Operation and Maintenance Manual for PAMBA Dam State of Kerala

Doc. No. 3_DSO_O&M_SGHEP:PAMBA_DAM

KSEBL_v1.0

Chief Engineer
(Civil- DRIP & Dam Safety)
Kerala State Electricity Board

Front Cover Photograph: Downstream and Upstream view of Pamba dam

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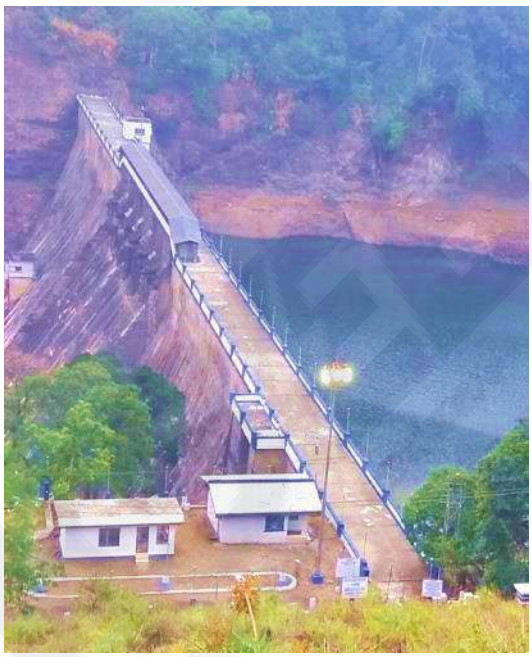
Government of Kerala

Operation and Maintenance Manual

Pamba Dam



KSEB

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Kerala State Electricity Board Ltd
Pallom, Kottayam.

February 2019

Government of Kerala
Kerala State Electricity Board Ltd
Dam Safety Organisation

Disclaimer

This *Operation and Maintenance Manual for Pamba Dam* in no way restricts the dam operators in digressing from her/his responsibilities. The Dam Operators must exercise appropriate discretion and good judgement based on actual site condition when implementing and using the operation and maintenance manual for managing the workings of the dam and appurtenant structures.

The manual is developed for the purposes of organization and managing the operation, inspection and maintenance of the dam for reducing risk and optimizing performance of the dam as a general guide.

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Message

India has more than 5200 large dams. Their health and safety are of paramount importance for sustainable use of the valuable assets, besides providing protection to the people and property in the downstream areas. The Ministry of Water Resources, River Development & Ganga Rejuvenation through the Central Water Commission (CWC), with financial assistance from the World Bank, started the Dam Rehabilitation and Improvement Project (DRIP) to rehabilitate 198 large dam projects in seven states. Kerala State Electricity Board Ltd, through Government of Kerala participated in DRIP to rehabilitate 37 dams under 12 Hydro Electric Projects in the state.

For managing a dam in a sustainable and scientific manner, it is very crucial for each dam owner to have dam specific Operation and Maintenance Manual that lays down procedures for the daily upkeep of the dam. An Operation and Maintenance Manual for a dam is essential for ensuring its safe functioning and for deriving continued benefits. This Operation and Maintenance Manual for Dam has been prepared following the Guidelines for Preparation, Operation and Maintenance Manuals published by CWC in January 2018 under DRIP and covers requirements for project Operation, Inspection, Maintenance, Instrumentation and Monitoring the health of Dam both during monsoon and non-monsoon periods.

I recommend the dam officials to use this manual for the efficient and safe Operation and Maintenance of the Dams on regular basis.

I compliment all the experts who have contributed to the development of this manual and congratulate the Dam Safety Organisation, KSEB Ltd, Pallom and CWC for the initiation of such important policy protocol to address dam safety management in Kerala.

Bibin Joseph,
Director Generation (Civil),
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Foreword

Globally, the Operation and Maintenance (O&M) Manual of a dam is one of the most important documents which is supposed to be put in practice right from the initial filling of reservoirs. In order to address the operation and maintenance aspects, ongoing Dam Rehabilitation and Improvement Project (DRIP) has requisite scope to prepare new or update existing O&M manuals for all DRIP dams, which will become very helpful to Dam Owners in addressing the dam specific issues comprehensively in future.

This Operation and Maintenance (O & M) Manual developed is a detailed set of written descriptions with step-by-step procedures for ensuring that the dam is safely operated, frequently inspected and properly maintained. In this era of shrinking budgets, timely inspection and preventative maintenance is necessary for the safe functioning of the dam and continued productive use of the dam and reservoir.

The format of this manual is prepared following the principles published in 2018 CWC Guidelines for Operation and Maintenance of dams for the use by all Dam Owners in developing their own site-specific manuals. Each section of the document provides the necessary instructions to operate inspect and maintain their dams.

It is recommended that all dam officials in charge to use this manual for ensuring that the dam is operated and maintained in a sustainable manner and will continue to derive benefits.

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PREFACE

Operation and Maintenance (O&M) Manual is a detailed written document of procedures and protocols for ensuring that a dam is operated and maintained properly and timely to avoid further health deterioration and extend service life of these assets. An Operation and Maintenance Manual is essential for a dam for ensuring its safe functioning and for deriving desired benefits from it by describing all the elements systematically for its operation, inspection, maintenance, instrumentation and monitoring of the health.

Central Water Commission has published the Guidelines for the development of New Manual and Updating of Existing Manual vide CDSO_GUD_DS_03_v1.0 Page xii January 2018. Accordingly Kerala State Electricity Board is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy dam safety management system.

Pamba dam under KSEBL do not have a comprehensive Operation and Maintenance Manual. Hence an attempt is made here to prepare the manual as per the new guidelines by CWC. The Sabarigiri HEP of KSEB Ltd commissioned in 1967 includes 3 main dams and 5 small dams. The main dams are Kakki, Anathode & Pamba of which Kakki is concrete gravity type and the other two are masonry gravity type. The small dams are Upper Moozhiyar, Kullar, Meenar I, Meenar II and Gavi. There are two major reservoirs viz. Kakki-Anathodu and Pamba for this project. Water from Pamba reservoir is conveyed to Kakki – Anathodu reservoir through an inter-connecting tunnel. The power house of SGHEP, located at Moozhiyar, generate 340 MW under a net head of 714.76m. Small augmentation reservoirs Kullar-Gavi (1990), Meenar I (1991) & Meenar II (1991) are serially connected to Pamba reservoir and Upper Moozhiyar (1979) augmenting to Kakki reservoir, after commissioning of the Project. A flow chart of SGHEP is given in the next page for reference.

This Operation and Maintenance Manual is prepared for the Pamba dam of SGHEP.

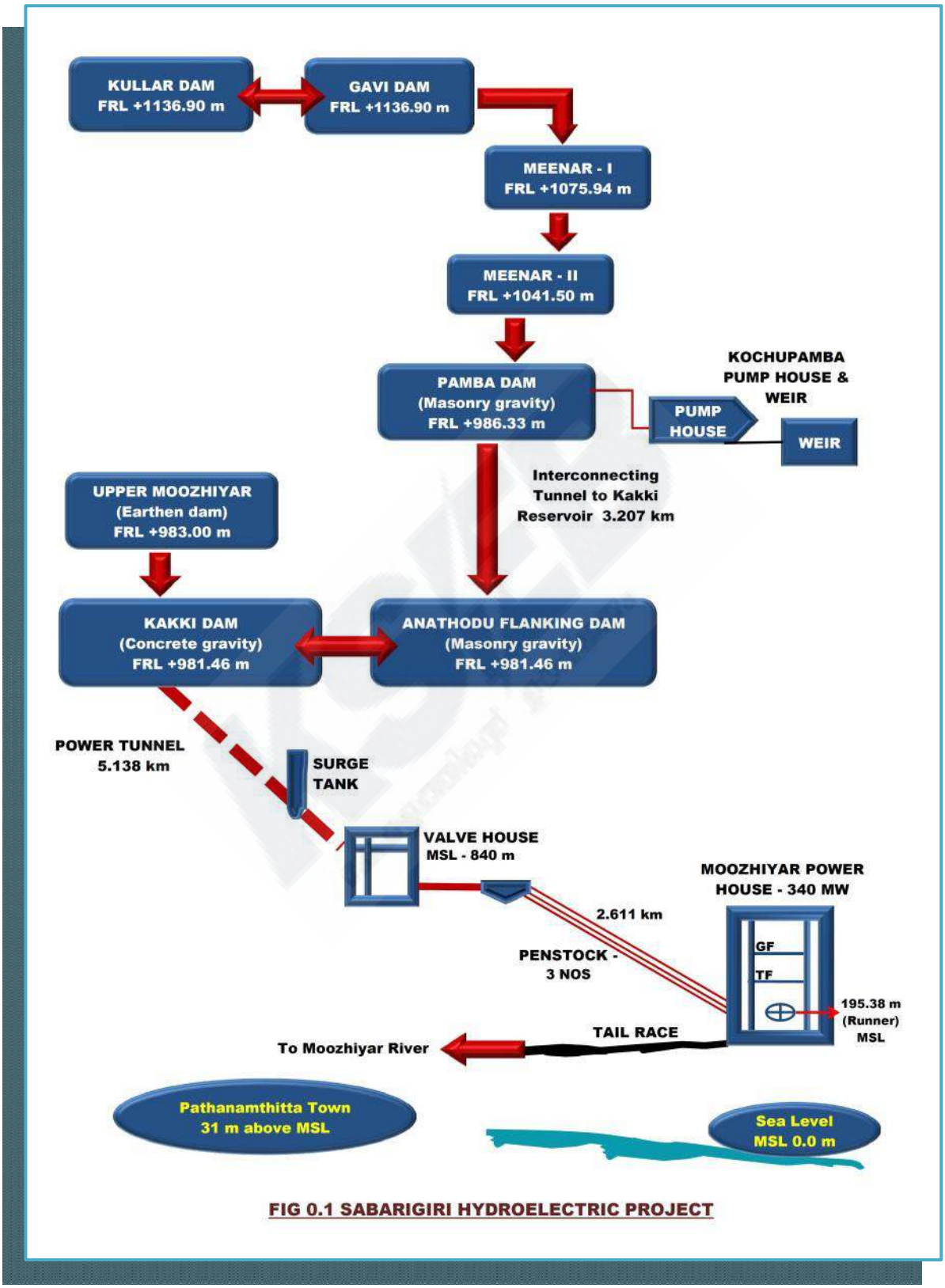

FIG 0.1 SABARIGIRI HYDROELECTRIC PROJECT

LIST OF ACRONYMS

The following acronyms are used in this publication:

AAR	**Alkali-Aggregate Reaction**
ACI	**American Concrete Institute**
ASTM	**American Society for Testing Materials**
CDSO	**Central Dam Safety Organization**
CWC	**Central Water Commission**
CWPRS	**Central Water and Power Research Station**
DDMA	**District Disaster Management Authority**
DHARMA	**Dam Health and Rehabilitation Monitoring Application**
DRIP	**Dam Rehabilitation and Improvement Project**
EAP	**Emergency Action Plan**
HCC	**Hindustan Construction Corporation Ltd**
IS	**Indian Standard**
KERI	**Kerala Engineering Research Institute**
KDSA	**Kerala Dam Safety Authority**
KSEB Ltd	**Kerala State Electricity Board Ltd**
KWA	**Kerala Water Authority**
NCDS	**National Committee on Dam Safety**
NCSDP	**National Committee on Seismic Design Parameters**
PMF	**Probable Maximum Flood**
PMP	**Probable Maximum Precipitation**
RCC	**Reinforced Cement Concrete**
ROUV	**Remotely Operated Underwater Vehicle**
ROV	**Remotely Operated Vehicle**
SDSO	**State Dam Safety Organization**
SISF	**State Industrial Security Force**
USBR	**United States Bureau of Reclamation**

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Chapter 1

General Information

1.1 Introduction

Sabarigiri Hydro Electric Project is the second largest hydroelectric project of Kerala State located in Pathanamthitta District. The catchment area falls between $77^0$6.3'N, $9^0$15'E & $77^0$7.6'N, $9^0$20.8'E. There are two main reservoirs for SGHEP viz. Kakki-Anathode and Pamba, of which Kakki-Anathode reservoir is the largest. This reservoir is formed by the construction of a concrete gravity Dam across Kakki River, a tributary to River Pamba. Anathode is another stream which joins Kakki River downstream of Kakki Dam and before the confluence with Pamba River. A flanking Dam called Anathode Flanking Dam of masonry gravity type is constructed across this stream to form common reservoir with Kakki. The spillway for the reservoir complex is located by the side of Anathode Flanking Dam. Kakki-Anathode reservoir receives water from Pamba reservoir through an interconnecting tunnel. The Power House of SGHEP is located at Moozhiyar which was designed to generate 300 MW under a net head of 714.76 m. The construction of Kakki Dam was completed in September, 1966 and Anathode in May 1967. The Power station was inaugurated by Sri V.V.Giri, the then Vice- President of India, on 28.08.1967 with an installed capacity of 300 MW (6 units of 50 MW each). Later, small augmentation reservoirs Kullar-Gavi (1990), Meenar I (1991) & Meenar II (1991) are serially connected to Pamba reservoir and Upper Moozhiyar (1979) augmenting to Kakki reservoir, after commissioning of the Project. The RMU of the Project was undertaken during the period from 2005 to 2009, increasing the installed capacity to 340 MW (4 Units of 55 MW each & 2 Units of 60 MW each).

