstream of the present Mullaperiyar Dam to achieve the twin goals of protecting the lives and properties of its people and for ensuring continued supply of water to Tamil Nadu. The new dam proposed is on the downstream of the old dam at a distance of 366 m with

the objective of carrying out the construction activities without affecting the structural safety of the old dam. This will further ensure continued drawal of the water by Tamil Nadu even during the period of construction of the new dam. The old dam will be demolished only after completion of the new dam and as such diversion of river flow for carrying out the construction of new dam will not be a major problem.

The new dam proposed below the existing dam is a concrete gravity structure having a length of 370.10 m and a height of 53.22 m from the deepest foundation. A saddle dam of length 137.00 m and height of 25.00 m will also be needed on the left flank abutting into the hill portion in between. The catchment area intercepted by the old dam is 624 sq. km, which lies entirely in the territory of State of Kerala. The new dam intercepts an additional catchment of 50.2 Ha. The total catchment area of the new dam is thus 624.5 Sq. km. The present water diversion structures viz. leading channel, intake arrangement, tunnel, etc. will remain unchanged as they are located independently of the dam structure on the upstream area of the reservoir and hence not forming part of the existing dam. As such, the present arrangement of water diversion to Tamil Nadu will continue to function uninterruptedly during the construction of the new dam and also after its commissioning.

1.2 Location

The old Mullaperiyar Dam is located in Peerumedu Taluk of Idukki District of State of Kerala. It lies inside the Periyar Tiger Reserve area. The new dam is proposed to be located at 366 m below the centerline of the existing dam. The centre line of the proposed alignment of the new dam is oriented at about 5^0 East of North. The proposed structure consists of a main dam and a saddle dam on the left flank. The right bank end of the

main dam lies at Latitude $9^0$31′48″N and Longitude $77^0$08′33″E and the left bank end of the saddle dam lies at Latitude $9^0$31′26″N and Longitude $77^0$08′33″E. The present alignment tends at N10^0W-S10^0E and runs parallel to the axis of the existing dam.

1.3 Access

The nearest airport is Cochin International Airport at Nedumbassery, which is 180 km away from the dam site. The nearest railway station is Kottayam, 110 km away. By road, one can reach Vandiperiyar through NH-220 and from there to Vallakadavu (located 8 km away) through Moozhiyar (Gavi) road. From Vallakadavu, the dam site can be reached by travelling 5 km along a forest jeep road. This existing road is to be suitably realigned and improved to facilitate transportation of required tools and plant and construction materials. The road network to the dam site through the forest area is to be planned and developed for taking up the construction activities.

1.4 Climate

There are no well defined seasons in Kerala State. The Summer and Winter are practically controlled by the South West and North East monsoons which are peculiar to the west coast of India. The Autumn and Spring seasons are practicably indistinguishable in regard to the climatic conditions. The South West monsoon remains active after middle of May upto September, while North East monsoon between October and middle of December. The period from January to middle of May is generally dry and the months of March and April form hot summer.

The average rainfall in the catchment is 2204 mm and the two periods of monsoons generally account for 76.22%of the annual rainfall based on the data from 1985-2010.

The catchment experienced a flood with volume of 34103 Mcft (155.87 cm in the catchment) for 21 days in July 1924. The catchment experienced another flood with a volume of 5118Mcft (23.38cm in the catchment) for a duration of 2days in January 1943, and again experienced a flood for 6-7 days with a volume of 13283 Mcft (60.67 cm in the catchment) in June 1961. The one day maximum observed point rainfall in a station (lat $10^0$06'N and long $77^0$04'E), very near to Mullaperiyar catchment, was observed on 16/7/1924 as 31.7 cm (Page 47 of the Central Water Commission Dam safety project Generalized PMP Atlas published by WAPCOS). The value read from the same Atlas in Figure 18 for 15/7/24 is 24cm. The estimates of one day PMP on page 15 of the WAPCOS Atlas of three stations near this catchment are 58.88 cm (Peermade residency), 64.16 cm (Peermade Taluk) and 48.3 cm at (Sivagiri). The data indicates that the area is situated in high rainfall zone and is referred to as Zone 101 in the WAPCOS Atlas.

1.5 Topography, Physiography and Geology of the Area

The hills and mountains in the region form part of the western ghat system. The general direction of the ranges is roughly North West-South East. The western slopes of the ghats are steeper and sheet rock exposed at many places is evidently due to heavier rainfall and better drainage. The eastern slopes are comparatively gentle.

The greater part of Periyar Basin is covered by rocks of the Archean group representing Pre-Cambrian formations of which the gneisses, schists and charnockites are predominant. Gneisses rock consists of very heterogeneous mixture of different types of granites intruded into schistose rocks after the latter were folded crumpled and metamorphosed.

The project zone lies in Seismic Zone III (IS 1893 Part I: 2002) as per Zoning map of India.

1.6 Population

The entire area is forest land inside the Periyar Wild Life Sanctuary with no habitation. Hence there will not be any necessity for rehabilitation and resettlement.

1.7 Land Use

The new dam submerges an additional area of 22.23 ha at an FRL of 136ft. The total land required for diversion including submergence area,batching plant, machinery and temporary buildings is 50 ha.

1.8 History

As early as in 1979, a team of engineers headed by the then Chairman, CWC had made a specific recommendation to construct a new dam as a permanent solution. In pursuance of the above recommendation, a joint team of engineers of Kerala and Tamil Nadu made a reconnaissance survey of the area downstream of the existing Mullaperiyar Dam. The team located a technically suitable site for a new dam 366.0 m (1300 ft) downstream of the present dam where a new dam could be constructed without affecting the safety of the old one. As part of further investigation, 19 boreholes were also taken during the period 1981-82 and found that good rock is available for founding the dam. But this proposal for construction of a new replacement dam was however not pursued at that time.

1.9 Alternative Studies

Preliminary investigation revealed the possibility of three alignments within a kilometer downstream of the existing Mullaperiyar Dam and in the territory of the State of Kerala. They were identified at distances of 366.00 m, 622.80 m and 749.90 m from the centre line of the present dam.

1.10 Inter State Aspects

Periyar river basin is the second largest basin of Kerala with a drainage area of 5398 sq km of which 114 sq km lies in the State of Tamil Nadu. But as far as Periyar River is concerned it is not an interstate river, but purely an intra state river. State of Tamil Nadu has absolutely no riparian right on the waters of this river except that derived from the lease deed of 1886. As far as Mullaperiyar reservoir is concerned, the entire catchment lies in the territory of the State of Kerala. The present/proposed dams and its entire submergence area also lie in the State of Kerala.

2. PHYSICAL FEATURES

Periyar is the longest river in the State of Kerala, and also the largest in potential, having a length of 244 km originates in the Sivagiri group of hills at an elevation of about +1830 m above MSL. This river basin is the second largest basin of Kerala State with a drainage area of 5398 sq km of which 114 sq km in the Anamalai fold lies in the State of Tamil Nadu. The Periyar Basin lies between 09^0 15′ N to 10^0 20′ N and longitude 76^0 10′ E to 77^0 30′E. From its origin, Periyar traverses through an immense cliff of rocks in a northerly direction receiving several streamlets in its course. About 48 km downstream, the Mullayar joins the main river at an elevation of +854 m above MSL. Afterwards, the river flows westwards and at about 11 km downstream of the confluence of Mullayar and Periyar, the river passes through a narrow gorge, where the present Mullaperiyar Dam is constructed in 1895. The name Mullaperiyar is derived from a portmanteau of Mullayar and Periyar.

Below the Mullaperiyar Dam, the river flows in a winding course taking a north westerly direction. On its travel down, it is enriched by many tributaries like Kattappana Ar, Cheruthoni Ar, Perinjankutty Ar, Muthirapuzha Ar and Idamala Ar. Lower down of Malayatoor; the river takes a meandering course and flows calmly and majestically for about 23 km through Kalady and Chowara and reaches Alwaye. Here, the river bifurcates into the Managalapuzha branch and the Marthanda Varma branch. The Managalapuzha branch flows in a northwesterly direction and is joined by Chalakudy Ar at Puthenvelikara. After receiving Chalakudy Ar, the Periyar expands itself into a broad sheet of water at Munambam and finally falls into the Arabian Sea. The Marthanda Varma branch flows

in a southerly direction. This branch splits up into two and flows through the industrial belt in the basin and ultimately falls into the Vembanad Lake at Varapuzha. Thus the entire length of the Periyar River flows through the territory of the State of Kerala before it empties into the Arabian Sea.

The Periyar reservoir is in a sheltered zone surrounded by high hills. The entire reservoir catchment is a protected wild life sanctuary area with dense forests.

3. INTERSTATE ASPECTS

The river Periyar is the longest of all rivers in the State of Kerala. It is having a length of 244 km which flows through the territory of State of Kerala. Periyar river basin is the second largest basin of Kerala with a drainage area of 5398 sq km of which 114 sq km lies in the State of Tamil Nadu. Under the Parambikulam Aliyar Project Agreement of 1970, State of Tamil Nadu diverts water from this 114 Sq.Km of catchment to their territory. As far as Mullaperiyar reservoir is concerned, the entire catchment lies in the territory of the State of Kerala. The present/proposed dams and its entire submergence area lie in the State of Kerala. So State of Tamil Nadu has no riparian rights in the waters of Mullaperiyar reservoir.

A Lease Deed made between the Secretary of State for India and the Maharaja of Travancore signed in the year 1886 to facilitate the waters of Periyar for the use of irrigation in the territory of then Madras Presidency. As per the provisions of the deed, His Highness, The Maharaja of Travancore had given full right, power and liberty to execute the Periyar Project structures for utilizing the waters for a period of 999 years. For the Project, an area of 8000 acres or thereabouts of land for submergence and another 100 acres of land for execution and preservation of the irrigation works were also leased out to Madras Government. Mullaperiyar Dam was constructed to divert all the waters of Periyar River to Vaigai basin. Though the right of Tamil Nadu is of a lessee, the dam is now owned, operated and maintained by Government of Tamil Nadu.

Periyar River is not an interstate river, but purely an intra state river. State of Tamil Nadu has absolutely no riparian right on the waters of this river except that derived from the lease deed of 1886.

4. SURVEY AND INVESTIGATIONS

4.1 Topographical survey

4.1.1 River survey

As per the guidelines of Central Water Commision(CWC) for investigation of Irrigation Projects, river surveys for a length of 10 km upstream and 10 km downstream of the diversion structure are to be carried out. On the basis of the survey a longitudinal section of the river was prepared and cross sections were taken 300m apart sufficiently above the HFL. In this case the observed maximum flood level during the 1924 was considered as the High Flood Level (HFL) for the survey.

River surveys are conducted at Periyar River from the existing dam to a length of 15.00 km. downstream of the proposed dam. The area covering up to a height of 840.00 m R.L. on either side of the Periyar River has been surveyed. Topographical map of the river basin on 1:1000 scale with 2 m contour interval is prepared. Cross sections were taken at an average interval of 200 m center to center along the river. Soundings are also taken for longitudinal section and cross sections where spot levels are required in water logged areas.

4.1.2 Reservoir Survey

The reservoir area of the old Mullaperiyar dam is 2644 hectares. When the construction of new dam is completed an area of 26 hectares lying between the existing dam and the new dam will also be added to the reservoir area. The area in between the old and new dam and the total area at different

elevations are worked out worked out and enclosed in Volume II of this report (DPR). Yields of the old and new catchments at different levels area worked out and enclosed in Volume II- Design & Drawings.

4.1.3 Dam Survey

Various merits and demerits of the three alignments are studied in great depth for selecting the final alignment. The following paragraphs contain a summary of the practical and technical points considered for each alignment in this regard.

The alignment at chainage 749.90 m is the farthest alignment from the existing dam. The advantages of this alignment are the probable economy in the cost of construction due to reduced length of main dam and the additional safety for carrying out excavation and construction as it is far away from the existing dam. However, the area of submergence of forest land in the wild life sanctuary is the maximum among the three, almost double the quantity of the closest alignment.

The alignment at chainage 622.80 m has the advantage of a straight alignment without a saddle. However, the length of the dam is 623.90 m, the longest of the three. This will invariably increase the cost of construction and is not advisable from economic point of view. The submergence area of forest land in the wild life sanctuary is also more.

The closest alignment to the existing dam is the one at chainage 366.00 m. It has the advantage of minimum submergence of forest land in the wild life sanctuary. Also the total length of the dam (including saddle) is the minimum among the three and has the definite advantage of the alignment intersecting the contours more or less perpendicularly. It is also

worth mentioning that a joint team of engineers of Kerala and Tamil Nadu had identified the same alignment as early as in 1980s and found the same technically the most suitable location for building a replacement dam without affecting the safety of the existing dam.

A Panel of Experts appointed by Government of Kerala, after inspecting and evaluating the merits and demerits of the above three suggested alignments, also recommended adoption of the closest alignment at chainage 366.00m for the replacement dam.

Topographical survey for the new dam alignment was conducted using Total Station. The area between the existing dam and 650 m downstream of the proposed new dam alignment was covered by the survey up to an elevation of +920 m. Accordingly a topographical map of the dam site with 2 m contour interval on 1:1000 scale was prepared.

4.1.4 Plant and Colony lay out

Locations of the batching plant, office buildings, quarters, etc. are marked at the site using Total Station survey. These can be accommodated in the left bank of the river, downstream of the alignment of the dam. Locations of cement store, workshop, labour sheds, water tank, stockyard for steel, stockyard for aggregates and belt conveyors, etc. are marked in a contour map included in Volume II of the DPR. The buildings will be of temporary nature and will be dismantled after the commissioning of the new dam. Final decision on the location of various components of plant and colony will be taken in consultation with the wild life authorities. The positions of cement store, workshop, labour sheds, water tank, stockyards for steel, stockyard for aggregates and belt conveyors, etc. are also located as shown in the contour map and included in the Volume II –Design & Drawings.

4.1.5 Intake and water conductor system

The present water diversion structures viz. leading channel, intake arrangement, tunnel etc. will remain unchanged as they are located independently of the old dam as well as new dam structure on the upstream area of the reservoir.

4.1.6 Catchment

The catchment area intercepted by the old dam is 624 sq km as estimated from the Survey of India Toposheets using GIS techniques, which lies entirely in the territory of State of Kerala. The new dam intercepts and additional catchment of 50.2ha. The total catchment area of the new dam is thus 624.5 Sq. km.

4.2 Other surveys

4.2.1 Communication Survey

Adequate communication facilities are already available to the nearest cities of the dam site by air, rail and road. No new communication surveys are needed now for new routes.

As stated earlier, the dam site can be reached by road NH 220 up to Vandiperiyar and from there to Vallakkadavu by travelling 8 km through Moozhiyar (Gavi) road and thereafter through 5 km forest road (Jeep road). It is proposed to improve the 3m wide existing Jeep road to a concrete carriage way of 5 m width, with 1.5m wide shoulders on either side with necessary widening at the hairpin bends. This road will serve as the access to the new dam area. Construction of a three-span concrete bridge of length 60 m and 5 minor culverts are also proposed to ensure all

weather accessibility to the dam site. Survey is needed for aligning this road, bridges and culverts. For electrical power, 3-phase line is available up to Vallakkadavu. From there electricity is to be made available to the dam site by laying underground cables. Necessary survey is to be undertaken for finalizing the best route alignment for the cable.

4.2.2 Right of way

As stated in para 4.2.1, a new road is to be aligned and constructed. This road will reach up to the top of the new dam. Another road is to be aligned from the front of the old spillway to reach the Vallakkadavu New Dam road. Suitable gradient is to be provided to this road to enable easy transport of dismantled dam materials. The existing dam from the old dam top to the spillway front is to be suitably formed.

4.3 Geology , Geotechnical features and Seismicity

4.3.1 Geology of dam site

As part of preliminary geological investigations for finding the quality of the rock available along the finally selected alignment, five boreholes were got drilled through M/s LBS Centre for Science & Technology, Thiruvananthapuram. The Subsoil Investigation Report of M/s LBS Centre for Science & Technology is included in Volume IV of this Report. According to the Report, the value of ultimate unconfined compressive strength of the rock extracted from the bore holes is 2400t/m2. They have recommended that it is possible to found the proposed dam on the hard rock present at the site.

The borehole explorations done by M/s LBS were witnessed by the Scientists of Centre for Earth Sciences Studies (CESS), Trivandrum and Geological Survey of India (GSI).

The GSI was entrusted with the geological mapping of the area of the new dam site. They have submitted two reports on the geotechnical investigation of the New Mullaperiyar Dam in August 2010 and September 2011. These reports were also included in the Volume IV of the Detailed Project Report. Geological mapping of the area shows that migmatitic charnockite and granite gneiss are the most dominant rock types, which are likely to be exposed in the foundation. Charnockite and Granite Gneiss are the hardest available rocks, ie, best suited for dam foundation. According to GSI, the foundation grade fresh rock is available between 1.58 m and 10.70 m depth. Assessment of the profile of the bed rock, through the exploration suggest need for two dams instead of a continuous one as the two dams would be separated by natural fresh rock barrier, between ch. 225 m and 282m, for 57m.

The first report of GSI (Geological Survey of India) was prepared, along with other observations, based on the loggings of 5 boreholes drilled and logged. As per the recommendations contained in this report of August 2011, 10 more bore holes were drilled and logged. The GSI report of September 2011 has further recommended to drill additional 13 bore holes for finalizing the foundation levels along the axis of the dam. Suitable changes in the gallery lay out etc in the main and saddle dams will be carried out after getting the recommendations of the GSI. In addition to this, they have recommended exploration of spillway area by drilling at least 8 more bore holes for ascertaining the fresh rock levels in the area of proposed energy dissipation arrangement of type II basin with basin

blocks. The design of the type II basin and the basin blocks will be finalized after getting the foundation rock levels from the drilled bore holes.

4.3.2 Regional Geology

The Mullaperiyar site lies on the western coast of India in the State of Kerala. The tectonic features near to the sites are the Periyar fault, Ottopalam Kuttampuzha Fault, and Kattagudi Kokkal Palani fault. There are several faults, shear zones and lineaments around the site which are seismogenic and have to be considered for the seismic hazard assessment. For the study of regional geology and tectonic set up of the region a 6° X 6° area bounded by latitudes 6.25°N and 12.25°N and longitudes 73.5°E and 79.5°E around the site has been considered.

The study area encompasses Kerala and Tamil Nadu states of South India. This forms part of Indian Peninsula and is one of the classic Archean terrains in the world. This region preserves all the elements of the well-developed Archean continental crust, such as the granulites, grantie gneisses and greenstone belts. The triangular shape of the southern part of the Indian Peninsula seems to have acquired its outline at the beginning of the Cretaceous and the major geological events in this part might have taken place during its existence in the Gondwanaland.

The Kerala region, consisting of Archean gneisses, charnockites, and Proterozoic khodalites and associated gneisses constitutes part of the 'charnockitic' mobile belt of South India. It seems that the region consisted of a system of rifts, which became filled with shallow water sediments derived from the surroundings. The west coast faulting marks the last

tectonic activity of the region during Late Cretaceous-Early Paleocene times. However, faulting in Late Cretaceous time responsible for separating India from Madagascar along the southwest coast of India were probably located at some distance west of the present coast. Occurrence of Late Cretaceous strata in the offshore basin and the available geophysical data indicate presence of fault to the about 50 km west of the coast, extending towards south from 19°15′ N.

Two major tectonic provinces could be recognized in the Kerala region, which are the Precambrian Tectonic Province and the Tertiary Tectonic Province. The Precambrian tectonic province comprises the higher ranges of the Western Ghats whereas, a narrow belt mostly between coastal and midland region extending from Trivandrum in the south to Kasaragod in the north constitutes the Tertiary Tectonic Province. The foothills and parts of the midland forms the western limb of a NNW plunging synclinorium, the axis of which is traceable from Tuticorin in the south to Dharwar and Belgaum in the north. The regional strike of foliation of Precambrian rocks is NW-SE to WNW-ESE with a steep dip towards SW. The Tertiary rocks are almost horizontal to sub-horizontal.

The region has been subjected to extensive folding as indicated by presence of different fold pattern. Rocks of the Precambrian tectonic province underwent many period of tectogenesis. Foliation pattern varies from NW-SE in the southern part of the state to NE-SW in the northern part (Nilgiri range). The E-W strike may possibly be the westerly continuation of the strike of the Nilgiris and may have a bearing on presence of the Palghat Gap. Based on a detailed structural analysis of the Precambrian rocks of Trivandrum and Quilon districts, established four

deformation phases have been established as manifested by structures of four generations.

Lineaments with (1) NW-SE to WNW-ESE, (2) NNW-SSE to N-S and (3) ENE-WSW trends have been identified within Archean territory of the Kerala region. In some cases, these coincide with the established fault zones like the Idamalayar fault, identifiable by the emplacement of basic dykes with their margins showing slickensided micaceous planes. The WNW-ESE trending lineaments are (1) Achankovil-Tambraparni shear zone, identified as a major shear belt of Proterozoic age. This shear zone limits the south Kerala Khondalite belt to the north with a distinct zone of highly sheared gneisses. South of it lies the parallel Tenmala shear and Shearing might have taken place during the Pan-African and prior to 550-540 Ma. Major WNW-ESE Bavali lineament show emplacement of rocks. Muvattupuzha-Thekkadi and Palghat Gap fracture zones are the other WNW-ESE lineaments. These fracture zones appear to extend into the coastal belt. Palghat Gap fracture and Achankovil-Tenmala shears show evidences of later reactivation and recent activity along these shears is indicated by earth tremors. Both the NW-SE and WNW-ESE lineaments often appear to be en-echelon in nature and the NW-SE trending lineaments are older as these have been disturbed by later WNW-ESE lineaments. Further, WNW-ESE lineaments also show activity as the fracture sets exhibit brittle displacement and occurrence of 1994 Wadakkancheri (Palghat Gap) earthquake (M=4.3).