1.2 Purpose, Location, Description of the Project

Sabarigiri Hydro Electric Project Location

The Dams and Power House are situated in Pathanamthitta District, Seethathode Panchayath, Chittar Village (Formally in Kollam District, Pathanamthitta Taluk and Perinad Village) of Kerala State. The only access road to the power house and to various dams is passing through the thick forest starting from Angamoozhi to Vandipperiyar (Road from Pathanamthitta-Angamoozhi-Veluthode-Moozhiyar-Kakki- Kochupampa- Gavi-Vandipperiyar-

Kumily). Nearest city/town is Pathanamthitta, nearest railway station is Chengannur and nearest Airport is Thiruvanathapuram/Nedumbasserry. The index map and route map of SGHEP are given in **Fig 1.1** and **Fig 1.2**.

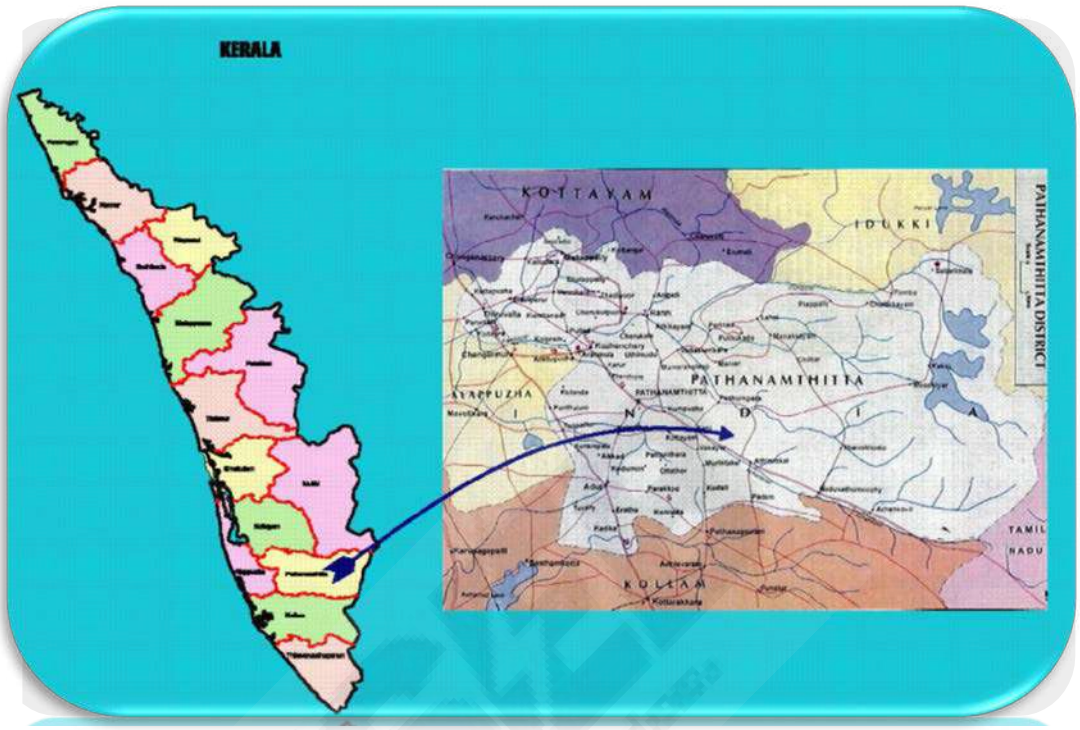

Fig 1.1 Index Map

The details of the different engineering structures of the project are:

1. Two main dams, one across river Pamba and the other across river Kakki, a tributary of the river Pamba.
2. A flanking dam above saddle i.e. Anathode dam, for Kakki- Anathode reservoir. A tunnel 3.2077 km long to interconnect the Pamba and Kakki reservoirs. A power tunnel 5.138 km long up to the center of the surge shaft starting from Kakki reservoir, which form the first part of the water conductor system.
3. A low pressure pipe line 0.409 km long, 3.75 m dia. from surge shaft to bifurcation point (where the valve house is located).
4. A set of 3 high pressure surface penstocks about 2.611 km long each bifurcating just above the generating station from where 6 branches are taken to the power house.
5. A power station on the bank of Moozhiyar accommodating six multiple jets Pelton turbine each coupled with a generator of 50 MW with an outdoor switch gear arrangements.

6. A 220 KV double circuit transmission line from the power station with each circuit to Pallom and Kalamassery.
7. One 220 KV DC line and one 220 KV SC line to Edamon.
8. A 220 KV interstate transmission link to Theni.

A schematic diagram of the project is outlined below in **Fig 1.3**.

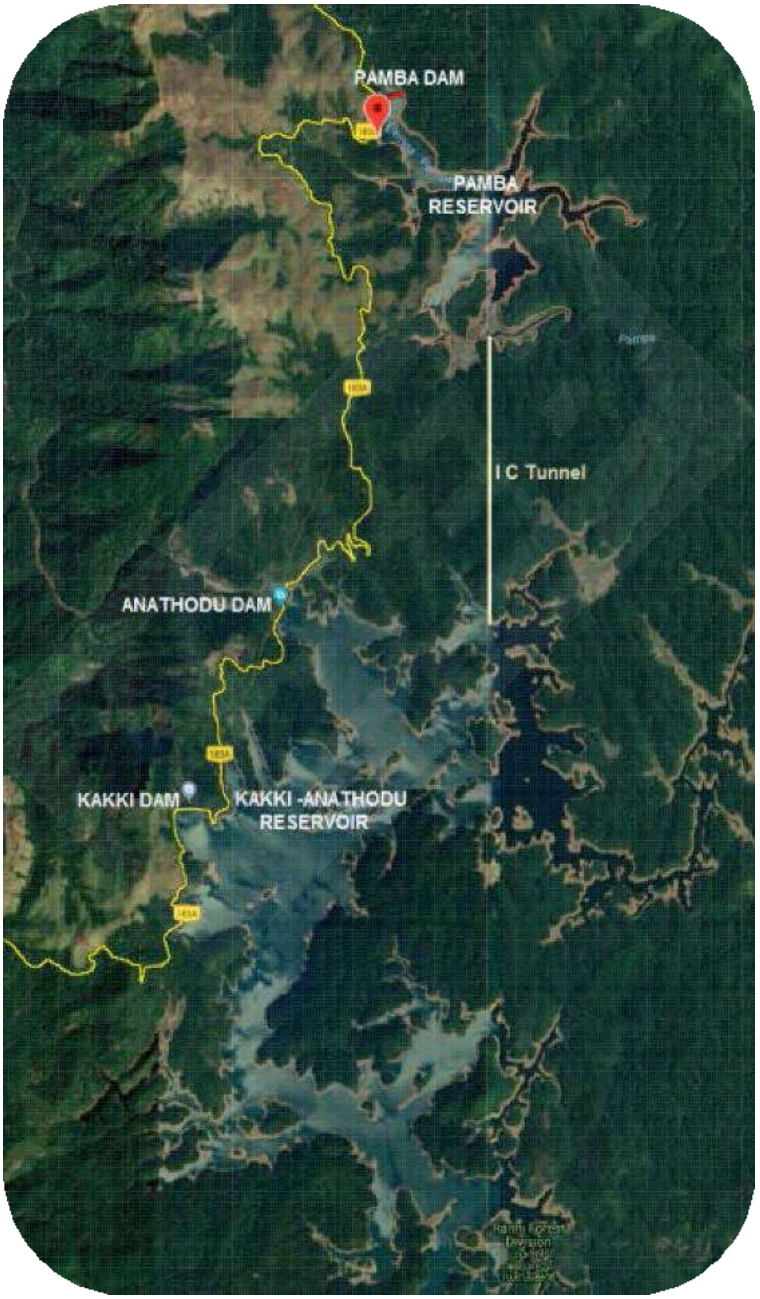

Fig 1.2 Google Map showing the Project

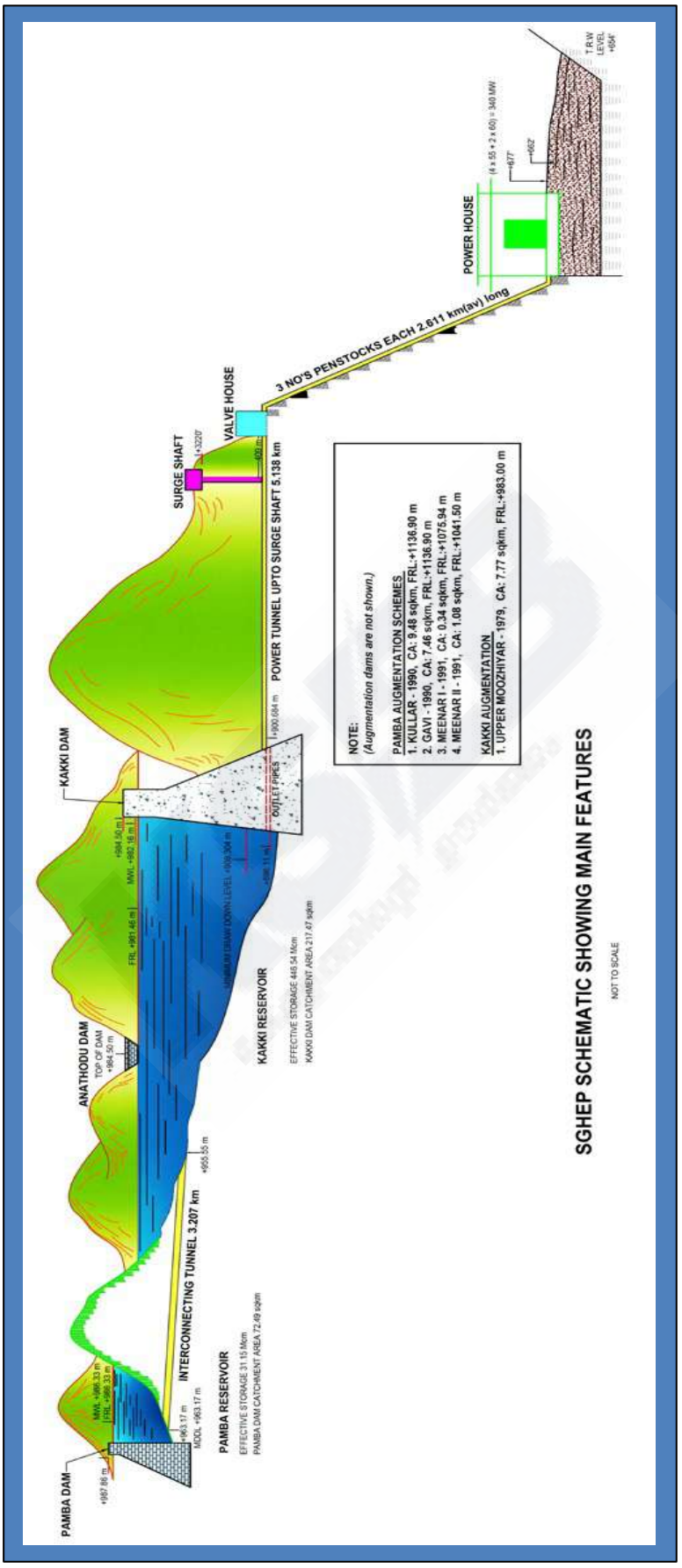

Fig 1.3 Schematic Diagram of the Project

MAIN FEATURES OF SABARIGIRI HEPROJECT

A	HYDROLOGY AND POWER POTENTIAL		
1	Total Catchment Area	:	316 Sq km
2	Average Annual rainfall	:	4572 mm
3	Average Annual runoff	:	824.112 Mm^3
4	Average Gross head available	:	762 m
5	Firm power at 100% L.F.	:	152.6 MW
6	Power generation at 60% L.F.	:	254 MW
B	DAM ACROSS PAMBA – **PAMBA DAM**		
1	Bed Level	:	+935.74 m
2	F.R.L	:	+986.33 m
3	M.W.L	:	+986.33 m
4	Top of dam	:	+987.86 m
5	Effective Storage above +963.17 m	:	31.15 Mm^3
6	Length of dam at top	:	281.48 m
7	Volume of masonry	:	0.1529 Mm^3
8	(a) Catchment area at Pamba Dam site	:	72.52 Sq km
	(b) Diversion catchment	:	18.28 Sq km
9	Design Flood	:	911.8 m^3/s
10	No. and size of radial gates	:	6 Nos of 7.01 m x 4.88 m
11	Length of Spillway	:	54.25 m
12	Height of dam above river bed	:	52.15 m
13	No. and dia. of outlet	:	1 No, 1.83 m
14	Discharge through outlets	:	29.17 m^3/s at F.R.L.
15	El. of sill of outlet	:	+958.29 m
16	El. of sill of interconnecting tunnel	:	+963.17 m
17	Dead storage below +963.17 m	:	8.07 Mm^3
18	No. of Adits to foundation gallery	:	2 Nos; one in each flank
C	FLANKING DAM FOR KAKKI- ANATHODE RESERVOIR AT **ANATHODE**		
1	Lowest level of saddle	:	+949.45 m
2	F.R.L.	:	+981.46 m
3	M.W.L.	:	+982.16 m
4	Top of Dam	:	+984.50 m
5	Length of Dam at Top	:	376.12 m
6	Height of Dam above saddle	:	35.05 m
7	No. of Adits to foundation gallery	:	2, one on each flank
8	Catchment area for Kakki Reservoir at Kakki Dam site		217.47 Sq km

9	Width of roadway at top of dam	:	3.66 m
10	Width of foot path	:	0.91 m
D	SPILLWAY FOR KAKKI – ANATHODE RESERVOIR NEAR FLANKING DAM AT ANATHODE		
1	Flood discharge	:	1784.16 m^3/s
2	Width of Spillway	:	59.13 m
3	Length of Spillway Channel	:	149.35 m
4	No. and size of radial gates	:	4 Nos. 12.80 m x 6.10 m
5	Slope of Spillway Channel	:	1/100
6	El. of Spillway Crest	:	+975.36 m
7	Clear roadway at Spillway bridge	:	4.572 m
8	El. of the top of Hoist Bridge	:	+992.58 m
9	Total width of Hoist Bridge	:	3.66 m
E	**KAKKI DAM**		
1	Bed Level	:	+874.78 m
2	F.R.L.	:	+981.46 m
3	M.W.L.	:	+982.16 m
4	Top of Dam, Road Level	:	+984.50 m
5	Height of dam above river bed	:	109.73 m
6	Effective Storage above El. 908.30 m	:	446.54 Mm^3
7	(a) Catchment area at Kakki Dam site	:	217.47 Sq km
	(b) Diversion catchment	:	7.77 Sq km
8	Length of Dam at Top		336.19 m
9	No. of outlets	:	2 each controlled by 1.37 m dia Hollow Jet valves
11	Size and type of emergency gates for each outlet	:	2.9 m x 1.52 m gates hydraulically operated from dam top
12	El. of sill of outlets	:	+896.11 m
13	Max. computed combined discharge through two outlets under F.R.L. Condition	:	84.95 m^3/s
14	Width of roadway over top of dam	:	3.66 m
15	Size of elevator shaft	:	2.16 m x 2.54 m
16	No. of Adits to foundation gallery	:	3 nos. two on the right bank and one on the left bank
17	No. of drift tunnels driven on the banks	:	4 nos. two on each bank
F	INTERCONNECTING TUNNEL (PAMBA-KAKKI)		
1	Length of tunnel	:	3207.72 m
2	Excavated area	:	15.87 m^2
3	Finished area	:	12.14 m^2

4	Sill level of tunnel at inlet	:	+963.17 m
5	Sill level of tunnel at Exit	:	+955.55 m
6	Max. discharge capacity	:	70.8 m^3/s
7	Lining Thickness	:	20 cm
8	Max. velocity	:	5.87 m/s
G	POWER TUNNEL		
1	Length of tunnel	:	5137.71 m up to surge shaft
2	Area of excavation	:	22.77 m^2
3	Finished area	:	16.42 m^2
4	Sill level at inlet	:	+900.68 m
5	Lining Thickness	:	30 cm
6	Design maximum Flow	:	54.37 m^3/s
7	Velocity	:	3.29 m/s
H	SURGE SHAFT		
1	Main Barrel		
	(a) Diameter	:	7.62 m
	(b) Depth	:	106.68 m
2	Top Expansion Chamber		
	(a) Diameter	:	13.72 m
	(b) Depth	:	25.91 m
3	Surge gallery at Bottom		
	(a) Diameter	:	6.71 m (Main Gallery)
			4.57 m (Spokes)
	(b) Length	:	106.68 m (Main Gallery)
		:	30.94 m each (Spokes)
I	PENSTOCKS		
1	L.P.P. (Low pressure pipe)		
	(a) No. of Pipes	:	1 No.
	(b) Diameter (External)	:	3.75 m
	(c) Length of Pipe	:	409.25 m
	(d) Gradient	:	1 in 100
2	H.P.P. (High Pressure pipe)		
	(a) No. of Pipes	:	3 Nos.
	(b) Diameter of each pipe up to		
	Anchor 9	:	2100 mm (ext.)
	A 9 to A 19A	:	2050 mm (ext.)
	A 19A to A 20	:	1950 mm (ext.)
	A 20 to bifurcation	:	1850 mm (ext.)
	Bifurcation to Turbine inlet	:	1350 mm (int.)

	(c) Length of each pipeline		
	(i) 2604.365 m		
	(ii) 2595.791 m		
	(iii) 2593.075 m		
J	POWER HOUSE		
1	Gross head available	:	762 m
2	Power House Floor level	:	+199.95 m
3	Centre line of runners	:	+195.38 m
4	Installed capacity	:	6 x 50 MW
5	Size of Machine Hall	:	103.63 m x 18.90 m
6	Size of Control Annexe	:	12.34 m x 26.82 m
7	El. of Switchyard	:	+208.79 m
8	El. of Feeder Bays	:	+220.68 m
9	Floor level of Tailrace culverts	:	+191.41 m (av)
10	Turbines	:	Pelton type, 6 Nos each of 50 MW
11	Step up transformers 11 KV/220 KV	:	Three Nos. Single Phase transformers of capacity 18500 KVA for each generator
12	Transmission Lines 220 KV	:	1 double circuit line to Pallom & Kalamassery, 1 single circuit line to Theni (T.N), 1 single circuit line to Edamon, 1 Double circuit line to Edamon.

The Reservoirs

Two reservoirs in Pamba Basin, viz; Kakki - Anathode & Pamba, contribute the water required for operation of the project. Both the reservoirs are boosted again by constructing Augmentation schemes. The layout map of the project is shown in **Fig 1.4**.

1) Pamba Reservoir

This reservoir is formed by the Pamba dam constructed across Pamba River. The water from this reservoir is taken to the Kakki- Anathode reservoir through an underground interconnecting tunnel of D-shape 3.6 m x 3.6 m and 3207.7 m long. From there, it is conveyed to the power house located at Moozhiyar under a net head of 714.76 m through Power tunnel 5137.71 m long. The inlet & exit sill levels of the inter-connecting tunnel are at +963.168 m and +955.55 m and Pamba reservoir can rise up to an FRL of +986.33 m. There are also a few number of small dams constructed across nearby rivulets to divert the discharges into this reservoir**.**

a. Augmentation dams of Pamba reservoir

1) Kullar, 2) Gavi, 3) Meenar-I, and 4) Meenar-II

In addition, a pumping scheme from Kochu Pamba weir is also constructed at the downstream of Pamba dam and water is pumped in to this reservoir using Pumps.

2) Kakki - Anathode Reservoir

Kakki and Anathode are the major tributaries of Pamba River in the upstream reaches. Kakki River originates at an altitude of +1760 m at Urani in DevarMala. Anathode originates at an altitude of +1816 m at SundaraMala. The catchment area is delineated from the Periyar lake catchment by a ridge. This reservoir is formed by construction of a dam across Kakki River. The water received from the Pamba reservoir and the rainfall received in its own catchment area form the water resource of this reservoir. The intake of the Powerhouse is from this reservoir.

There is a flanking dam at Anathode named as Anathodu Flanking Dam with details as below. Gates for flood releasing of Kakki -Anathode reservoir is provided at Anathodu Dam.

1.	Water Spread Area	17.6 Sq km.
2.	Catchment Area	225.33 Sq km (Kakki : 217.56 Sq km and Upper Moozhiyar : 7.77 Sq km)
3.	Average Rainfall	4572 mm
4.	Full Reservoir Level (FRL)	+981.46 m above MSL
5.	Minimum Drawdown level (MDDL)	+908.30 m above MSL
6.	Effective Storage at FRL	455.02 Mm^3
7.	Gross head at power house	762.00 m

b. Augmentation Dam of Kakki - Anathode reservoir

Upper Moozhiyar Dam is the Augmentation dam of Kakki reservoir.

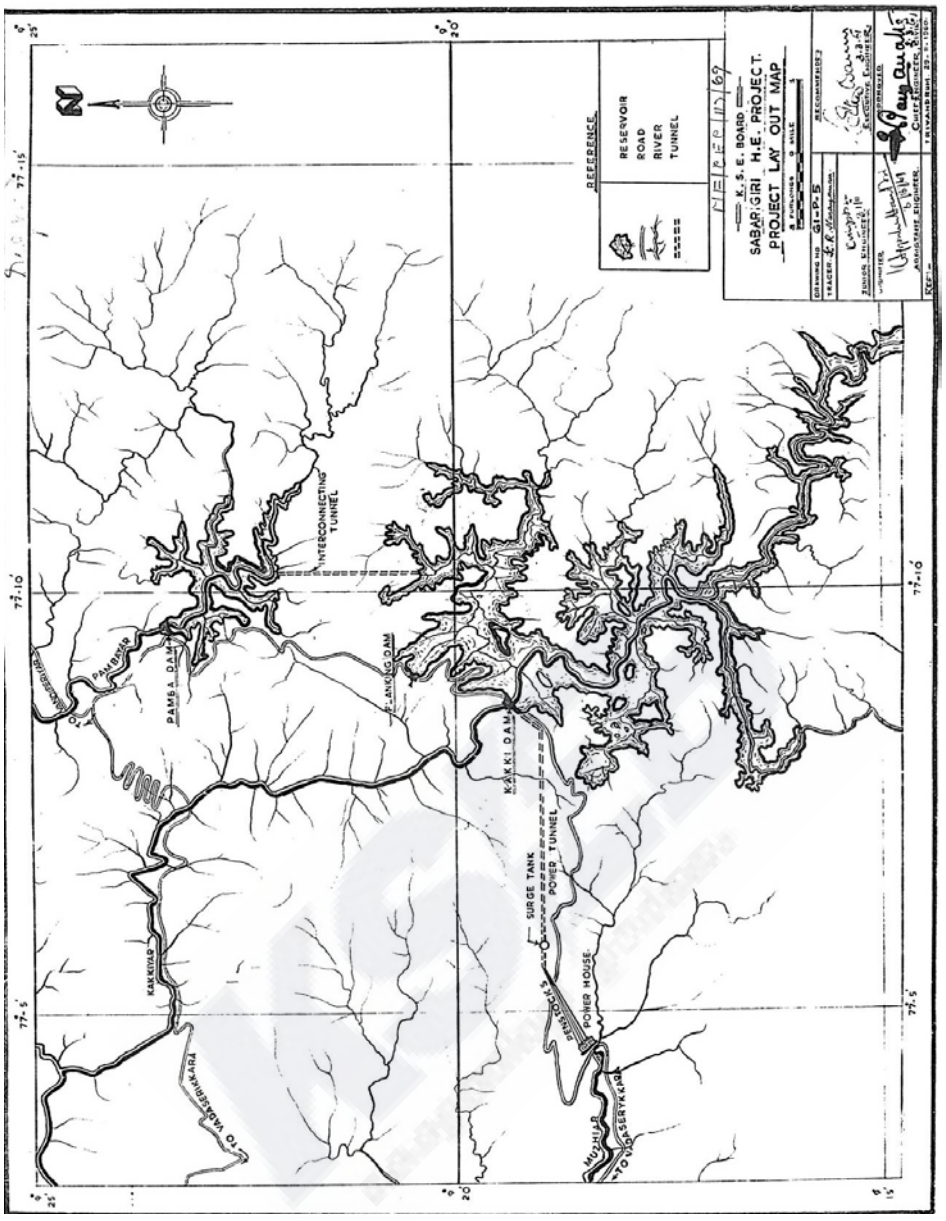

Fig 1.4 Layout Map of SGHEP

Power House

The SGHEP Power House is constructed at Moozhiyar, Seethathodu village, Konni Taluk around 60 Km from Pathanamthitta. The Power Station was commissioned during 1967 with Six Generating units having vertical shaft Pelton turbine coupled to Generating units of 50 MW capacities each. After power generation, water from the power station is released to the Moozhiyar reservoir. Google view of SGHEP power house is shown in **Fig 1.5.**