The NNW-SSE to N-S lineaments is more prominent in the southern and northern extremity of the Western Ghats. These lineaments can be identified on the satellite images representing a series of prominent, generally intermediate lineaments (around 50 km length) mainly at the

contact zone between the steeply rising Western Ghats and step like coastal terraces. The WNW-SSE trending lineaments define a weak zone along which the west coast evolved by faulting, and the Western Ghat uplifted. Indirect evidences like the displacement of laterites and youthful geomorphological features indicate that these movements have extended throughout Tertiary and well into the Quaternary period. Recent tremors along the NNW-SSE Idamalayar lineament would indicate that this is active even today. The NE-SW to ENE-WSW lineaments is present both within the Western Ghats and in the coastal belt. The ENE-WSW fractures controls the west flowing rivers in the Western Ghats. It is suggested that the southernmost parts of the Western Ghats have been uplifted along these faults. Recent activity along these fractures is evident from the earth tremors occurring along these lineaments within the Western Ghats(e.g. the tremors along the Bodinayakkannur pass on June7-8, 1988.

In Tamil Nadu Precambrian crystalline rocks cover over 80 percent of the terrain and towards north, rocks of the Charnockite Group and migmatites are dominant. Faults and crustal fractures in the terrain trend NNE-SSW and in some localities are these features are marked by syenite, carbonatite and ultramafic emplacements. In this region several tectonic blocks have been recognized. These are southern Karnataka-North Tamil Nadu block, Coimbatore-Salem block, Madurai block and Trivandrum block. These blocks are separated by the Moyar-Bhavani-Attur fault, the Palghat-Cauvery fault and the Achankovil fault. The Madurai block, bounded by the Palghat-Cauvery fault in the north and the Achankovil fault in the south is also known as the Pandyan mobile belt. Again on the basis of different lithological assemblages, igneous intrusives, styles of deformation recognized independent tectonic blocks, separated by linear belts in the Tamil Nadu terrain. These blocks are the Yercaud-Madras

Tectonic Block (YM), the Dimbam-Tattakarai-Krishnagiri Block (DTK), the Gudiyattam-Arakkkonam Block (GA) and the Tiruchirapalli-Madurai-Palayamkottai (TMP).

The NE-SW fold trend is well defined in the Kalrayan, Chittery and Shevaroy hills. In the Nilgiri hills, the NE-SW trend is defined in the eastern part and in the western part the trend swerves to NW-SE, suggesting the culmination of the two trends in the Nilgiri hills. Studies near Chennai have brought out five generations of folds with concomitant metamorphism and anatexis. This style of folding is considered to have given rise to a series of culminations and depressions in the form of domes and basins, as near Tiruvannamalai. Faults and fractures in five directions, including E-W to WNW-ESE, NNE-SSW to NE-SW, ENE-WSW, N-S and NW-SE have been deciphered in the state. The E-W to WNW-ESE system is defined by the Moyar-Bhavani-Attur and Palghat-Cauvery faults, characterized by anorthosite, ultramafic and granite emplacements. The NNE-SSW faults are marked by syenite and carbonatite bodies in the northern part of Tamil Nadu and also define the crystalline-sedimentary contact near the east coast. The Mettupalaiam-Bhavani Sagar fault, skirting the southern and the southeastern foothills of the Nilgrir hills trends in a NNE-SSW direction.

In the study area, the Cauvery Shear Zone (Cauvery fault) is the most extensive tectonic feature that has been interpreted as an ancient suture zone. The feature is an E-W running zone with a maximum width of about 60 km and marks a line of division between the Dharwar Craton in the north and the Pandyan Mobile belt in the south. The western extension of the belt in Kerala constitutes the Wynad Schist Complex and towards the east coast of Tamil Nadu, the belt goes down under Phanerozoic sediments. Difference in structural styles is also defined in the terrains to

the north and south of the Cauvery Shear Zone (CSZ). Cauvery fault truncates the structural trend to the south of the suture zone in the Tiruchirapalli-Madurai-Palayamkottai block.

There are several other shear zones present in the study area. The Moyar-Bhavani shear zone (Moyar-Bhavani-Attur fault) has also been considered to be a suture zone. The Gangavalli shear zone trends in a NNE-SSW direction and marked by the presence of phyllonites and cataclasites. The NW-SE trending Achankovil Shear (AS) zone truncates the regional fabric and fold patterns in this part of Western Ghat hills ranges. This shear zone marks the northern boundary of the Kanyakumari-Tenkasi Belt (KTSB) running in a roughly NW-SE. Palar Lineament marking the contact between the Gudiyattam-Arakkonam Block (GA) in the north and Yercaud-Madras Block in the south is narrow when compared to the other three straight belts. It is marked by emplacement of granite bodies near Sholinghar and Tiruttani.

The study area is traversed by numerous lineaments. The major lineament directions coincide with known fault/shear directions, and that most of them originated, while the region was well within the Gondwanaland. The NW-SE faults were the earliest, and ultimately determined the configuration of the west coast. The WNW-ESE lineaments, hosting Proterozoic dykes in north Kerala, and early Paleozoic granites and pegmatites towards south, constituted intra-cratonic basin boundaries. The NE-SW to ENE-WSW fault lineaments are the youngest (Nair, 1990) as the recent activity is recorded in all the sets. Whereas, in Tamil Nadu, faults and fractures in five directions, including E-W to WNW-ESE, NNE-SSW to NE-SW, ENE-WSW, N-S and NW-SE are present in the state. Syenite,

carbonatite and ultramafic emplacements mark faults and crustal fractures in some localities.

4.3.3 Seismicity

The Mullaperiyar dam site lies on the western coast of India in the State of Kerala. It lies in Seismic Zone III as per the seismic zoning map of India where a maximum intensity of VII is expected.

The seismic hazard assessment of the old dam has been carried out using deterministic as well as probabilistic approach by the IIT Roorkee. The safety of the old dam was checked for a recommended MCE condition with a peak ground acceleration of 0.21g. This recommendation is followed in the design of New Mullaperiyar Dam also.

5. HYDROLOGY

5.1 Working Table

The existing Mullaperiyar reservoir is having a scheme catchment of 624 sq.km and the new dam intercepts an additional catchment of 0.5 sq.km. Hence the total catchment area under the new dam is 624.5 sq.km.

The monthly rainfall details of the rainfall gauge station in the Mullaperiyar Dam for the last 25 years, ie, from 1985-86 to 2009-10 are available from the records of the field office. The above data is reproduced as **Table-1**. The annual average rainfall for the last 25 years is 2204 mm and out of this 76.2%, ie, 1680mm, occurs during the monsoon period of June-October. The maximum annual rainfall recorded during the above period was 3652 mm and the minimum rainfall recorded is 1338mm.

Regarding the inflow, annual inflow data for the last 50 years, ie, from 1960-2009 are available. But the monthly distribution of the inflow records is only available from the water years 1985-86 to 2009-10 (25 years). The Annual Inflow series for the last 50 years (1960-2009) are analysed in detail. The annual inflow is reproduced in e **Table-2**.

The average inflow recorded is 665.24MCM while the 50% dependable inflow is 628.22MCM. The 75% dependable inflow is worked out as 523.04 MCM and the 90% and 98% dependable inflow into the reservoir are 398.22 MCM and 270.22 MCM respectively. The maximum inflow of 1581.96 MCM is observed in the year 1961 and the minimum inflow of 270.20 MCM is observed in the year 2003. The monthly inflow data is

processed and reproduced as **Table -3**, which is used for preparation of the working table.

Water Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1985-1986	773.50	249.50	174.50	127.00	99.00	94.00	44.50	10.00	25.00	17.00	19.00	46.50	**1679.50**
1986-1987	210.00	214.50	457.00	97.50	101.00	158.00	10.00	5.00	0.00	48.00	29.00	57.00	**1387.00**
1987-1988	190.00	66.50	307.60	197.60	196.00	174.70	124.00	0.00	0.00	80.00	179.50	54.00	**1569.90**
1988-1989	253.00	285.00	339.00	280.00	22.00	46.00	11.00	0.00	0.00	55.50	89.00	54.00	**1434.50**
1989-1990	472.00	944.00	145.00	159.50	217.00	91.00	5.00	62.00	10.00	18.00	53.00	300.00	**2476.50**
1990-1991	601.00	355.00	230.00	56.00	313.00	269.00	20.00	9.00	25.00	14.00	110.00	93.00	**2095.00**
1991-1992	945.00	871.00	214.00	119.00	208.00	113.00	5.00	0.00	36.00	0.00	46.00	206.00	**2763.00**
1992-1993	826.00	716.00	335.00	291.00	305.00	518.00	34.00	0.00	31.00	47.00	65.00	131.00	**3299.00**
1993-1994	340.00	564.00	278.00	73.00	372.00	250.00	38.00	30.00	20.00	13.00	65.00	64.00	**2107.00**
1994-1995	442.00	566.00	350.00	198.00	425.00	223.00	0.00	2.00	0.00	45.00	111.00	323.00	**2685.00**
1995-1996	390.00	409.00	406.00	359.00	137.00	173.00	0.00	23.00	4.00	38.00	114.00	46.00	**2099.00**
1996-1997	381.00	561.00	220.00	251.00	195.00	13.00	55.00	0.00	0.00	46.00	144.00	72.00	**1938.00**
1997-1998	125.00	446.00	325.00	217.00	400.00	354.00	129.00	0.00	3.00	0.00	139.00	179.00	**2317.00**
1998-1999	442.00	475.00	257.00	279.00	359.00	250.00	96.00	0.00	22.00	3.00	67.00	396.00	**2646.00**
1999-2000	362.00	423.00	161.00	79.00	393.00	64.00	13.00	9.00	258.00	7.00	47.00	76.00	**1892.00**
2000-2001	428.00	205.00	744.00	105.00	61.00	86.00	93.00	22.00	23.00	3.00	358.00	66.00	**2194.00**
2001-2002	443.00	468.00	303.00	176.00	222.00	209.00	18.00	0.00	10.00	100.00	47.00	147.00	**2143.00**
2002-2003	214.00	179.00	220.00	10.00	298.00	78.00	42.00	1.00	23.00	39.00	184.00	50.00	**1338.00**
2003-2004	246.00	291.00	205.00	87.00	539.00	89.00	5.00	11.00	0.00	35.00	98.00	327.00	**1933.00**
2004-2005	646.00	169.30	436.00	180.80	287.00	81.00	0.00	64.00	29.00	64.00	122.00	68.00	**2147.10**
2005-2006	454.00	890.00	206.00	443.00	229.00	255.00	100.00	22.00	5.00	113.00	62.00	372.00	**3151.00**
2006-2007	309.00	467.00	312.00	432.00	470.00	164.00	65.00	0.00	6.00	12.00	180.00	24.00	**2441.00**
2007-2008	725.00	834.00	390.00	620.00	466.00	131.00	106.00	4.00	65.00	209.00	76.00	26.00	**3652.00**
2008-2009	380.00	378.00	378.00	172.00	347.00	52.00	24.50	1.00	3.00	78.00	31.00	71.50	**1916.00**
2009-2010	251.00	550.50	130.40	241.70	131.20	211.10	18.00	26.60	0.00	23.90	165.30	57.00	**1806.70**
Average	**433.94**	**463.09**	**300.94**	**210.04**	**271.69**	**165.87**	**42.24**	**12.06**	**23.92**	**44.34**	**104.03**	**132.24**	**2204.41**