Commissioning details of the units

Unit	Rating	Date of Commissioning
U # 1	50 MW	18.04.1966
U # 2	50 MW	14.06.1966
U # 3	50 MW	29.12.1966
U # 4	50 MW	22.06.1967
U # 5	50 MW	09.09.1967
U # 6	50 MW	26.11.1967

RMU works were undertaken in the Power Station from 2005 to 2009. Capacity of units 4 and 6 were enhanced by 10 MW each and all other units were enhanced by 5 MW. Thus the total installed capacity of the station became 340 MW. The commissioning dates of renovated units are as below:

Installed capacity : 340 MW
Firm annual generation capability : 1338 MU

Unit	**Rating**	**Date of Commissioning**
U # 1	55 MW	03.12.2009
U # 2	55 MW	07.02.2009
U # 3	55 MW	17.03.2008
U # 4	60 MW	06.05.2014
U # 5	55 MW	05.05.2006
U # 6	60 MW	01.07.2005

Fig 1.5 Sabarigiri Power House Google View

Tail Race Schemes

There are 5 other Power generating stations in the Tail race of Sabarigiri Power House.

1. Kakkad Power House
2. Ullumkal Power House
3. Karikkayam Power House
4. Carborandom HEP
5. Ranni-Perinad Power House.

Pamba Irrigation Project (PIP) uses water from the left bank of Maniyar Dam and Carborandom SHEP at D/S of Maniyar Dam take water from right bank of Maniyar Dam. Pamba Irrigation Project starts from Maniyar and passes through so many areas of Pathanamthitta & Alappuzha Districts.

There are so many water supply schemes running in the tail race of SGHEP from Seethathode to Kuttanad. One of the most important benefits of the project is that it releases fresh water throughout the year and protect the water supply schemes and peoples living along the river side from Moozhiyar to Kuttanad area. The Kakki reservoir also a good flood control system from Moozhiyar to Kuttanad area. The scheme also protects the Kuttanad area from back water effect of Arabian Sea by supplying fresh water throughout the year.

1.3 Background Details of the Project

The Pamba -Kakki scheme was conceived in different ways at different periods. The earliest report on the scheme was prepared in 1946 by the Public Works Department (PWD). In 1955 another scheme with the power station located at the right bank of Kakkiar was prepared. The Planning Commission approved a part of the scheme in 1958. Even when this scheme was sanctioned by the Planning Commission, there was a proposal for developing power from the combined Pamba -Kakki catchments in one stage. But because of objection raised by the Tamil Nadu government the Planning Commission did not give approval to this proposal (Project Report on Pamba -Kakki Scheme, 1960). Hence the State Government had to satisfy itself with the first stage of the scheme.

When the preliminary work on the first stage was in progress during July 1959, the scope of the project was changed so as to combine the first stage and second stage by locating the generating station at the banks of Moozhiyar. Consequently works sanctioned in the first stage were delayed.

A new proposal was sent to the Planning Commission and the Commission granted

sanction to the scheme in August 1960, at an estimated cost of Rs. 24.91 crores, in spite of the objections raised by Tamil Nadu. The KSEB gave administrative sanction to the project in August 1961. The loan agreement for the project was signed between the U.S and Indian Governments in 1962.

a. Date of Starting the construction : 1960

b. Date of Completion : 1967

c. Name of Designing Agency : KSEB Ltd

d. Name of Contractor : M/s HCC Ltd., Bombay

Sri. B M Edward, Cochin, Kerala

e. Major accidents/incidents if any : No major accidents reported during construction

1.4 Salient Features of Pamba Dam

Component Structures

1. Dam & Reservoir	
Type	Masonry – gravity
Latitude	$9^0$23'14" N
Longitude	$77^0$09'30.8" E
Bed level	935.74 m
Deepest foundation	930.86 m
FRL	986.33 m
MWL	986.33 m
Top of Dam	987.86 m
Length at top	281.48 m
Height above bed	52.12 m
Live storage	31.15 Mm^3
Design flood	911.8 m^3/s
IC tunnel sill	963.17 m
MDDL	963.17 m
Dead storage	8.07 Mm^3
Dam volume	0.153 Mm^3

No & dia. of outlet (disperser)	1 no, 6' (1.83 m) dia. outlet – controlled by 5'4" Howell-Bunger Valve at Ch. 850, Block 9
Trash rack	3 sets, 2.74 m x 1.83 m, bottom level – 3134' (955.26 m)
Sill level of outlet	958.29 m
Outlet discharge capacity	1030 cusecs (29.17 m^3/s) @ FRL 986.33 m
Gate size for outlets	Emergency 2.89 m x 1.52 m
Roadway width	6.1 m
Foundation gallery	1 on each flank
Drainage gallery	5' x 4'6" (1.64 m x 1.37 m) rectangular top semicircular
Grout holes	2.5" – 15'/20' apart (63 mm @ 4.5 m/6.0 m apart)
Drain holes	3" dia. @ 10' c/c (76 mm dia. @ 3.0 m c/c)
Contraction joints	@ 60' – 110' (18 m – 33 m)
Base width	45.187 m
No of blocks	10
Max length of block	33.83 m
No of drain holes	31
Floor level of transverse galleries	964.311 m x 957.834 m

2. Spillway

Shape	Ogee shaped
Flood discharge	911.8 m^3/s
Radial gate – No & size	6 no – 7.01 m x 4.87 m
Ryve's C for flood discharge	3500 (FPS system)
Spillway crest	981.46 m
Spillway length	54.25 m
Depth of ogee concrete over masonry	6.4 m
Clear roadway at spillway	3.05 m
Top of hoist bridge	989.686 m
Width of hoist bridge	3.40 m
Spillway bridge	6 spans (7.01 m clear span)

Bridge pier thickness	2.44 m
Crest equation	$x^2 = 40y$
Bucket radius	15.85 m
Bucket bottom	918.97 m & 935.74 m
Energy dissipation	Up-turned buckets

Pamba Dam and Reservoir: Pamba reservoir is the second largest reservoir of the project. The reservoir is formed by the construction of a masonry gravity dam across River Pamba. The length of this dam is 281.48 m at road level and the top width is 6.10 m. The dam has a catchment area of 72.52 Sq km. The spill way of the dam is 54.25 m long has 6 nos. of steel radial shutters. Water from Pamba Reservoir is conveyed to Kakki -Anathode Reservoir through a 3.6 m x 3.6 m D-shaped inter-connecting tunnel of 3207.7 m length. The inlet & exit sill levels of this tunnel are at +963.168 m and +955.55 m and Pamba reservoir can rise up to an FRL of +986.33 m. The water from Pamba reservoir is fed into Kakki -Anathode reservoir through this IC Tunnel. There are also a few numbers of small dams - Kullar, Gavi, Meenar I & II - constructed across nearby rivulets to divert the discharges into the Pamba reservoir. Since the sill level of IC tunnel is +963.168 m, there will be a constant dead storage of 8.07 Mm^3.

There is a reverse pumping system in Pamba Reservoir. The water level of **Kochu Pamba Weir** on reaching FRL, the water spread area extends to the downstream of Pamba Dam. When the water level of Pamba Reservoir falls down, the water from downstream (Kochu Pamba) is pumped back to the reservoir. The pumps are placed at a pumping station at the downstream of Pamba dam in the right bank of spill way channel. Photograph showing downstream of Pamba dam with reverse pumping station is given below in **Fig 1.6.**

Photograph showing downstream elevation and upstream elevation of Pamba dam are given in **Fig 1.6a** & **Fig 1.6b**. Sectional plan of Pamba dam is shown in **Drg 1.1** of **Annexure 1**. Google view of Pamba dam is shown in **Fig 1.7**.

Fig 1.6 Pamba dam downstream with reverse pumping station

Fig 1.6a Downstream Elevation of Pamba Dam

Fig 1.6b Upstream Elevation of Pamba Dam

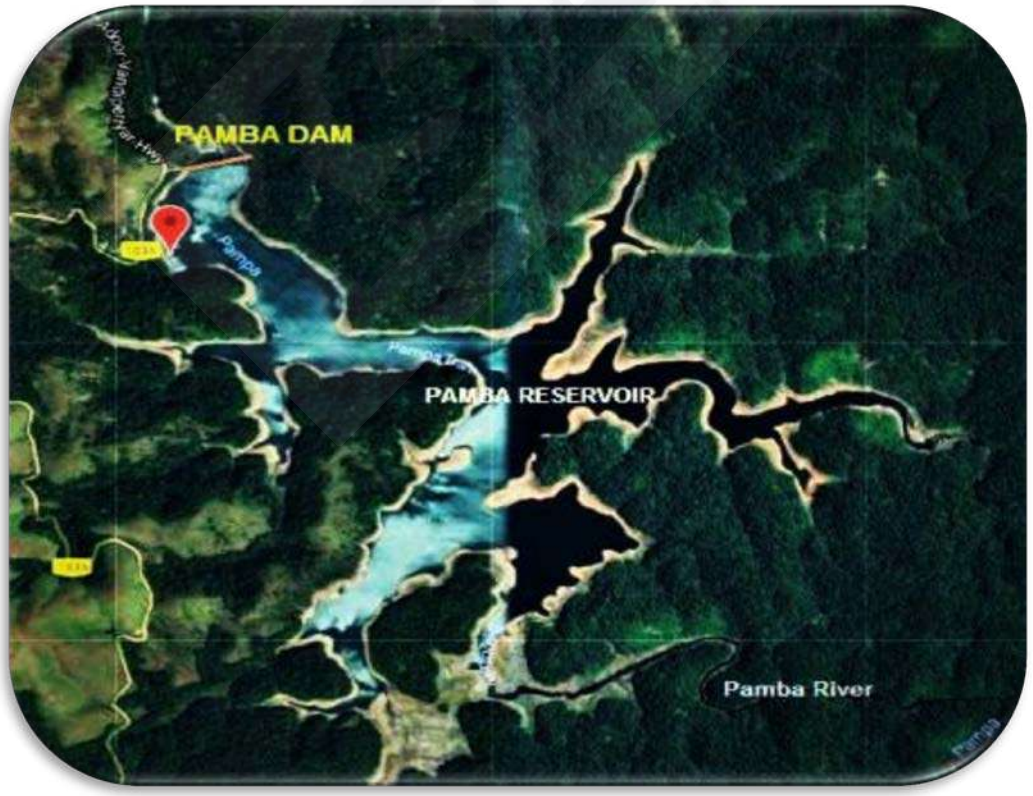

Fig 1.7 Google map view of Pamba dam

Galleries: Pamba dam has one Gallery (drainage cum inspection) of rectangular cum semi-circular shape and size 1.52 m x 2.13 m and two Adits on each bank. This gallery is confined between Chainages 330' (100.58 m) in Block No.3 and 910' (277.37 m) in Block No. 10. The porous drain holes and the foundation drain holes are discharging in to this gallery. The longitudinal drain is connected to the drainage culverts located in between Ch. 210' (64.01 m) to Ch. 330' (100.58 m) in Block No. 2 & 3 and Ch. 910' (277.37 m) to Ch. 960' (292.61 m) in Block No. 10. All the water collected through the drain in the drainage gallery is ultimately collected at EL. 3090' (941.83 m) in Block No. 8 and the whole water is lead through drainage culvert. The drainage culvert is located at Ch. 780' (237.74 m) in Block No. 8 and has dimension 3' x 2'6". The collection sump inside the culvert is of size 6" x 9". The collected water is led to the downstream side of drain over the right bank of spill way. Two transverse galleries / adits are there as an access to the drainage cum inspection gallery. They are located at Ch. 415' (126.49 m) in Block No. 4 on left bank and Ch. 885.50' (269.90 m) in Block No. 9 in right bank. The floor levels are 3163.75' (964.31 m) and 3142.50' (957.83 m) respectively. The dimensions of transverse galleries are same as that of longitudinal gallery. The transverse gallery / Adits on the right bank, on the right side of spill way, leads into Adit-house. Steps are provided to reach the approach road on the right bank at EL. 3184' (970.48 m).

Interconnecting Tunnel

The water from Pamba Reservoir is conveyed to Kakki-Anathode Reservoir through a 3.6 m x 3.6 m D-shaped inter-connecting tunnel of 3207.70 m long. The inlet & exit sill of this tunnel are at +963.168 m and +955.55 m. Pamba reservoir can rise up to an FRL of +986.33 m. The water from Pamba reservoir is fed into Kakki-Anathode reservoir through this IC Tunnel. The minimum draw level of reservoir is 963.17 m and the tunnel has a gradient of 1 in 400. Maximum discharge through this tunnel is 70.79 m^3/s and maximum velocity of 5.867 m/s. The tunnel has average lining thickness of 11", with a minimum of 8". The tunnel mouth is guarded by trash racks, arranged in a triangular pattern at the tunnel mouth as base and supported by columns and ribs. The intake tunnel and control shaft are given in **Drg 1.2** & **Drg 1.3** of **Annexure 1.**

Salient Features of IC Tunnel

Particulars	IC Tunnel
Length	10524' (3207.7 m)
Shape (finished)	D – 12' x 12' (3.6 m x 3.6 m)

Lining thickness	8" min, 11" av
Inlet sill	3160' (963.168 m)
Exit sill	3135' (955.55 m)
MDDL	**3160' (963.17 m)**
Distance of control shaft from inlet	175' (53.34 m)
Control shaft	17' x 12'3" Elliptical (5.18 m x 3.73 m)
Gradient	1/400
Max discharge	2500 cusecs (70.79 m^3/s)
Max velocity	19.25'/s (5.867 m/s)
Control arrangement	Shaft type vertical lift gate sealed on U/S
Gate size	12'3" x 9'6" (3.73 m x 2.90 m)
Lifting & lowering (by electric power)	2' in 20 seconds(0.61 m / 20 seconds)
Lowering by gravity	8'/minute (2.44 m/minute)
Lifting by hand	1"/minute (25 mm/minute)
Total weight	13 Tons
Motor speed	750 rpm
HP	6.25 HP
Power supply	400-440 V, 3 phase, 50 cycles
Trash racks	Triangular pattern
Hoist capacity	13 Tons

Photograph showing intake gate of inter connecting tunnel between Pamba and Kakki - Anathode reservoirs is given below in **Fig 1.8**.

Fig 1.8 Intake Gate of Inter Connecting Tunnel Pamba-Kakki

KochuPamba Weir

KochuPamba weir is located on $9^0$23'14"N, $77^0$9'30.8"E built across Pambayar in Pathanamthitta District, Kerala State. The weir is of concrete gravity having total length of 52.45 m at top, out of this 30.15 m is spillway portion and 22.15 m is non-overflow portion. The bed level of weir is +932.53 m and height above bed level is 3.65 m. The weir is over flow type with spill way crest level at +935.73 m, which is the same as FRL of the reservoir. MWL of the weir is +936.18 m. The top level of weir is +936.18 m. The layout plan of Kochu Pamba weir is shown below as **Fig 1.9**. The photograph of Kochu Pamba Weir is shown in **Fig 1.9a.**

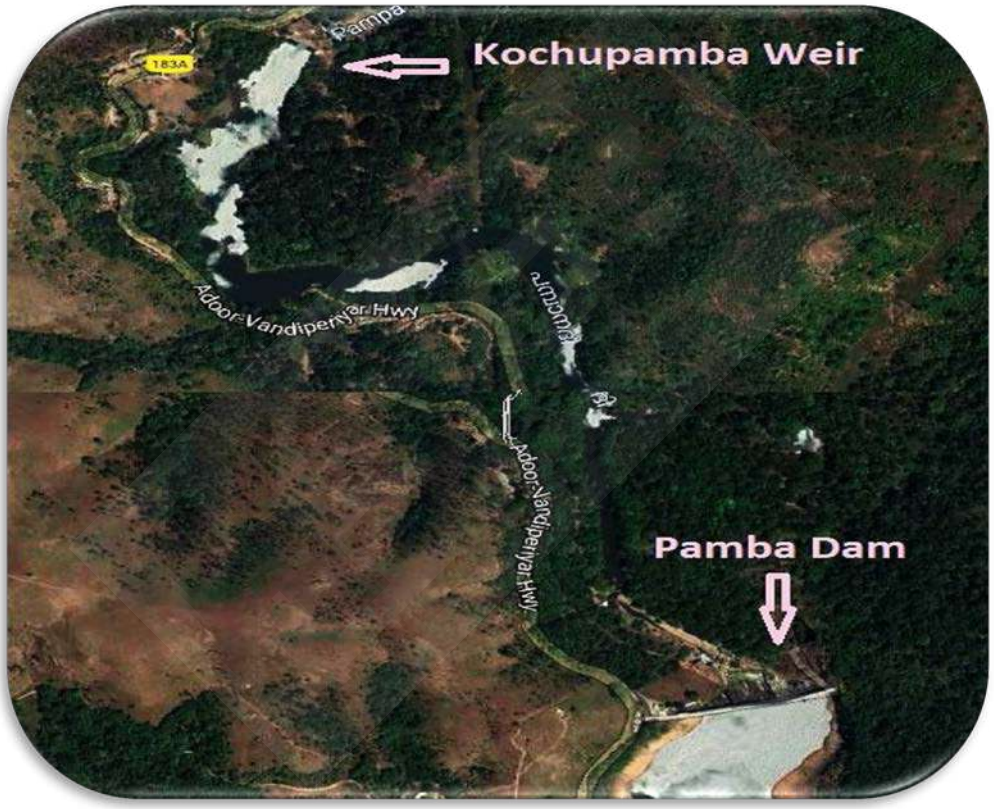

Fig 1.9 Google Layout of Kochu Pamba Weir

The sluice of the dam is for maintaining water level at 'Thriveni Pamba' in connection with the pilgrimage at Sabarimala. The reservoir of Kochu Pamba Weir is the secondary source of water at 'Thriveni Pamba". The scour sluice is operated as per the direction from higher officials of KSEB Ltd, based on the requirement from District Collector. The flow path while spilling and sluicing are passing through habitation for a certain kilometers. Intimation regarding spill is given to habitants living by the sides of river course on downstream through mike announcement.

Fig 1.9a Kochu Pamba Weir

Salient Features of Kochu Pamba Weir

Name of Dam	Kochu Pamba Weir
Type	Gravity over flow type
Bed level	+932.53 m
FRL	+935.73 m
MWL	+936.18 m
Top of Dam	+1140.00 m
Level at top	+936.18 m
Height above bed	3.65 m
Shape	Ogee shaped
Radial gate – No & size	Nil.
Dam Spill	Un-shuttered Ogee shaped spill way

1.5 Assignment of Responsibility

Kerala State Electricity Board Ltd is the owner and has the final authority and responsibility for the operation and maintenance of the dam. Identification of all areas of responsibilities connected with the operation and maintenance of the dam are covered in this section. The officer's responsibilities for the various functions (civil, mechanical, electrical, instrumentation etc.) are identified by their designation and, in particular, the responsibilities of operating personnel are specifically identified including the regularly scheduled duties which staff personnel are required to perform as outlined.

Project Administration Office	-	Chairman & Managing Director, KSEB Ltd.
Chief Controlling Officer	-	Chief Engineer (Civil - DS & DRIP), KSEB Ltd, Pallom.
Authority of Spillway operations and Flood releases	-	Chief Engineer (Civil - DS & DRIP), KSEB Ltd, Pallom.
Operation and safety of the dam	-	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, KSEB Ltd.
Controlling / Operation Officer at dam site	-	Executive Engineer, Dam Safety Division No. I, Seethathode.
Reservoir operations, inspection & maintenance	-	Executive Engineer, Dam Safety Division No. I, Seethathode.
Dam Health Engineer	-	Executive Engineer, Dam Safety Division No. I, Seethathode.
Recording reservoir data, inspection, monitoring and maintenance at site	-	Assistant Executive Engineer, Dam Safety Sub Division, Pamba.
Handling Dam operations, inspection, monitoring and performing duties as Maintenance Officer at dam	-	Assistant Engineer, Dam Safety Sub Division, Pamba.

1.5.1 Roles and Responsibilities of the AEE and AE during Monsoon

Flood condition assessment, warning, flood mitigation, and other responsibilities

1. Coordinate with the Asst. Exe. Engineers of other Sub Divisions and get the information on rain fall in the catchment, inflow status, reservoir level and to bring it to the notice of the EE/Dy CE.

2. Assist the EE/ Dy CE /CE to issue notification to the inhabitants downstream in Newspapers, Radio, and TV News channel to be alert regarding the flood situation.

3. Assist the EE/ Dy CE /CE to coordinate with the Revenue authorities (District Administration) to alert the downstream inhabitants to evacuate the flood zone to prevent loss of life and livestock.

4. Assist the EE/ Dy CE /CE to coordinate with the CWC flood monitoring authorities on the flood condition.

5. Maintain the reservoir water level gauge register and to update on hourly basis during floods and report to EE/ Dy CE /Chief Engineer.

6. Assess the inflows in the reservoir as per the approved reservoir operation and to prepare Proforma consisting of the status of the reservoir capacity and releases from the reservoir as per the standard Performa and to submit to the EE/ Dy CE /CE.

7. Submit to the EE/ Dy CE /CE on the inflows and releases from the reservoir and status of the reservoir twice in the day.

8. Maintain the spillway crest gate operation log book.

9. Operate the Spillway crest gates for flood mitigation as per the instructions of the EE/ Dy CE /CE and to update the Gate operation Log book

10. Observe the seepages in the drainage Gallery with respect to the reservoir head and record the seepages in the infiltration gallery and to immediately bring to the notice of the EE/ Dy CE /CE in case of excessive seepage/leakage in any specific blocks and porous drains.

11. Maintain the pump operation log books for the dewatering pumps in the drainage gallery and to submit to EE/ Dy CE /Chief Engineer.

12. Observe the gates and to see that the drain holes are not clogged and floating debris is not deposited in the gate components.

13. Monitor the condition of the welding transformers, gas cutting sets, umbrellas, tool kits, torches, chain blocks, ropes, ballies etc on daily basis and to see that things are in place to handle any emergency situation.

14. Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors, pumps or vibrations in the gate.

15. Observe and ensure that the dam top, embankment, catwalk, approach roads are well maintained by housekeeping personnel.

16. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to report to the EE/ Dy CE /CE in case of any untoward incidents or malfunctioning of the gates of excessive seepages, leakages etc.

17. Assist EE/Dy CE /CE to coordinate with the Generating staff of Moozhiyar Powerhouse downstream in the operation and power generation.

18. Assist EE/Dy CE /CE to share the flow data and the reservoir storage details to the Media on day to day basis during flood.