Table -1 Rainfall in Mullaperiyar Dam (mm) 1985-2010

Year	Inflow in MCM		Year	Inflow in MCM
1960	1511.28		1985	687.34
1961	1581.96		1986	503.08
1962	748.50		1987	407.34
1963	591.06		1988	427.62
1964	761.78		1989	748.19
1965	359.97		1990	669.05
1966	660.61		1991	581.09
1967	440.90		1992	1060.08
1968	610.68		1993	588.09
1969	475.78		1994	834.96
1970	573.42		1995	651.12
1971	718.18		1996	674.62
1972	515.96		1997	823.32
1973	578.18		1998	854.04
1974	597.06		1999	523.04
1975	790.98		2000	592.50
1976	336.07		2001	605.90
1977	764.11		2002	334.14
1978	613.83		2003	270.20
1979	897.08		2004	642.60
1980	604.37		2005	762.89
1981	831.95		2006	784.66
1982	398.22		2007	913.34
1983	476.75		2008	642.77
1984	661.06		2009	580.50

Table 2 – Annual Inflow in MCM (1960-2009)

Water Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1985-1986	133.004	106.484	44.228	40.815	55.966	98.502	59.050	17.808	27.126	15.371	18.196	8.606	**625.156**
1986-1987	28.070	51.923	172.453	24.652	52.646	61.277	24.572	14.772	3.176	7.955	3.093	12.751	**457.340**
1987-1988	19.991	9.546	43.391	25.390	95.543	87.682	84.378	13.430	6.220	12.862	24.406	9.090	**431.930**
1988-1989	46.540	73.530	62.905	88.428	28.458	44.490	13.650	5.107	0.476	10.403	7.950	5.779	**387.714**
1989-1990	72.234	344.447	96.453	49.290	69.172	89.996	28.738	86.225	9.203	7.985	7.447	10.058	**871.249**
1990-1991	63.770	62.376	61.945	13.861	140.583	150.332	56.154	22.412	5.494	8.963	10.572	0.453	**596.915**
1991-1992	108.995	170.902	98.055	22.291	39.404	76.788	15.239	5.032	6.403	2.276	9.347	18.316	**573.047**
1992-1993	122.875	195.288	133.556	97.694	159.869	270.421	40.338	11.601	4.605	11.673	5.665	5.623	**1059.208**
1993-1994	19.899	87.062	95.557	19.320	76.361	195.900	54.050	26.182	18.658	6.414	13.231	3.040	**615.676**
1994-1995	59.293	146.916	118.882	78.695	143.612	135.342	24.284	16.561	3.713	5.594	13.256	46.425	**792.574**
1995-1996	59.547	125.748	70.548	200.403	41.952	57.634	9.746	11.226	6.306	5.108	14.670	2.792	**605.680**
1996-1997	60.386	157.277	79.789	76.471	176.228	37.098	47.263	9.564	2.432	5.050	7.022	7.602	**666.180**
1997-1998	4.724	46.497	75.930	50.189	159.421	294.944	159.946	33.635	12.859	4.766	5.638	12.550	**861.098**
1998-1999	47.461	119.157	102.024	64.652	112.243	153.679	185.375	23.707	11.110	1.693	3.565	21.818	**846.484**
1999-2000	64.264	92.193	63.968	20.752	132.111	53.732	34.129	19.289	19.284	13.951	3.053	4.012	**520.736**
2000-2001	72.559	65.633	212.108	82.701	48.487	27.421	24.017	59.811	11.583	2.827	26.871	7.723	**641.743**
2001-2002	27.495	114.220	61.108	38.153	89.104	134.368	32.638	17.251	15.653	4.557	5.237	11.306	**551.089**
2002-2003	12.183	15.483	62.138	10.232	66.068	93.683	20.350	3.551	8.448	6.462	8.347	8.660	**315.604**
2003-2004	9.317	25.484	23.760	10.113	88.087	56.521	21.439	8.968	3.557	1.262	4.979	21.299	**274.787**
2004-2005	138.140	35.329	108.772	46.878	121.372	124.114	27.938	10.893	8.610	5.033	20.632	8.070	**655.781**
2005-2006	26.607	166.495	163.758	111.349	66.902	90.950	83.580	23.771	9.206	16.087	10.657	19.991	**789.353**
2006-2007	40.812	91.718	64.366	75.680	141.397	252.621	38.364	13.888	4.553	3.081	11.919	1.928	**740.328**
2007-2008	61.291	205.727	94.034	137.667	155.464	149.059	74.716	18.818	37.073	88.636	33.922	2.853	**1059.259**
2008-2009	15.862	72.311	95.898	67.535	125.121	49.995	34.748	8.765	2.591	4.871	4.003	1.160	**482.860**
2009-2010	10.571	135.910	37.421	70.672	71.573	192.595	40.354	16.321	4.705	2.349	4.856	5.661	**592.988**
Average	**53.036**	**108.706**	**89.722**	**60.955**	**98.286**	**119.166**	**49.402**	**19.944**	**9.722**	**10.209**	**11.141**	**10.303**	**640.591**

Table 3 – Monthly Inflow in MCM (1985-2010)

Similarly the diversion to the State of Tamil Nadu from the Mullaperiyar reservoir from 1963-64 to 2009-10 is reproduced in **Table -4**. The analysis revealed that the average annual diversion from the existing Mullaperiyar reservoir to the State of Tamil Nadu is 585.640 MCM while the 50% and 75% dependable diversion are 603.775 MCM and 502.91 MCM respectively. The maximum diversion and the minimum diversion done were 884.00 MCM and 288.07 MCM respectively. The monthly diversion data is available for the period 1985-86 to 2009-2010, ie last 25 years. The above data is given in **Table -5.**

Even though, the 75% dependable diversion from the Mullaperiyar reservoir since 1963 is only 502.91 MCM, State of Kerala has proposed for an assured diversion of 580.150 MCM subject to availability of the inflows. The Vaigai Reservoir of Tamil Nadu, which collects the diverted flows from Mullaperiyar before releasing for irrigation to their ayacut gives a lot of flexibility of operation for Tamil Nadu. Keeping this in mind, to arrive at an optimum monthly diversion pattern for the working table, the monthly data was critically analysed for various scenarios. The final monthly diversion pattern arrived is given below:

Month	**Diversion (MCM)**
Jun	31.059
Jul	80.652
Aug	95.565
Sep	74.340
Oct	71.212
Nov	88.036
Dec	58.400
Jan	45.844
Feb	22.091
Mar	6.855
Apr	2.280
May	3.818
Total	**580.151**

Year	Diversion		Year	Diversion
1963-64	481.25		1987-88	389.98
1964-65	573.42		1988-89	391.62
1965-66	356.62		1989-90	633.79
1966-67	515.68		1990-91	616.52
1967-68	417.73		1991-92	562.18
1968-69	634.36		1992-93	828.27
1969-70	500.25		1993-94	619.18
1970-71	583.22		1994-95	787.58
1971-72	720.38		1995-96	631.89
1972-73	502.91		1996-97	661.09
1973-74	510.27		1997-98	660.13
1974-75	574.16		1998-99	770.42
1975-76	706.71		1999-00	551.87
1976-77	319.87		2000-01	653.95
1977-78	720.98		2001-02	669.33
1978-79	615.87		2002-03	296.37
1979-80	649.17		2003-04	288.07
1980-81	590.01		2004-05	578.80
1981-82	738.79		2005-06	683.83
1982-83	400.54		2006-07	695.15
1983-84	603.78		2007-08	884.00
1984-85	737.71		2008-09	610.32
1985-86	586.08		2009-10	579.52
1986-87	441.24		**Average**	**585.64**

Table 4 – Annual Diversion to Tamil Nadu in MCM (1963-2010)

Water Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1985-1986	21.951	113.665	93.107	58.551	44.895	71.865	75.293	50.882	20.619	19.015	0.441	14.605	**584.889**
1986-1987	8.603	24.169	97.271	86.660	61.229	70.905	35.741	22.932	11.278	7.032	6.632	7.758	**440.210**
1987-1988	10.012	14.404	14.749	22.531	30.063	89.463	46.420	88.443	48.930	11.527	0.536	12.656	**389.734**
1988-1989	38.089	48.990	71.607	63.573	54.439	44.719	38.126	9.919	6.365	2.277	5.275	6.514	**389.893**
1989-1990	16.028	67.016	133.483	101.434	72.483	57.233	61.618	48.833	30.988	22.875	18.153	2.489	**632.633**
1990-1991	53.232	82.092	65.870	34.129	36.547	109.649	96.114	46.663	65.729	23.147	3.037	0.000	**616.209**
1991-1992	59.238	94.435	125.306	93.160	51.790	49.887	39.113	21.822	11.589	6.605	5.042	3.886	**561.873**
1992-1993	36.515	109.393	140.335	121.290	134.358	106.212	58.138	43.668	40.887	28.292	0.000	7.319	**826.407**
1993-1994	42.957	44.417	105.744	48.113	37.063	99.805	59.442	51.305	62.667	52.765	11.227	1.824	**617.329**
1994-1995	33.376	86.463	131.600	113.570	108.154	113.335	89.596	59.131	22.485	5.663	0.570	13.985	**777.928**
1995-1996	54.969	86.482	98.785	135.210	105.488	74.967	36.122	12.177	9.249	6.691	6.410	3.743	**630.293**
1996-1997	19.047	60.954	125.648	96.458	116.845	80.960	103.103	27.280	13.096	5.788	4.942	5.651	**659.772**
1997-1998	3.149	11.790	58.649	51.733	80.219	136.317	140.276	91.311	57.343	24.713	2.321	1.998	**659.819**
1998-1999	31.613	100.297	100.014	91.093	85.764	116.486	102.448	90.163	45.081	5.200	0.000	2.448	**770.607**
1999-2000	31.936	97.358	107.098	45.268	59.783	90.600	57.211	31.527	19.272	3.938	0.000	1.712	**545.703**
2000-2001	64.551	87.721	71.851	115.110	106.814	59.679	32.242	89.601	24.064	4.211	0.000	1.528	**657.372**
2001-2002	65.206	110.368	96.490	50.878	60.861	89.839	82.842	61.452	34.342	10.947	1.283	1.722	**666.230**
2002-2003	6.728	15.916	36.003	25.595	45.795	77.423	51.871	17.905	8.618	1.521	2.714	0.616	**290.705**
2003-2004	15.514	18.981	24.667	23.570	46.201	68.686	29.869	28.453	10.386	1.530	1.712	8.450	**278.019**
2004-2005	65.652	90.638	90.849	52.131	79.560	89.607	90.398	44.330	19.717	6.977	6.836	3.965	**640.660**
2005-2006	18.096	53.173	136.798	113.192	92.271	68.368	40.253	46.440	41.811	29.132	17.336	5.016	**661.886**
2006-2007	58.438	80.910	73.434	75.667	83.571	95.862	103.314	76.376	19.994	11.215	10.346	4.140	**693.267**
2007-2008	10.727	126.066	134.229	103.935	123.238	140.799	86.659	61.671	66.893	27.394	0.000	2.445	**884.056**
2008-2009	26.924	102.510	98.282	97.101	86.058	94.921	56.069	27.365	13.753	1.144	0.980	5.211	**610.318**
2009-2010	8.457	62.896	73.051	57.864	69.884	107.903	107.556	60.645	23.353	4.338	0.438	3.139	**579.524**

Table 5 – Monthly Diversion of Water to Tamil Nadu in MCM (1985-2010)

The deficit, if any, in a particular month will be carried over only to the subsequent month. If the surplus water is available in the subsequent month it is released but the carryover will be limited to the subsequent month only. Carry over from a water year is not passed on to the subsequent water years. The evaporation losses are estimated from the evaporation loss data made available by the Tamil Nadu Public Works Department and is given in **Table- 6.** An average monthly evaporation loss obtained from the above database is used in the working table.