1.5.2 Roles and Responsibilities of the Dy CE and EE during Monsoon

1. Conduct Periodical (Pre and Post Monsoon) inspections to assess the health of the Dam and to direct the Executive Engineer for the immediate repair and maintenance for the smooth operation. Submit the inspection reports to the Chief Engineer and upload in DHARMA.

2. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists before and after monsoon and to issue necessary instructions to the Executive Engineer.

3. Coordinate with the Engineers of the three sub divisions & to get the information in respect of rainfall and inflow status and to bring to the notice of the CE.

4. To issue notification to the inhabitants downstream in Newspapers, Radio, TV News channel to be alert regarding the flood situation.

5. Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers to evacuate the flood zone to prevent loss of life and livestock.

6. Assist the CE to coordinate with the CWC flood monitoring authorities on the flood condition.

7. Submit to the CE the daily inflows and releases from the reservoir and status.

8. Operate the Spillway crest gates for flood mitigation as per the instructions of the CE and to update the Gate operation Log book.

9. Observe the seepages in the drainage Gallery with respect to the reservoir head and record the seepages in the infiltration gallery and to immediately bring to the notice of the CE in case of excessive seepage, leakage in any specific blocks and porous drains.

10. Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors, pumps or vibrations in the gate.

11. Observe the dam top, embankment, catwalk, approach roads are well maintained by housekeeping personnel.

12. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to report to the CE in case of any untoward incidents or malfunctioning of the gates of excessive seepages, leakages etc.

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

1. To issue sanction for flood release notification after discussing with Kerala Disaster Management Authority and Revenue Authority (District Administration).

2. Coordinate with the CWC flood monitoring authorities on the flood condition.

3. Issue necessary instructions to the engineers to operate the reservoir based on the in-flows, rainfall data, releases from the upstream reservoirs and status of the reservoir.

4. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to issue necessary instructions to the Dy CE/EE.

5. Coordinate with the Generation wing of KSEB Ltd regarding the power generation requirement.

1.6 Collection & Reporting of Dam and Reservoir Data

Dam Reservoir Data and vital information as below are collected, recorded and documented for the record.

- Reservoir water surface elevation.
- Reservoir inflow.
- Spillway outflow.
- River releases.
- Irrigation, water supply and hydropower releases.
- Weather related data
- Instrumentation data
- Water quality

MWL (m)	FRL (m)	Crest Level (m)	Present Water Level (m)	Previous Year Water Level	Percentage Storage	Rainfall (mm)	Generation (Mu)	Spill	Gate operation details

Table 1.1 Daily Reservoir Data

Instruction is given to the Executive Engineer for daily collection and reporting of inflow and outflow data in a standard Proforma as in **Table 1.1** above to the Deputy Chief Engineer.

Date	Water Level	Previous Year Same day Water Level	Rainfall	Previous Year Rainfall	Storage	Generation	Gross Inflow	PH Discharge + Losses	Spill	Net Inflow	Remarks

Table 1.2 Daily Reservoir Status

On collecting the details in the above format, a daily reservoir status is submitted to the Chief Engineer as in the **Table 1.2**.

Records/Logbooks of the operations for the following activities at Pamba Dam are maintained in a chronological manner for reference. These records are helpful for identifying preventative maintenance measures that may need to be taken up, troubleshooting the cause of potential equipment failure and documenting development of any unusual conditions.

- Date and Time date record
- Attendance statement during normal operations – both during monsoon and non-monsoon periods.
- Operations of the spillway gates and outlet works.
- Operating hours of mechanical equipment.
- Testing / Operation of spillway gates, stop-logs and associated controls.
- Testing/operation of Outlet gates, valves and associated controls.
- Maintenance activities carried out.
- Reservoir and dam inspections.
- Unusual conditions or occurrences.
- Safety and special instructions.
- Names of officers and staff carrying out inspections and maintenance.

Periodical collection of Dam and Reservoir Data are done as follows:

Reservoir water surface elevation	This is collected daily
Reservoir inflow	This is calculated daily
Spillway outflow	This is calculated during spill
River releases	The tail water release is measured at Moozhiyar Power house and released to Moozhiyar Dam of Kakkad H E Project
Irrigation, water supply and hydropower releases	The reservoir water is used for power generation at Moozhiyar Power house and there are 5 other Power generating stations and one Irrigation project running in the Tail race of Moozhiyar Power House. 1.Kakkad Power House, 2.Ullumkal Power House, 3.Karikkayam Power House, 4. Carborandom HEP, 5. Ranni-Perinad SHEP.

	In addition to this Pamba Irrigation project (Common Dam of Carborandom HEP) and large number of water supply schemes working under this tail water of SGHEP.
Weather related data	Collected and reported daily
Surveillance/Security arrangements	Provided at one security check posts near dam. The watch and ward of the dam structure and premises is arranged by Police Force under Govt. of Kerala. CCTV surveillance will be provided soon to cover the dam area and adjoining premises.
Water quality	Water sample analysis is also conducting once in a month. The analysis consists of Physical & Chemical tests are being conducted at the Analytical Laboratory, Jala Bhavan, Thiruvanathapuram.
Attendance statement during normal operations	Both during monsoon and non-monsoon period maintained at field office.
Operations of the spillway gates and outlet works	The spill way is designed for a safe discharge of 911.8 m^3/s. There are 6 no of radial gates for spillway operation. Take record of actual operations.
Operating hours of mechanical equipment	Maintained at field office
Testing/Operation of spillway gates and associated controls	The testing and operation are being carried out as per the manual and maintenance schedule. Other details maintained at field Office.
Testing/operation of Outlet gates, valves and associated controls	Maintained at field office
Maintenance activities carried out	Details maintained at field office
Reservoir and dam inspections	Periodically inspected and details maintained at field office
Unusual conditions or occurrences, including acts of vandalism	Details maintained at field office
Attendance statement at dam during emergency operations	Details maintained at field office
Changes to normal operating procedure	Details maintained at field office
Communication network checks	Network is available at Dam site at certain locations. Police wireless system regularly checked and maintained.

Safety and special instructions	Safety equipment are available
Names and addresses of official visitors	Record of inspections maintained at office

1.7 Public Utilities and Safety

As safety of Project Staff is of prime concern, safety instructions & protection measures at the dam are to be followed by all staff / project personnel. IB and Canteen are provided near Pamba Dam. There is only one approach road from the left bank.

Distances to the nearest medical assistance, Police station, Government Primary Health Centre which is located at Seethathode 65 km away from the dam need to be displayed. Also similar information about the location of a Private hospital, Government District Hospital at Pathanamthitta, Police Station at Angamoozhy about 55 km from the dam is displayed. Safety equipment like first aid kit and fire extinguisher are available at the dam site.

1.8 Restricted Areas

Certain areas of the dam and reservoir are restricted for entry of the general public. The purpose of restrictions is for security of the dam, public safety and uninterrupted safe operation of the dam. Two warning boards showing the restricted area are placed at the dam premises,

1. by the side of road & 2. Near to entrance.

In addition to the general lighting on the dam top and premises, three nos of high mast lights are provided to facilitate prompt watch and ward. Nowadays, a lot of tourists are visiting the dam area. Sometimes the crowd is uncontrollable and the police personals cannot control all of them. To overcome such situations, provision of Camera Surveillance System with Digital Video Recorder (DVR) is included under DRIP.

1.8.1 Dam safety surveillance including instrumentation

Security arrangements are provided near dam at security check post at the dam top on left bank. Also CCTV surveillance will be provided soon for covering the dam and its premises.

V notch is provided for seepage measurement. Some new digital instruments are also proposed under DRIP.

Security Arrangement Existing - Kerala Police Force 5 Shifts per day
(Head Constable - 1 No and Police Constable- 4No)

Proposed (as recommended by SISF) - Kerala Police Force 7 Shifts per day
(Head Constable - 1 No and Police Constable - 6 No)

1.9 Staff position, Communication & Warning System

The number & description of operating unit personnel posted/placed at different locations of the dam are noted in supporting documents and referenced in this Manual. Means of communications both in normal and emergency situations are identified in the Communication Directory. Communication means available include landline, mobile and satellite phones, wireless sets etc. Basic facilities like communication facilities, sirens etc. are available.

A hierarchy of organizational structure for the control and safety of Pamba dam is outlined below in **Fig 1.10**.

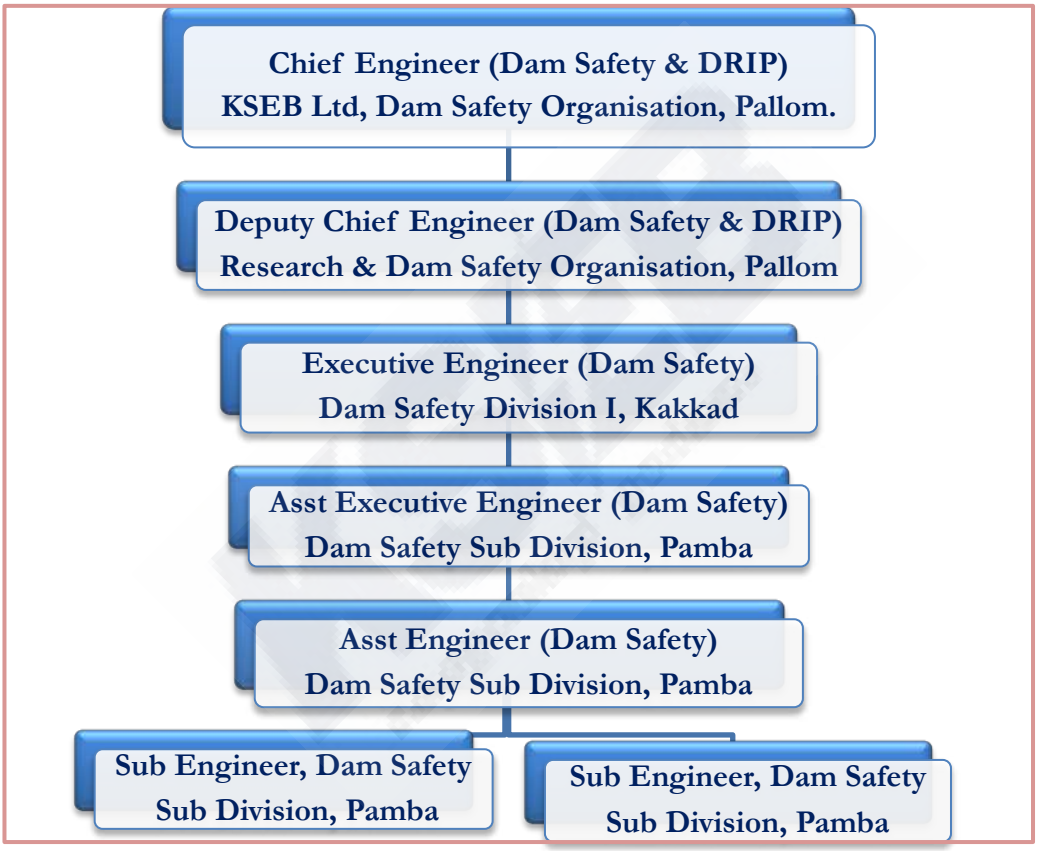

Fig. 1.10 Dam Safety Organisation Structure for Pamba Dam

Present hierarchy of Controlling officers and their contacts are as below:

Designation and office address	Contact number and e-mail
Chief Engineer Civil (Dam safety & DRIP), KSEB Ltd, Dam Safety Organization, Pallom, Kottayam	Ph: 9446008005, 9446008964 e-mail: cedamsafety@kseb.in, cedamsafety@gmail.com
Deputy Chief Engineer, Research & Dam Safety Organization, Pallom	Ph: 9446008492, 0481-2432290, 9496011540 e-mail: dirroplm2@gmail.com
Executive Engineer, Dam Safety Division No. I, Kakkad	Ph: 9446008424 e-mail: ddrdskkds@gmail.com
Assistant Executive Engineer, Dam Safety Sub Division, Pamba	Ph: 9496018371 e-mail:aeedssdmzhr@gmail.com
Assistant Engineer, Dam Safety Sub Division, Pamba	Ph: 9496011950 e-mail:aeedssdmzhr@gmail.com

Warning system -Mike announcement, Newspaper and Television are used for providing warning to the downstream areas during floods.

Spillway flood releases

Pamba reservoir was being operated as per 'Guidelines for Operation of Reservoirs' (IS 7323:1994). For storage reservoirs and for conservation purposes like power generation, no spilling of water over the spillway will normally be permitted until FRL is reached. During flood season, Various Alerts at specified levels for opening of spillway gates are given. The **first warning** as water level reaches 983.50 m, **second warning** as water level reaches 985.00 m and **third warning** as water level reaches 986.00 m are given for opening of spillway gates. After giving first warning at +983.50 m level, further warning is given in local media including TV etc. regarding the possible opening of spillway gates continuously up to +985.00 m level. Also intimations are given to Disaster Management, District Administration, and Police Department etc. Based on the 2018 Flood, the alert levels are revised as in **Chapter 2 (Cl.2.3.5).**

Releases for various purposes like irrigation, water supply, and hydropower

The water from Pamba reservoir is fed into Kakki-Anathodu reservoir through IC Tunnel which is mainly used for power generation of **340** MW at Moozhiyar power house of

KSEBL around 60 Km from Pathanamthitta. The tail water from power house discharges into Moozhiyar River further downstream. The reservoir of Kochu Pamba weir is the secondary source of water at 'Thriveni Pamba' and the sluice operated for maintaining water level at 'Thriveni Pamba' in connection with the pilgrimage at Sabarimala.

Routine inspection

Usually monthly inspection and quarterly inspections are carried out by the operating/controlling officers. Pre-monsoon inspection and Post monsoon inspection as per CWC guidelines are carried out by the respective officers and reports are supplied to CWC. As per the present norms, the pre-monsoon and post monsoon reports are to be updated in DHARMA web site in the prescribed revised format.

Maintenance

Routine maintenance is carried out for Spillway radial gates, H B Valve, Emergency gate and hoisting mechanism, sluice valves of weir, I C tunnel control gate and hoist before the onset of monsoon. Details are given under the Chapter Project Maintenance.

1.10 Distribution of Operation & Maintenance Manual

The following officers/ field staff at different levels in the Division under the supervision of Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom and administrative control of Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom have been entrusted with the specific responsibility for carrying out O & M activities for Pamba dam.

1) Executive Engineer, Dam Safety Division No. I, Kakkad
2) Assistant Executive Engineer, Dam Safety Sub Division, Pamba
3) Assistant Engineer, Dam Safety Sub Division, Pamba
4) Personnel in charge of works of the Dam

The list of offices to whom the O&M Manual of Pamba dam are to be distributed are:

1. Dam Safety Division No. I, Kakkad
2. Dam Safety Sub Division, Pamba
3. Assistant Engineer in charge of Pamba dam
4. Office of Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom

5. Office of Chief Engineer, Dam Safety Organization, KSEB Ltd, Pallom

1.11 Supporting Documents & Reference Material

This O & M Manual is the key instruction document. Supporting documents and necessary instructions for all phases of the operation, inspection and maintenance of the dam, reservoir and appurtenant works indicated below are available at the dam control room for reference.

- Detailed drawings of the Project
- Emergency Action Plan (EAP)
- Latest Hydrology Review Report
- Latest DSRP Report
- Flood forecasting and operating criteria
- Agreements with user agencies
- Power station operation plan
- Administrative procedures
- Maintenance schedules
- Gate Manufacturer's manual and drawings
- Regional communication directory
- Instrumentation reports / results

1.12 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned official are tabulated below in **Table 1.3.**

Sl. No.	Component/ Duty	Frequency	Personnel
1	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Tunnel Intake	Daily	Sub Engineer/Dam operators on contract

2	Record water surface elevation, reservoir inflow and spillway discharge.	Daily (Hourly basis during monsoon)	Sub Engineer/Dam operators on contract
3	Record meteorological data, Record releases from outlets /sluices	Daily	Sub Engineer/Dam operators on contract
4	Check security and safety devices, Complete logbook / site register which include the above information.	Daily	Assistant Engineer
5	Record seepage from drainage systems, Gallery drains etc. and record meteorological data.	Weekly	Sub Engineer/Dam operators on contract
6	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Tunnel Intake	Weekly	Assistant Engineer
7	Check stand by generator (DG Sets), Drainage systems, Gallery drains etc	Weekly	Assistant Engineer
8	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Tunnel Intake	Fort nightly	Assistant Executive Engineer
9	Check security and safety devices, logbook and site register which include the above information.	Fort nightly	Assistant Executive Engineer
10	Check stand by generator (DG Sets), Drainage systems, Toe drains, Gallery drains etc.	Fort nightly	Assistant Executive Engineer
11	Measuring devices, communication devices, status of instruments, vegetation growth	Fort nightly	Assistant Executive Engineer
12	Check Sign/Warning display boards near vulnerable locations	Fort nightly	Assistant Executive Engineer

13	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Tunnel Intake	Monthly	Executive Engineer
14	Check measuring devices/Instruments, Security and safety devices, Communication Devices, Status of Vegetation growth – rectification, if needed.	Monthly	Executive Engineer
15	Check Sign/Warning display boards near vulnerable locations	Monthly	Executive Engineer
16	Replace fuse light bulbs, Inspect to maintain ventilation system, cleaning of control panel boards.	Monthly	Assistant Engineer
17	Check outlet works, updating operating instruction, check gate air vents, clean gate control switchboxes, check operation of gates, grease gate hanger/dogging	Quarterly	Executive Engineer
18	Check condition of trash rack of intake structure, Check condition of Outlet works & its Energy Dissipation Arrangement, Check operation of Valve house	Quarterly	Executive Engineer
19	Check condition of spillway, log and safety boom, Check for debris in inlet channel, Check operation of gates, Check for damages in spillway glacis, energy dissipation arrangement, d/s area etc, Check and clear spillway bridge drains, Clean inside of motor control cabinet.	Quarterly	Executive Engineer
20	Check for adherence to instrumentation schedule, Record pertinent information in Operation of Gates, Check condition of V-Notch/seepage measuring devices, Check hydro mechanical components.	Quarterly	Executive Engineer

21	Inspection of Spillway & outlet works, hydro mechanical components, Check paint on gates, Check lubrication of wire ropes and application of Cardium compound, Check mechanical hoist bearings and flexible coupling bearings, Check gear systems, Exercise gates and valves, Check oil reservoir level in hydraulic system, Check pressure release valve, Check lubrication of gate rollers, Check rubber seals and seal clamp bar.	Half yearly (Pre and Post Monsoon)	Deputy Chief Engineer along with Executive Engineer in charge of dam
22	Submission of Inspection report to State DSO, CWC and uploading into DHARMA.	Half yearly	Chief Engineer/ Deputy Chief Engineer
23	Comprehensive inspections	Annually	Dam Safety Authority along with Dam Owners
24	Inspect dam and gate structures, trash racks and stilling basin / energy dissipation arrangement, which normally are underwater (by dewatering or by divers/ROV as necessary). Review Dam operation procedures and EAP and update as necessary.	Five Yearly	Chief Engineer/ Deputy Chief Engineer
25	Comprehensive inspection of performance of the dam and gate structures and reservoirs, trash racks and stilling basin /energy dissipation arrangement.	Ten Yearly	DSRP

Table 1.3 Schedule of duties/inspections

1.13 Hydro-Mechanical Inspections / Checks

Frequent inspections/checks for hydro-mechanical components are to be conducted and necessary action to be taken up during maintenance. Routine maintenance is carried out for Spillway gates and hoisting machinery as part of routine maintenance before the onset of monsoon. Details are given under the Chapter Project Maintenance.


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Chapter 2

Project Operation

The operation of a dam will involve regulation of its reservoir as per project specific requirements, keeping records and ensuring public safety. Proper operation procedures are crucial for normal or day to day operation of a dam for maintaining a safe structure.

2.1 Basic Data

The Pamba operation plan consists of step-by-step instructions for operating the dam and reservoir during routine (normal) and emergency conditions. The operating procedures for normal operations are discussed in this chapter including operating criteria for the reservoir, spillway & outlets. The operation of a dam involves regulation of its reservoir as per rule curve and project specific requirements. This includes the use of area capacity curves and design flood, both are described below.

2.1.1 Dam

Pamba dam is 281.48 m long at road level and the top width is 6.10 m. The deepest foundation level is 935.74 m and the top of the dam is 987.86 m. The FRL and MWL of the dam is 986.33 m. The effective storage above the dead storage level of 963.17 m is 31.14 Mm^3. The dam has a catchment area of 72.52 Sq km and has a masonry content of 0.153 Mm^3.

The dam is divided into 10 blocks with contraction joints at suitable chainages with copper sealing strips on the upstream. The dam was completed in 1967. Altogether 96 nos. of boreholes was taken along proposed alignment of dam (upstream & downstream). Out of which 30 nos were taken along the centre line. Maximum depth of borehole is 50' at the riverbed portion. The dam is constructed with rubble in cement mortar and upstream side of the dam is finished with hammer dressed face stones for the full height. At the spillway portion stone masonry is stopped at EL. 3191 above which the concrete for the spillway forms face of dam.

The downstream and upstream sectional elevation of dam, showing the details and important levels are as shown in **Drg 2.1** and **Drg 2.2** of **Annexure 1**.

2.1.2 Spillway

The spillway for Pamba dam is 68.28 m high and consists of 6 nos. radial gates of size 7.01 m x 4.87 m for regulating the flood discharge 911.8 m^3/s. The crest level of spillway is 981.46 m and the thickness of intermediate piers is 2.45 m. The gates are of structural steel frame work with a steel skin plate on the upstream side, resting on a sill beam embedded on the crest. The hoisting arrangements of shutter are installed over the top of Hoist Bridge at EL. 989.69 m. The hoisting arrangement consists of a central drive and two lateral drives coupled by a pipe shafts. The central drive has a spur type reduction gear, self-arresting worm-gear, a double shoe brake with electro hydraulic central device. The hoisting can be done either **electrically or manually**. For hand operation, there is a hand crank and a safety device for switching off electrical system, when the handle crank is to be used. The lateral drum consists of spur-type reduction gears and a rope drum. The mechanism also consists of indication needles and electrically controlled top & bottom position limit switches. The location plan of spillway and plan & downstream elevation of spillway of Pamba dam are given in **Drg 2.3** and **Drg 2.4** of **Annexure 1**.

2.1.3 Outlet arrangements

The dam is installed with a disperser outlet arrangement of 1 No. 1.83 m diameter, controlled by 1.626 m Howell Bunger Valve at Ch. 850' (259.08 m) in Block No. 9. The drawings showing valve assembly and discharge curve are included in **Annexure 2**. This valve can be operated by a mechanism placed on the winch room at downstream face of the dam. The access to this winch room is through the transverse galley at Block No. 8. The sluice valve is supported by an emergency shutter of size 9'6" x 5' (2.896 m x 1.524 m) at the water side. The hoisting winch of the same is placed on the winch room at dam top. The sluice gate is placed at El. 3144 ft (958.29 m), with a discharging capacity of 1030 cusecs (29.17 m^3/s) at FRL. The bell mouth at the entrance on the upstream is rectangular in section 9'6" x 5' (2.896 m x 1.524 m) and this section ends in 6' (1.83 m) dia. circular outlet system in a suitable transition. The cross section showing trash rack structure & disperser house and details of intake are shown in **Drg 2.5** & **Drg 2.6** of **Annexure 1**. The upstream entrance of the bell mouth, 3 sets of trash racks of size 9' x 6' (2.743 m x 1.829 m), fabricated with steel members, are provided. The sectional plan of trash rack arrangement is shown in **Drg 2.7** of **Annexure 1**. The valve house downstream of dam is given in **Fig 2.1** below.