Also an allocation for catering to the environmental flow at the rate of 2.5cumecs from January to May (Summer month period) is provided in the working table. The environmental flow is worked out as around 5% of the average inflow.

Summary of the working table from 1985-86 to 2009-10 is given as **Table -7.** The detailed monthly workout of the working Table is given as **Table -8.** The working table ensures 50% dependable diversion of 580.151 MCM to Tamil Nadu, which is equal to the assured diversion to Tamil Nadu offered by the State of Kerala. The 75% dependable diversion is 515.22 MCM which is more than 502.91 MCM diversion *(75% dependable diversion between 1963-2010).*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2001	1.501	1.189	1.492	0.552	1.369	1.172	0.430	0.579	0.968	0.535	0.977	1.510	**12.277**
2002	1.396	1.047	1.369	1.130	0.948	2.871	0.395	0.553	1.436	0.579	0.926	0.974	**13.624**
2003	1.475	1.213	1.422	0.909	1.369	0.586	0.413	0.000	0.000	0.000	0.000	0.000	**7.387**
2004	0.000	1.388	1.457	0.934	0.316	0.357	2.010	2.914	0.476	0.562	0.892	1.668	**12.974**
2005	1.089	1.554	1.282	0.875	1.255	1.563	0.000	0.806	0.801	0.623	0.552	1.466	**11.866**
2006	1.738	1.982	1.668	1.419	0.904	0.917	0.228	0.711	0.314	0.114	0.595	1.501	**12.092**
2007	1.185	1.150	1.440	0.994	1.303	0.960	0.093	0.876	0.051	0.013	0.824	1.519	**10.407**
2008	1.887	1.092	0.737	1.843	2.590	0.374	0.363	0.290	0.076	0.246	0.850	0.781	**11.130**
2009	1.150	1.554	1.484	1.470	1.238	1.011	0.966	1.203	0.785	1.132	0.584	1.106	**13.682**
Average	**1.428**	**1.352**	**1.372**	**1.125**	**1.255**	**1.090**	**0.544**	**0.992**	**0.613**	**0.476**	**0.775**	**1.316**	**11.715**

Table 6 – Evaporation Losses in MCM (2001-2009)

Water Year	Intial Storage	Inflow	Evaporation loss	Env Flow	Water Available	Diversion to Tamil Nadu	Final Storage	Spill
1985-1986	623.317	625.156	12.338	32.616	1203.519	580.151	623.368	0.000
1986-1987	137.878	457.340	12.338	32.616	559.113	437.209	121.904	0.000
1987-1988	116.324	431.929	12.338	32.616	503.299	376.115	127.184	0.000
1988-1989	70.120	387.716	12.338	32.616	424.995	366.718	58.277	0.000
1989-1990	1470.507	871.248	12.338	32.616	2296.801	580.151	1588.334	128.317
1990-1991	1397.453	596.915	12.338	32.616	1949.414	580.151	1369.263	0.000
1991-1992	930.219	573.048	12.338	32.616	1465.102	535.306	847.129	82.668
1992-1993	1502.288	1059.208	12.338	32.616	2516.542	580.151	1570.515	365.877
1993-1994	856.743	615.674	12.338	32.616	1427.463	580.151	847.312	0.000
1994-1995	1471.814	792.573	12.338	32.616	2219.433	580.151	1511.572	127.710
1995-1996	1086.363	605.680	12.338	32.616	1650.423	567.688	981.261	101.474
1996-1997	880.373	666.182	12.338	32.616	1501.601	580.151	902.862	18.589
1997-1998	1004.554	861.099	12.338	32.616	1820.699	495.125	1106.497	219.077
1998-1999	1795.110	846.484	12.338	32.616	2596.640	580.151	1787.555	228.935
1999-2000	1045.304	520.738	12.338	32.616	1521.088	580.151	940.937	0.000
2000-2001	794.164	641.741	12.338	32.616	1390.951	580.151	810.800	0.000
2001-2002	249.513	551.090	12.338	32.616	761.528	541.163	220.366	0.000
2002-2003	4.872	315.605	12.338	32.616	281.702	276.830	4.872	0.000
2003-2004	16.399	274.786	12.338	32.616	259.506	233.577	25.929	0.000
2004-2005	863.675	655.781	12.338	32.616	1474.502	580.151	894.351	0.000
2005-2006	1584.040	789.353	12.338	32.616	2328.439	580.151	1678.530	69.759
2006-2007	1537.647	740.327	12.338	32.616	2233.020	580.151	1471.952	180.917
2007-2008	1852.106	1059.260	12.338	32.616	2866.412	580.151	1949.208	337.054
2008-2009	1309.892	482.860	12.338	32.616	1747.798	580.151	1156.379	11.269
2009-2010	338.079	592.988	12.338	32.616	886.113	560.625	325.488	0.000

Table 7 – Summary of Working Table (1985-2010)

5.2 Probable Maximum Flood

The Probable Maximum Flood (PMF) for the Project catchment is estimated by the IIT, Delhi. IIT, Delhi estimated the two day probable maximum precipitation as 687.8 mm based on the Report of for West Flowing Rivers of Western Ghats, WAPCOS, September 1999. They have proposed a unit hydrograph based on Nash method with n=2 and k=1.5 is recommended for the Project catchment. The Unit hydrograph is reproduced below:

Time in hrs	Runoff in cumecs	Time in hrs	Runoff in cumecs
0	0.00	12	3.22
1	410.39	13	1.79
2	421.41	14	0.99
3	324.54	15	0.54
4	222.16	16	0.30
5	142.58	17	0.16
6	87.84	18	0.09
7	52.62	19	0.05
8	30.87	20	0.03
9	17.83	21	0.01
10	10.17	22	0.01
11	5.75		

Table 8 – Unit hydrograph

Based on the above unit hydrograph, the PMF is worked out as 8676.30 cumecs. The recommended PMF hydrograph by IIT, Delhi is as follows:

Time in hours	Inflow in cumecs	Time in hrs	Inflow in cumecs
1	56.63	36	2317.92
2	179.30	37	2476.07
3	305.29	38	2688.59
4	402.30	39	2978.04
5	468.70	40	3219.22
6	511.32	41	3500.69
7	537.57	42	3734.59
8	553.31	43	4004.99
9	562.55	44	4221.02
10	570.70	45	4484.45
11	576.62	46	4808.11
12	580.58	47	5635.56
13	583.08	48	7630.58
14	737.01	**49**	**8676.30**
15	894.42	50	6911.13
16	1015.48	51	4822.95
17	1098.30	52	3144.04
18	1151.43	53	1970.50
19	1184.16	54	1208.00
20	1203.76	55	734.43
21	1215.25	56	449.11
22	1221.88	57	280.96
23	1225.67	58	183.52
24	1227.80	59	127.79
25	1229.01	60	96.25
26	1238.13	61	78.55
27	1252.86	62	68.70
28	1268.38	63	63.23
29	1280.41	64	60.23
30	1294.37	65	58.59
31	1308.30	66	57.68
32	1420.41	67	57.20
33	1642.27	68	56.92
34	1845.96	69	56.78
35	2101.12	70	56.63

Table 9 – PMF hydrograph

6. DESIGN FEATURES AND CRITERIA

6.1 Structure and layout

A Dam Design Committee was constituted by Government of Kerala for the design of the new dam at Mullaperiyar. Meetings of the Committee were held regularly and the design aspects discussed. The dam and appurtenant works are designed by the engineers of the Design Central Organization of the Irrigation Department (IDRB) who are also members of the Design Committee. The IDRB is headed by the Chief Engineer..The design parameters, assumptions, design details, relevant IS codes, methods of analysis etc are detailed in the following paragraphs.

6.1.1 General

For the new Mullaperiyar dam, straight gravity concrete dam is proposed. Suitable earth quarry is not available near the Mullaperiyar area. Speed of construction will be naturally less with an earth dam. Provision of spillway will require a concrete or masonry portion. Quarry for rubble is difficult to locate near the site and there is acute shortage of masons. In view of all these earth dam and rock fill dam options are ruled out.

Availability of materials for concrete such as coarse and fine aggregates and cement are available within reasonable distance from the site. Roads are available for the transport of these materials. Near the dam site, only a small stretch of existing dam is to be re aligned and widened. Speedy construction is possible with mechanisation. In view of these, it is decided to construct a straight gravity concrete dam. The spillway can also be located in the main dam in the river portion.

6.1.2 Geology, Seismicity and Foundation.

The head works of the new dam is proposed 366 m below the existing old Mullaperiyar Dam. 15 bore holes are drilled along the proposed alignment. In the first phase, 5 bore holes are drilled. Samples were taken from the above bore holes and tested in the laboratories. The officials of both GSI and CESS were present at the time of taking the bore holes and testing. The officials of both GSI and CESS were present at the time of bore hole exploration and it was as per the direction of GSI additional 10 no of bore holes are drilled along the same axis. The samples from the additional bore holes are also tested. GSI has submitted their report on the first 5 bore holes and also on the 10 additional bore holes. These reports are appended as stated earlier. Unconfined compressive strength has been obtained as 2400 t/m2.As per the observation of GSI, the rock existing below the proposed alignment is suitable for founding a dam and fresh rock is available between 1.58 m and 10.70 m below ground. GSI has pointed out the need for two dams, a baby and a main dam instead of a continuous one after assessing the profile of the bed rock. The two dams would be separated by a natural fresh rock barrier between ch: 225 m and ch: 282 m.

Exploration by a drill hole in the natural rock barrier has indicated the availability of charnockite gneiss much above the top of the dam. Permeability test was also conducted in the additional 10 bore holes and permeability range of 0 to 8.07 lugeons has been obtained. The minor preamble nature of the barrier can be controlled by extending curtain grouting. GSI has suggested in their second report (included in Vol IV-Annexures) to drill 13 additional bore holes to ascertain the fresh rock levels along the axis.

Details of geological investigation of the foundation by GSI, CESS (Centre for Earth Science Studies), LBS centre for Science and technology, College of Engineering, Thiruvananthapuram are already furnished in 4.3.1 geology of dam site.

The new dam has been designed for earthquake forces also. The site is located in seismic zone III as per seismic zoning map. The Peak Ground Acceleration (PGA) value of 0.21g recommended by the Department of Earthquake Engineering, IIT, Roorkee for the old Mullaperiyar Dam is considered for the pseudo static analysis of the dam. 2D Plain Stress static and dynamic analysis will be carried out before commencement of construction foe confirming the adequacy of the design evolved. The details of Seismicity have already been dealt with in 4.3.3 Seismicity.

Effect of self weight of dam, water pressure, soil and silt pressure of upstream side ,uplift pressure, wave pressure, weight of soil and silt in upstream side, weight of water on the upstream side and seismic forces have been taken into account for design. The dam section has been arrived at by analysing all the 7 load combinations prescribed in IS 6512-1984. The depth of tail water can be obtained only after model studies are conducted and as such effect of tail water has not been taken in the design. The effect of tail water and passive earth pressure will only add to the stability of the dam.

The maximum compressive stresses, tensile stresses and the principal stresses are found to be within the allowable limit as per the relevant IS codes in all the seven cases. Factor of safety against sliding and overturning are also

found to be within allowable limits. A free board of 1.5 m has been provided which satisfies the IS stipulations.

6.1.3 Alternate studies for fixing dam alignment

Preliminary investigation revealed the possibility of three alignments within a kilometer downstream of the existing Mullaperiyar Dam and in the territory of the State of Kerala. They were identified at distances of 366.00 m, 622.80 m and 749.90 m from the centre line of the present dam.

Comparisons of the Alignments

Features	**Distance of alignment from the existing dam**		
	366.00 m	**622.80 m**	**749.90 m**
Length of dam	Main - 370.3 m Saddle -137.0 m	Main -623.9m Saddle - Nil	Main – 367.6 m Saddle 177.0m
Bed level (MSL)	+828.00 m	+823.30 m	+826.60 m
Height of dam from river bed	45.50 m	45.20 m	46.90m
Area of submergence	22.23 ha	47.93 ha	54.34 ha

In the case of all the three alignments, spillway can be accommodated in the body of the main dam itself and in the river course. There is no necessity for

rehabilitation or resettlement of evictees as all the three sites are located well within the wild life sanctuary area with no inhabitants. Also the three alignments lie outside the protected area, as per Rule 8 of Defense of India Rule 1962. The protected area is fixed within 1000 feet from the toe of the existing dam.

Various merits and demerits of the three alignments are studied in great depth for selecting the final alignment. The following paragraphs contain a summary of the practical and technical points considered for each alignment in this regard.

The alignment at chainage 749.90 m is the farthest alignment from the existing dam. The advantages of this alignment are the probable economy in the cost of construction due to reduced length of main dam and the additional safety for carrying out excavation and construction as it is far away from the existing dam. However, the area of submergence of forest land in the wild life sanctuary is the maximum among the three, almost double the quantity of the closest alignment.

The alignment at chainage 622.80 m has the advantage of a straight alignment without a saddle. However, the length of the dam is 623.90 m, the longest of the three. This will invariably increase the cost of construction and is not advisable from economic point of view. The submergence area of forest land in the wild life sanctuary is also more.

6.1.4 Choice of final alignment

The closest alignment to the existing dam is the one at chainage 366.00 m. It has the advantage of minimum submergence of forest land in the wild life sanctuary. Also the total length of the dam (including saddle) is the minimum among the three and has the definite advantage of the alignment intersecting the contours more or less perpendicularly. It is also worth mentioning that a joint team of engineers of Kerala and Tamil Nadu had identified the same alignment as early as in 1980s and found the same technically the most suitable location for building a replacement dam without affecting the safety of the existing dam.

6.1.5 Design Flood and Sedimentation studies

The Department of Civil Engineering, IIT Delhi was entrusted with the study of determination of Probable Maximum Flood (PMF) of the Mullaperiyar catchment and Flood Routing studies with the PMF. A value of 8767 cumecs was recommended by the IIT. This value of PMF is taken as design flood for the design of New Mullaperiyar Dam.

Sedimentation surveys are proposed to be undertaken to find the extent of siltation that has occurred in the reservoir.

6.1.6 Free Board.

A free board of 1.5 m has been provided which satisfies the IS stipulations.

6.1.7 River Diversion Arrangements

The new Mullaperiyar dam is proposed to be constructed at a distance of 366 m from the existing dam. Overflow from the existing reservoir will happen only during flood season when state of Tamil Nadu is not able to draw water

due to rains in that area. This overflow will last only for a few of days and the quantity of water spill will not be substantial. Construction of new dam can be carried out by providing a diversion conduit of suitable size in a low block in the river portion. This diversion conduit can be plugged when the construction of the new dam is completed.

6.1.8 Construction Materials

Since it has been decided to construct a concrete gravity dam, large quantities of materials such as broken stones, sand, cement and steel are required. Considering the scarcity of river sand, it has been suggested to use crushed / manufactured sand (M-sand). The quarry for broken stones and crushed sand is identified at Chenkara which is at a distance of 35 km from the dam site. The samples from this quarry are tested at the Kerala Engineering Research Institute (KERI), Peechi and found satisfactory. Main concrete mixes are already carried out using both Ordinary Portland cement (OPC) and Portland Puzzolona Cement (PPC). The report of KERI containing mix details of M20, M25, M30 grades are included in Vol IV - Annexures. The design of mix M15 grade concrete is being done by KERI, Peechi.

6.1.9 Details of the Model studies for important structures.

Downstream protection is provided for energy dissipation for spillway portion. Type II basin with basin blocks are proposed for energy dissipation. The design will be modified taking into consideration the findings of the model study. The model study will be conducted in Kerala Engineering Rerseach institute (KERI), Peechi.

6.2 Dam

6.2.1 Concrete/Masonry Dam/Weirs

Effect of self weight of dam, water pressure, soil and silt pressure of upstream side ,uplift pressure, wave pressure, weight of soil and silt in upstream side, weight of water on the upstream side and seismic forces have been taken into account for design. The dam section has been arrived at by analysing all the 7 load combinations prescribed in IS 6512-1984. The depth of tail water can be obtained only after model studies are conducted and as such effect of tail water has not been taken in the design. The effect of tail water and passive earth pressure will only add to the stability of the dam.

The maximum compressive stresses, tensile stresses and the principal stresses are found to be within the allowable limit as per the relevant IS codes in all the seven cases. Factor of safety against sliding and overturning are also found to be within allowable limits.

6.2.2 Spillway

The design has been done for the section having maximum height. For finding the widths at base at the other portions, the corresponding dimensions are taken. Maximum head over crest is 5.85 m and design head for the spill way is taken as 5.2 m. Ogee type spill way is proposed.

Flood routing analysis is carried out based on the flood hydrograph, capacity curve and spillway rating curve for different number of vents. For 19 vents of 12 m width each, the MWL came to 155.20 feet (i.e., about 6 cm more than provided for). The results of the studies are included in Vol II Designs and

Drawings of the Detailed Project Report. Since the excess rise is only very small and exists only for a very short duration of one hour (the out flow is to be restricted to 1.22 lakh cusecs in view of the limited safe flood carrying capacity of the river downstream of the New Mullaperiyar Dam), number of vents is decided as 19. Two more vents are needed to take care of the 10% inoperative condition. Thus the total number of vents provided is hence 21.

The crest level and FRL is kept the same and hence actually no shutters are necessary. But since the out flow is to be restricted to 1.22 lakhs cusecs, whenever reservoir level reaches a particular level between 148 and 149 feet, the effective vent way is to be reduced by lowering the shutters to the required level. On economic consideration, nine vents are left ungated. When reservoir level reaches MWL all shutters are to be opened. Taking into consideration the 10% inoperative condition the number of vent ways to be left ungated is 7. Hence out of the total of 21 spillway vents, 14 numbers are gated. Total length of spill way portion (including pier width) comes to 305.9 m and maximum height up to crest level comes to 46.875 m. Maximum base width obtained is 42.253 m.

Downstream protection is provided for energy dissipation for spillway portion. It is tentatively proposed to adopt Type II basin with basin blocks for energy dissipation. This will be modified based on the findings of the model studies.

6.2.3 Salient features of the Overflow and Non-Overflow sections

Details of Reservoir

Full Reservoir Level	+ 867.405 m
Maximum Water Level	+873.198 m
Dead Storage level	+857.66 m

Details of Dam

Type of dam	Concrete gravity
Top level of dam	+874.69 m
Deepest bed level	+830.22 m
Top width	6.00 m
Bottom width	42.253 m
Height of dam	52.16 m *(From deepest foundation up to road level)*
Details of Foundation	Rock has been observed at an average depth of 5 metre

Details of Spillway

Total length	305.9 m(including piers)
Profile	Ogee
Crest level	+867.405 m
Bottom width	42.253 m
Type, Number & size of gate	Radial gate 14 nos, 12.0 x 6.40 m *(7 numbers ungated)*
Height of dam	46.875 m (From the deepest foundation to crest level)

(1) For gated portion 2.50 m in mid portion and 3.50 m (with a construction joint of 4 cm in centre) at the end portion.

(2) For ungated portion 1.50 m in mid portion and 2.0 m (with a construction joint of 4 cm in centre) at the end portion.

Type of energy dissipation Type II basin with basin blocks

The levels noted above are with reference to MSL taken as 0.00 m.

The design calculations and drawings are contained in Volume II –Designs & Drawings of this Report.

6.2.4 Opening through Dams

Foundation gallery is provided throughout the length of the dam following the provisions in the relevant Indian Standard. In addition to this, a horizontal inspection gallery of the same size as that of the foundation gallery is also provided. The locations of these galleries are contained in the relevant drawings forming part of the Vol II Designs & Drawings of Detailed Project Report. An outlet of 1 m diameter for releasing summer flows to the downstream and a scour outlet of 1 m diameter at a lower depth are also provided in the dam body. Suitable control gates will be designed and provided on the upstream with necessary hoisting arrangements located at the top of the dam. The locations of the outlet and scour outlet are indicated in the relevant drawings.

6.2.5 Instrumentation of the dam

Gathering of instrumentation data is an important part of overall programme of assessing the safety and proper functioning of the dams. It is a common practice that all dams exceeding 30 m high are instrumented for monitoring purposes. The usual factors that must be monitored in concrete dams include stress and strain, temperature in concrete, structural displacements, deformations, settlement, seepages, piezometric levels on dam foundation and uplift pressure within the structure foundation. Since the Mullaperiyar region has become seismically active, highly sensitive accelerographs will be included in the instrumentation package. A detailed scheme for instrumentation will be finalised and implemented in the new dam.

7. RESERVOIR

7.1 Fixation of storage and reservoir level

Dead storage level	: + 857.66 m
Low water (minimum drawdown) level	: +857.66 m
Full Reservoir level	: +867.41 m
Maximum water level	: +873.20 m :
Freeboard	: 1.5 m
Top of dam	: +874.70 m

7.2 Sedimentation data and studies

Arrangement are being made to estimate the amount of siltation in two stages. The area beneath the lake will be estimated using DGPS bathometry and the area above the lake will be found out by physical surveying. The study will yield the latest status of sedimentation in the present reservoir and an idea of the rate of siltation in the catchment.

7.3 Capacities

7.3.1 Capacities

Full Reservoir Level (FRL) at the

time of construction of the dam : +867.41 m.

Full Reservoir Level (FRL) after

50 years of operation : + 867.41 m feet.

Maximum Water Level (MWL) at the

time of construction of the dam : +873.20 m .

Maximum Water Level (MWL) after

50 years of operation : +873.20 m.

Low water (Minimum draw down level)

LWL/MDDL at the time of construction of the dam : +857.66 m

Low water (Minimum draw down level) LWL/MDDL

after 50 years of operation : +857.66 m

7.3.2 Storage (MCM)

Storage Capacity Provided at FRL	:	175.02 MCM
Gross Storage at FRL	:	341.48 MCM
Gross storage at MDDL	:	146.6 MCM

7.3.3 Water tightness of the Reservoir

The existing reservoir area has proved to be watertight by its performance during long years of service. As there are no faults and seams in the area going to be inundated by the construction of the new dam, the total reservoir will also be water tight.

7.3.4 Annual Losses (MCM)

a) Evaporation losses

Annual Evaporation losses in MCM for the years 2001-2009 have been found out and the average for the above years comes to 11.715 MCM.

b) Seepages in the reservoir

The existing reservoir area has proved to be almost water tight by its performance during long years of service. Hence, the seepages in the reservoir are negligible.

7.4 Effect on sub soil water table

Effect on sub soil water table in the adjoining forest areas particularly on the downstream of the dam will not be much affected.

7.5 Area of Submergence at (Acres)

7.5.1 Maximum Water Level:

(+873.2 m) - 8652.26 acres (Total)

7.5.2 Full Reservoir Level

(+867.41 m) - 4733.35 acres (Total)

7.6 Land Acquisition, Property submerged and rehabilitation.

Only about 50 Ha of forest land is to be acquired for the construction of the new dam. Land for compensatory afforestation as per the existing norms is already identified. As the area lies inside Periyar Tiger Reserve (PTR), there

are no settlers and hence the question of eviction and rehabilitation does not arise.

7.7 Recreation facilities

The present reservoir formed by the old Mullaperiyar Dam is a leading tourist attraction for boating. The extended new reservoir will enhance the tourist potential of the region.

8. CONSTRUCTION PROGRAMME

After getting the clearance from the Hon'ble Supreme Court and also after availing all the mandatory sanctions, construction of the new dam will be taken up and completed within a period of 4 years. Experiences contractors will be entrusted with the construction works. The bar chart showing the construction schedule is attached. The annual requirements of funds and materials are also indicated.

9. ENVIRONMENT, ECOLOGY AND FOREST ASPECT OF THE PROJECT.

The dam site lies inside PTR area. The dam is proposed to be constructed without any unnecessary distribution of forest environment .Underground cables are proposed for power and communication lines. Regarding buildings like site office, shelters, storage etc only temporary dwelling are proposed which can be easily erected and dismantled. The layout of the buildings have been so decided that only have minimum disturbance to the forest life will occur. Only those trees that will act as hindrance to the construction will alone be cut and removed.

The vegetation of the area is identifiable into two sections:

1. The 25 ha area adjacent the fortifications of the existing dam, and
2. The area further downstream.

The entire area is recognizable into four biotopes:

i. The River course
ii. The Eucalypt plantation, on the east bank of the river course
iii. The Semi-evergreen forest, on the west bank of the river course, and
iv. The Low altitude grassland, west of the semi-evergreen forest

The River course

The River course is composed of impoverished, remnant riparian vegetation. Characteristic species of the riparian biotope encountered are:

Ochlandra travancorica (Bedd.) Benth. ex Gamble

Ludwigia perennis L. Onagraceae – Herb

Cyperus sp. Cyperaceae

Osbeckia sp. – Melastomataceae - shrub

Nephrolepis sp. – Lomariopsiadaceae

Costus speciosus (Koenig) J.E.Smith – Zingiberaceae- Herb

The river course practically is devoid of a natural flow of water and there are many tiny stagnant pools separated by rocks and boulders. These waters are found contaminated with the notorious invasive weed, Salvinia molesta D. Mitch. (the 'African payal'), and is an indication of the past disturbance in the area.

A good population of the cultivated tree, guava (Psidium guajava L., Myrtaceae), is also seen along the river course and could be the left over from the people who stayed there during the construction of the dam or afterwards.

Other common species found in the area are given below. Many of them are common ruderal species, generally considered as weeds, comprising both exotic and indigenous ones.

Cryptolepis buchananii Roem. & Schult. – Periplocaceae – Climbing shrub.

Solanum torvum Sw.

Mimosa pudica L -Momosaceae

Croton bonplandianum Baill – Shurb – Euphorbiaceae –

Euphorbia hirta L. Euphorbiaceae – Herb

Scoparia dulcis L. – Scrophulariaceae – Erect herb

Vernonia cinerea (L.) Less. – Asteraceae - Herb

Bidens sulphurea (Cav.) Sch.-Bip – Asteraceae – Herb

Biophytum reinwardtii (Zucc.) Kotzsch var. reinwardtii - Oxalidaceae - Herb

Ipomoea sp. - Convolvulaceae

Persicaria glabra (Wild.) Gomez – Polygonaceae – Herb

9.2 The Eucalypt plantation, on the east bank of the river course

The Eucalypt Plantation situated on the east of the river course is apparently in its second rotation coppice. The trees are small, generally under 30 cm dbh, and a good nuber of them in pole stage. A good portion of the plantation is apparently part of the grassland afforestation initiative. The plantation on the east naturally merges with the natural grasslands and the rocky landscape of the hill.

In many parts of the plantation, particularly nearer the stream many natural moist deciduous tree species have established in due course. Grewia tiliifolia Vahl (Chadachi, Tiliaceae), Dalbergia sissoides Grah. ex Wt. et Arn. (Rose wood, Fabaceae), Briedelia scandens (Roxb.) Willd. (Euphorbiaceae), a scandent shrub, Diospyros montana Roxb. (Ebenaceae) are typical examples.

Many grasses and herbs, together with Eupatorium glandulosum Kunth (Compositae), a common weed of medium to high altitude belts constitute the undergrowth of the plantation.

9.3 The Semi-evergreen forest on the west bank of the river course

Semi-evergreen forests, situated on the right bank of the River course is an ecotonal vegetation, intermediate between evergreen and moist deciduous forests, and therefore characteristically comprise of floral elements of both the forest types.

The under mentioned species encountered in the ecosystem are typical of evergreen forests:

Actinodaphne malabarica Balakr – Lauraceae – Large tree

Actinodaphne bourdillonii Gamble –Lauraceae

Cinnamomum sp - Lauraceae

Tabernaemontana heyneana Wall. – Apocynaceae

Canarium strictum Roxb. – Burseriaceae – Large tree

Elaeocarpus tuberculatus Roxb. Elaeocarpaceae –Large tree

Hydnocarpus pentandra (Buch.-Ham.) Oken - Flacourtiaceae –Medium tree

Artocarpus hetrophyllus Lam. Moraceae –Large tree

Glochidion sp. Euphorbiaceae – small tree

Callicarpa tomentosa (L.) Murr. – verbinaceae – Small tree

Mallotus tetracoccus (Roxb.) Kurz. – Euphorbiaceae – Medium tree

Memecylon umbellatum Burm.f. –Melastomataceae –small tree

The moist deciduous elements of the biotope are composed of the following species:

Olea dioica Roxb – Oleaceae - Tree

Radermachera xylocarpa (Roxb.) K. Schum. – Bignoniaceous – Medium tree

Macaranga peltata (Roxb.) Muell.-Arg. – Euphorbiaceae – Meduium tree

Melicope lunu-ankenda (Gaertn.) Hartley – Rutaceae medium tree

Lagerstroemia speciosa (L.) Pers. Lythraceae – Medium tree

A number of climbers characteristic of the two ecosystems also are encountered.

Naravelia zeylanica (L.) DC. Rununculaceae – Climbing shrub

Calamus hookerianus – Palmae

Cissampelos pareira L. var. hirsuta (Ham. Ex DC) Forman – Menispemaceae – herbaceous climber

Schumannianthus virgatus (Roxb.) Rolfe – Marantaceae – Rhizomatous herb

Protasparagus racemosus (Willd.) Oberm. – Liliaceae – climbing shrub

Cayratia sp – Vitaceae –climbing shrub

The herbaceous flora also is a fair mix of species characteristic of the moist deciduous and evergreen forests.

Angiopteris erecta (G.Forst.) Hoffm .– Marattiaceae

Thunbergia sp. – Climber – Acanthaceae

Achyranthes aspera L. var. aspera – Amaranthaceae – Herb

Piper sp. – Piperaceae- Climber

Lepianthus umbellata (L.) Rafin –Piperaceae

Hydrocotyle javanica Thunb. – Apicaceae – herb

On the whole, the vegetation is neither evergreen nor moist deciduous in physiognomy. It should also be noted that contrary to the profusion of large diameter trees in undisturbed natural forests, none of the trees in the site had a diameter over 30 cm. This means that the vegetation is a new growth established subsequently, after the disturbance that occurred in the area during the construction of the existing dam.

9.4 The Low altitude grassland, west of the semi-evergreen forest

Grassland, adjoining the Semi-evergreen forests, is vast barren expanse clothed with gregarious growth of the common low elevation grass species, Cymbopogon flexuosus (Nees ex Steud.) Wats. In some places, évidence of progressive succession can be seen; isolated trees of Emblica officinalis Gaertn., Euphobiaceae, Terminalia paniculata Roth, Combretaceae, Large tree, and Lagerstroemia microcarpa Wt., Lythraceae, which are characteristic of the moist deciduous forests are seen. The invasion of these species into the grasslands indicate low disturbance, after the construction of the dam.

Weedy gregarious shrubs Lantana camara L., Verbinaceae, Stachytarpheta jamaicensis (L.) Vahl, Verbenaceae, Pteridium aquilinum (L.) Kuhn, the bracken fern, Hypolepidaceae, also have their presence in the grasslands, but not in gregarious populations.

A number of herbaceous species are also observed in the grassland: Hedyotis corymbosa (L.) Lam. – Rubiaceae – Herb; Desmodium triflorus (L.) DC – Fabaceae – Prostrate herb; Pleiocraterium verticillare (Wight & Arn.) Bremek. Rubiaceae – Herb; Mitracarpus villosus (Sw.) DC. – Rubiaceae – Erect herb;

Spermacoce latifolia Aubl. – Rubiaceae – Erect herb; Indigofera sp. Fabaceae – Shrub.

Observed by direct sightings:-

Nilgiri langur (Trachypithecus johnii),

Indian Bison (Bos gaurus)

Grey hornbill (Tockus gracius)

Indian darter (Anhinga melanogster)

Assessed by indirect evidences of dung/droppings and other signs

Elephants (Elephas maximus)

Sloth bear (Melursus ursinus)

Sambar (Cervus unicolor)

Wild boar (Sus scrofa)

Black naped hare (Lepus nigricollis)

Malabar giant squirrel (Ratufa indica maxima)

Elephants use the area in different time period as is evidenced by the presence of large number of dung piles in varying state of decay.

A cement platform made at the proposed dam location is used by sloth bear for rest and defacation as evidenced by droppings of sloth bear.

The grassland has large number of dung/droppings of Gaur, sambar, wild boar and black-naped hare.

9.5 Highlights of various groups of animals

Highlights of the various groups of animal groups reported from Periyar Tiger Reserve are as follows:-

Periyar Tiger Reserve has 66 species of mammals in 11 Orders and 25 families with 66 species. 10 species mammals belong to the endemic species of Western Ghats.

The avifauna of Periyar Tiger Reserve is represented by 323 bird species.

The reptile fauna is represented with 48 species in 12 families and 33 genera. Seventeen species of reptiles are endemic to Western Ghats.

The amphibian fauna is represented with 29 species in nine families and 17 genus of which twelve species are endemic to Western Ghats.

The fish fauna is represented by six order, 11 families and 23 genus with a total of 45 species. Sixteen species endemic to Western Ghats.

167 butterflies are recorded from Periyar Tiger Reserve.

10. ESTIMATE

The total estimate amount as per kerala Public Works Deartment (PWD) of 2011 comes to Rs.663 Crores. The details of the estimate such as quantities and unit rates are contained in Vol III Estimate of this report.

11. FINANCIAL RESOURCES

In the budget presentation 2007-2008, the Finance Minister of Kerala announced that a new dam is to be constructed to replace the old aged dam to safeguard the lives as well as properties of the people residing in down stream area. The scheme will be covered as per the decision of Government. An amount of Rs.10 crores was set apart for the detailed investigations of the new dam at Mullaperiyar.

Also in the Budget speech 2011-2012, the Finance Minister has announced that a special authority will be entrusted with the construction of the new dam. A provision of Rs.5 Crores is made for preliminary works for this year. Decision has been taken for the formulation of a special purpose vehicle for expeditious execution of the proposed new Mullaperiyar Dam within a time frame of 4 years. This agency is being contemplated with special financial powers for the speedy and time bound completion of the new dam.

Government of Kerala will make available sufficient funds for the speedy and expeditious construction of the new Mullaperiyar dam.

12. FUTURE UTILIZATION OF FACILITIES CREATED (BUILDING)

Most of the buildings to house labourers, materials, construction staff etc are proposed as temporary structures which can be easily erected and dismantled. The number of permanent buildings will be reduced to the minimum so as to cause minimum disturbance to the environment.

13. PROPOSED ORGANIZATION SET UP

As stated earlier a special purpose vehicle will be formed for the time bound execution of the proposed new dam at Mullaperiyar. Action has already been inintiated for making this a reality. The organisational setup of the Special purpose vehicle will be decided in such a way as to achieve the target within the time frame of 4 years fixed for the construction. For the time being the following organizational set up as indicated below is contemplated for the site office of the project.

Designation		Number
Executive Engineer	-	1
Assistant Executive Engineer	-	2
Assistant Engineer	-	6
First grade overseer	-	3
Second grade	-	8
Third grade	-	8
Lascar	-	6
Peon	-	3
Typist	-	3
Watcher	-	3
Sweeper	-	2
Clerk	-	3
Divisional accountant	-	1
Junior Superintendent	-	3

Head Clerk - 1

14. DISMANTLING OF THE EXISTING MULLAPERIYAR DAM AFTER THE CONSTRUCTION OF THE NEW DAM

Mullaperiar dam is having a height of 47.24 m (155 ft) above the river bed level of 0 ft and a length of 366 m (1200 ft). A Baby Dam with a height of 16.48 m (54 ft) and length 73.15 m (240 ft) at the top, an Earth Dam with a height of about 5 m (16.4 ft) and length 73.15 m (240 ft) and the Main Mullaperiyar Dam close the gorge and creates the reservoir. Earth Dam is located on the extreme left and the Baby Dam is located in between the Earth Dam and Main Dam. An earth mound is existing between the Main Dam and the Baby Dam.

After completion of the new dam at Mullaperiyar the existing dam will have to be dismantled to allow water to enter the portion between the old and new dams and to make the reservoir one continuous entity. The situation existing at Mullaperiyar is quite unique and cannot be straightaway compared to other reported instances elsewhere, which outwardly seem to be similar. The primary objective of almost all reported cases of decommissioning carried out in other countries has been restoration of the river to the conditions that existed prior to construction of the dam at the site. This has been carried out based on an objective assessment of the impacts of the dam, primarily adverse, on the environment. Typically, in these cases, a number of issues such as silt removal, effect on dams downstream of the dam being decommissioned, impact on aquaculture and economy etc are considered before approval is granted to the decommissioning process and hence the decision making process is very time consuming. Though many instances of dam decommissioning have been reported from all the world over, a situation of the kind existing at Mullaperiyar, wherein a new dam is proposed to be constructed very close to the site where the existing dam is

located, has been reported only very rarely. The old Victoria dam (1891-1990), situated on the Darling Scarp near Lesmurdie, Perth, Western Australia, was partially demolished and a new dam was built at the same location in 1991, on the upstream side of the old one, as against the downstream side in the present case. The present situation regarding the Mullaperiyar dam cannot be termed a case of decommissioning as it involves only removal of the dam structure and most of the environmental issues in a conventional decommissioning process do not exist except for the operation of demolition of the structure and removal of debris, and consequent environmental impacts.

An action plan for achieving the dismantling is presented in the following paragraphs in a logical and chronological sequence.

Construction of the new dam shall be taken up and completed in all respects. The bottom level of the foundation of the baby dam is +104 ft. This level also corresponds to the level of the sill of the diversion tunnel which carries water to Tamil Nadu. Hence water in the reservoir below this level cannot be drawn under normal conditions and remains as dead storage. The entire baby dam structure including its foundation shall be demolished to the lowest level to which the reservoir goes down during the summer season. From previous records, it is seen that this lowest level is of the order of +110 ft. Taking advantage of this low reservoir level, we can demolish the Baby Dam to +110 ft or so. The amount of debris to be removed will not be huge and the removal can be done without much difficulty. The method of dismantling and the removal of the debris are dealt with separately.

The earth Dam is located on the left side of the Baby dam. On the right side an Earth Mound is situated. The foundation of the Baby Dam at or below +104 ft is very weak. During dismantling of the Baby Dam, great care shall be exercised not to disturb the side slopes of the earth Dam and the Earth Mound. After the demolition, the side slopes are to be suitably protected to prevent sliding of earth mass and consequent slope failure.

It is extremely important that the existing dam structure is not subjected to any 'shock' during the transition phase, particularly in view of our serious doubt regarding the structural integrity of the main Mullaperiyar Dam. To ensure this, it is proposed that the water levels on the upstream and downstream sides of the main dam shall be balanced by flooding the area between the existing dam and the new dam. This flooding operation shall be done in an extremely controlled manner. Making an artificial breach of small length, either in the main Mullaperiyar Dam, Baby Dam or the Spillway on the right flank is not advisable as this could result in dangerous consequences. After bringing down the water level in the existing reservoir to the lowest possible level, say +110 ft, steel or PVC pipes of about 1 m diameter shall be laid for draining out water from the existing reservoir to the reach of the river between the new dam and the existing dam by siphonic action. PVC pipes of this size may not be readily available. However, preliminary enquiries indicate that these can be custom made on specific demand. Sufficient numbers of these pipes shall be laid on the existing ground at the locations of the demolished Baby Dam in such a way that water can flow from the existing reservoir to the downstream side of the existing dam by siphonic action. The pipeline shall be air-tight and siphonic action can be mechanically initiated by using vacuum pumps. Flow shall be regulated by installing valves so that the entire flooding operation can be

effectively controlled. The number of pipes and its diameter can be decided based on the time available for carrying out this flooding operation, availability of pipes, and the procedures employed for installation. These pipes can be removed after the flooding and balancing operation is completed.

In this context, a large scale siphoning operation carried out elsewhere may be recalled. The connection between Lake Bonney and River Murray, roughly 200 km east of Adelaide in Southern Australia was cut off in September 2007 causing the water level in the lake to fall. Lake Bonney is roughly 6.5 km x 4 km with a surface area of about 1700 hectares. Eighteen (18) siphons each of internal diameter 200 mm were installed and about 1.5 m depth of water was filled in the lake from the Murray River in about 50 days, starting December 2008. Options such as pumping and laying buried pipelines were also considered but were found to be 25 and 10 times costlier respectively.

After balancing the water levels on the downstream and upstream sides of the existing dam, the portion of the existing dam above the water level can be demolished. Demolition has to be carried out in a controlled manner and without the use of any type of explosives. The demolition can be carried out by mounting the most appropriate mechanical demolition equipment on barges positioned in the reservoir on the upstream side of the existing dam. The size and type of barge will depend on the equipment being employed and can be finalized before the work is taken up. The mechanical demolition process can be continued to any desired level up to the water level in the reservoir at the time of demolition.

For ensuring the efficient operation of the spillways in the new dam and to facilitate removal of silt to the maximum extent possible, it is advisable to dismantle the main Mullaperiyar Dam even below the lowest water level in the reservoir to deeper depths, even though such removal of the portion of the dam permanently submerged is optional. The portion of the dam under water can be scooped out by using dredging and subsea excavation equipments (such as grab excavation system of sea tools, Netherlands). Since bulk of the main dam structure has been constructed of lime surkhi concrete, it will have relatively low strength and hence mechanical demolition using excavators is quite feasible and appropriate. The depth to which the main Mullaperiyar Dam is to be demolished will be decided after conducting detailed study and considering various options.The dismantled debris is to be transported away from the reservoir area and dumped. This can be accomplished by deploying barges in the reservoir on the upstream side of the existing dam. As demolition will be carried out by equipment mounted on barges located at the same location, the debris can be easily deposited onto the barges. These barges shall transport the debris to locations upstream in the reservoir from where road access is available. Thekkady on the upstream is one such location. The debris shall be transferred to trucks at these locations and disposed of at suitable locations after ensuring that adverse environmental impacts do not occur. This will not need elaborate infrastructure development and also helps to avoid massive operations on the downstream side of the new dam, thereby minimizing adverse environmental impacts on the reserve forest areas located there. Also, the cost of transporting the debris by water will be comparatively less compared to that by road.

Action is initiated to identify and procure required land, government or private, for stacking the debris. As per preliminary investigations, suitable land for depositing the debris is found available at a distance of 12 km from Vallakkadavu. During the entire period of dismantling operations, utmost care and caution should be exercised to ensure that the environment and ecology of the area is least affected. Constant interaction with the environmentalists is an essential requirement in this regard.

About 40 percent of the demolished material will be rubble. This can be processed to coarse aggregates and fine aggregates which are construction materials of much demand. The balance portion of the debris consisting of mainly lime surkhi concrete can be used for filling and reclaiming low and waste lands.

There are two other proposals for filling the reservoir apart from the siphoning process discussed above. The first proposal is the following.

On the spillway structure side, the ground level upstream is about +136 ft. One proposal is to cut a channel of about 40 ft depth in the spillway portion on the right flank and releasing water to the gap between the new and old dams for filling. This flank has firm rock outcrops on both the downstream and upstream sides. Hence constructing a channel of this size will involve large amount of rock cutting/ blasting. Chemical blasting is an option; but constructing a channel of regular shape along a predefined alignment by this method is ruled out. Even if cutting is possible, it is likely to reduce the stability of the bed rock and this is not advisable especially in the seismic

context. Micro tunnelling might be a possible technical alternative but is likely to be prohibitively costly apart from causing large levels of noise pollution besides reducing the stability of bed rock.

The second proposal is to make an artificial channel on the Baby Dam side. This too would need large amount of excavation. The quality of rock in this area below +104 ft, the bottom level of Baby Dam is generally weak with seams and fissures. This may cause difficulties and problems during and after the excavation of a channel. The presence and extent of firm rocky stratum in this region has to be ascertained before the effort involved in cutting and issues related to stability can be assessed.

Considering the above factors, it is felt that any modification to the existing natural ground formation is highly risky and is likely to be very costly. The method of filling the reservoir by siphoning is preferred.