An emergency shutter and its hoisting system, supplied by M/s Pacific Co., USA, are

placed to regulate the flow to the bell mouth valve. The hoist consists of electric motor, solenoid brake and a rope drum. The drawings of the emergency gate and hoist (plan, section, elevation, hand wheel and connection diagram etc.) are included in **Annexure 2**. There is a fan brake, independently acting under different brake torques. There is a suspension beam for the shutter, moves along with the gate, for downward movement. There is breather system for this outlet arrangement, made of 2" (0.05 m) dia. steel pipes, to avoid the negative pressure and subsequent blocking of water way inside. The sectional plan and elevation of hoist house of emergency gate is given in **Drg 2.8** of **Annexure 1**. Photos from downstream and upstream of intake gate are given in **Fig 2.2.**

Fig 2.1 Sluice Valve House

Fig 2.2 IC Tunnel Intake Gate downstream & upstream

The intake gate for Inter Connecting tunnel is of 13 T capacity and with hoist motor of 6.25 HP. Salient features are given in **Chapter 1. Cl.1.4.** Section through intake of IC Tunnel and control shaft are given in **Drg 1.2 & Drg 1.3** of **Annexure 1.** The control unit with motor is given **Fig 2.3.**

Fig 2.3 IC Tunnel Hoist Motor

2.1.4 Elevation Capacity Curve

The area and capacity curve of Pamba Reservoir during design is shown in **Drg 2.9** of **Annexure 1** and tabulated in **Table 2.1.** The elevation capacity (storage) curve for Pamba Reservoir based on **Table 2.1** is shown in **Fig 2.4.**

PAMBA RESERVOIR

I C Tunnel Sill level - 963.168 m
Spillway Crest level - 981.456 m
Full reservoir level - 986.332 m

Table of Reservoir Capacity Details

Level m	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
963	8.00	8.05	8.10	8.17	8.24	8.31	8.38	8.45	8.52	8.60
964	8.68	8.76	8.84	8.92	9.00	9.00	9.16	9.24	9.32	9.40
965	9.48	9.56	9.64	9.72	9.80	9.88	9.96	10.04	10.12	10.20

966	10.28	10.36	10.45	10.55	10.65	10.75	10.85	10.95	11.05	11.15
967	11.25	11.35	11.45	11.55	11.65	11.75	11.85	11.95	12.05	12.15
968	12.25	12.35	12.45	12.55	12.65	12.75	12.85	12.95	13.05	13.15
969	13.25	13.35	13.45	13.55	13.65	13.75	13.85	13.95	14.05	14.15
970	14.25	14.35	14.45	14.55	14.65	14.75	14.85	14.95	15.05	15.15
971	15.25	15.35	15.45	15.55	15.65	15.77	15.89	16.01	16.13	16.25
972	16.37	16.49	16.61	16.73	16.85	16.97	17.09	17.21	17.33	17.45
973	17.57	17.69	17.81	17.93	18.05	18.17	18.29	18.41	18.58	18.65
974	18.77	18.89	19.01	19.15	19.30	19.45	19.60	19.75	19.90	20.05
975	20.20	20.35	20.50	20.65	20.80	20.95	21.10	21.25	21.40	21.55
976	21.70	21.85	22.00	22.15	22.30	22.45	22.60	22.75	22.90	23.05
977	23.20	23.35	23.50	23.65	23.80	23.95	24.10	24.25	24.40	24.55
978	24.70	24.85	25.00	25.15	25.30	25.45	25.60	25.75	25.90	26.05
979	26.20	26.35	26.50	26.65	26.80	26.95	27.10	27.25	27.40	27.55
980	27.70	27.85	28.00	28.15	28.30	28.45	28.60	28.75	28.90	29.05
981	29.20	29.37	29.55	29.73	29.91	30.09	30.27	30.45	30.63	30.81
982	30.99	31.17	31.35	31.53	31.71	31.89	32.07	32.25	32.43	32.61
983	32.79	32.97	33.15	33.33	33.51	33.69	33.87	34.05	34.23	34.41
984	34.59	34.77	34.95	35.13	35.31	35.49	35.67	35.85	36.03	36.21
985	36.40	36.60	36.80	37.00	37.20	37.40	37.60	37.80	38.00	38.20
986	38.40	38.60	38.80	39.00						

Table 2.1 Pamba Reservoir Characteristics

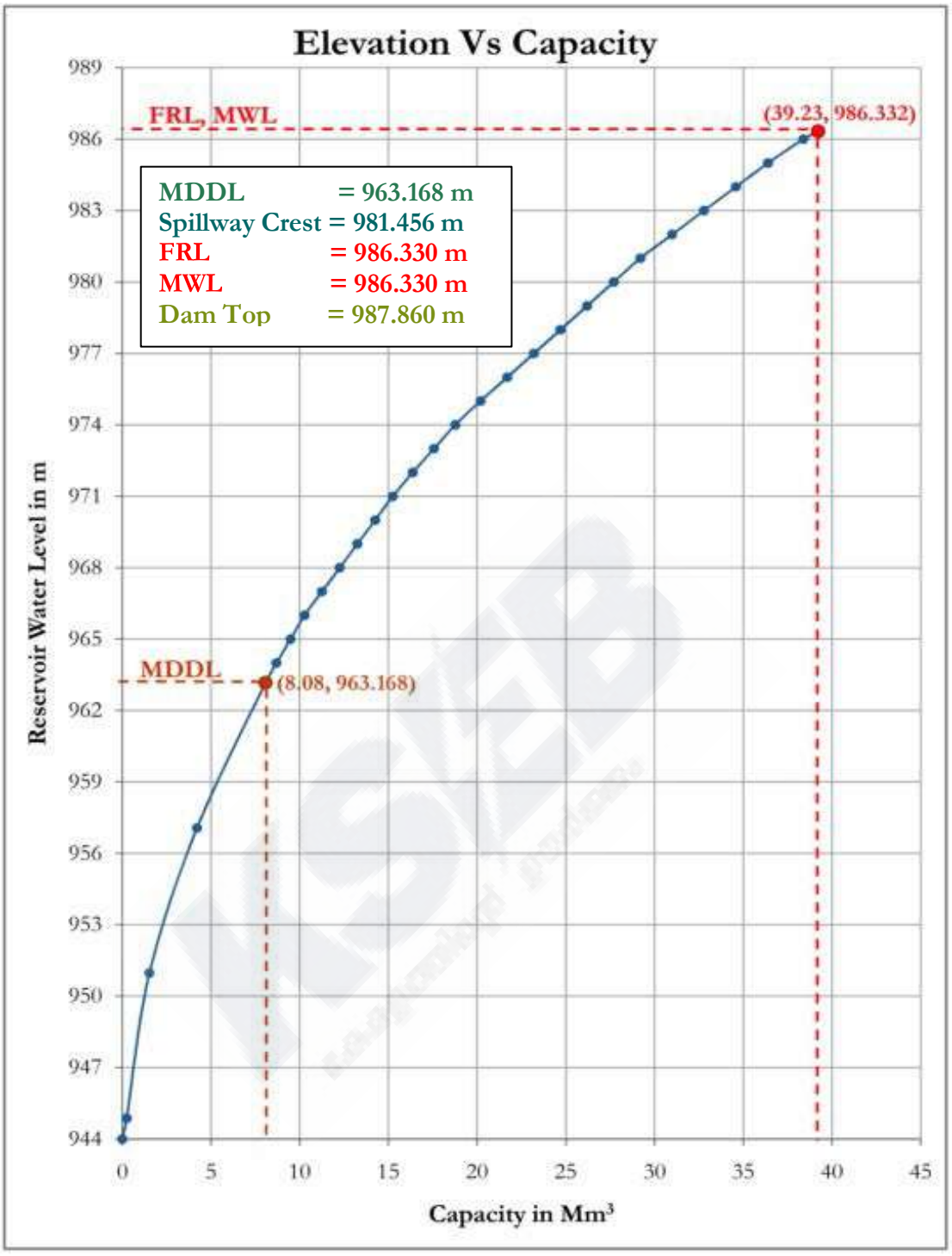

Fig 2.4 Elevation- Capacity Curve

2.2 Operation Plan

An effective operation plan and schedule is required for the safe project operation for which the project specific features shall be known. The salient features of the dam are given in **Chapter 1**.

2.2.1 Data of the historic floods

As per historical records, the maximum flood observed in Western Ghats was during 1924. The centre of the storm of the 1-day rainfall of 17th July 1924 and 2-day rainstorm of July 16-17 was located at Devikulam in Kerala in which rainfall of 484 mm and 751 mm respectively was recorded.

The second historical flood occurred during August 14 to 17 in the year 2018, which resulted in record inflow in to the reservoir. The SW monsoon of the year 2018 in the State similar to that of 1924 Devikulam storm, Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted in severe flooding in 13 out of 14 districts in the State. It is seen that the 2-day and 3-day rainfall depths of 15-17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. For the entire Kerala, out of 758.6 mm rainfall from 1 August 2018 to 19 August 2018, about 414 mm rainfall occurred in just three days viz. 15-17, August 2018, which created severe flooding in the State, while the same during 16-18, July 1924 was 443 mm. The 3-day rainfall of 14-16, August 2018 at Pamba dam site was 422 mm. The 4 –day rainfall of 15-18, August 2018 at Pamba dam site was 495 mm.

Pamba spillway gates were opened during 2013 and 2018 for flood control. Spill details and inflow details of the year 2013 are tabulated below in **Table 2.2** and **Table 2.3**. Spill details of the year 2018 are tabulated below in **Table 2.4**. The rainfall and reservoir water level of the years 2013 and 2018 are included in **Annexure 3**.

Year	Date		Water level in m	Storage in Mm^3	Spillway discharge in Mm^3
	Pamba				
2013	19.09.2013	06:30	985.50	37.40	29.068 (8 days)
	26.09.2013	04:00 PM	986.25	38.90	

Table 2.2 Spill details of 2013

Date	Water Level in m	Storage in Mm^3	Gross Inflow in Mm^3	Spill in Mm^3
18.09.2013	984.50	35.49	2.34	0.00
19.09.2013	985.50	37.40	3.99	2.08
20.09.2013	986.33	39.22	9.99	8.17
21.09.2013	986.25	38.90	7.69	8.01
22.09.2013	986.25	38.90	4.94	4.936
23.09.2013	986.15	38.70	1.90	2.097
24.09.2013	986.10	38.60	1.81	1.907
25.09.2013	986.25	38.90	2.00	1.698
26.09.2013	986.25	38.90	0.17	0.170
Maximum Inflow observed in 2013 = 9.99 Mm^3/day (on 20.09.2013)				

Table 2.3 Inflow details of 2013

Date	Water Level in m	Rainfall in mm	Storage in Mcm	Gross Inflow in Mcm	Spill in Mcm
10/08/2018	986.20	110.00	38.81	2.63	2.22
11/08/2018	985.50	37.00	37.40	9.36	10.77
12/08/2018	985.40	5.00	37.20	2.49	2.69
13/08/2018	985.65	77.00	37.71	1.23	0.72
14/08/2018	985.75	72.00	37.91	2.78	2.58
15/08/2018	985.75	203.00	37.91	11.16	11.16
16/08/2018	985.55	147.00	37.51	19.40	19.80
17/08/2018	985.70	60.00	37.80	11.60	11.31
18/08/2018	985.75	85.00	37.90	7.85	7.75
19/08/2018	986.00	33.00	38.41	5.15	4.64
20/08/2018	985.90	37.00	38.22	2.02	2.20
21/08/2018	985.75	38.00	37.91	1.95	2.26
22/08/2018	985.40	5.00	37.21	0.44	1.14
23/08/2018	984.75	3.00	35.94	-0.32	0.95
24/08/2018	983.90	1.00	34.41	-0.58	0.95
25/08/2018	983.00	0.00	32.79	-0.99	0.63
26/08/2018	982.10	30.00	31.17	-0.54	1.08
Total Spill =82.848Mm^3 Maximum Inflow observed in 2018 = 19.40Mm^3/day (on 16.08.2018)					

Table 2.4 Spill details of 2018

2.2.2 Design Flood and Features Related to Safety

Pamba River originates at an altitude of +1372 m at Chinnamel Mala. The catchment area is delineated from the Periyar lake catchment by a ridge. The construction of Pamba Dam was completed in the September 1967. The catchment area falls between latitude 77^0 9' 30.8" N, 77^0 15' N & longitude 9^0 26' 33" E, 9^0 20' E.

Hydrology during the initial period as available gives the total catchment area of Pamba Reservoir as approximately 72.52 Sq km**.** Being in virgin forest, rainfall readings of representative stations inside the catchment are not available for sufficiently long periods, the hydrology of scheme was worked out based on gauge - flow data of the Pamba river by the Madras Government from 1909 to 1916 and not on rainfall records.

In 1955, new gauging weirs were constructed at Pamba and Kakki River. Actual flow measurements observed from the above weirs from 1956 onwards clearly established that a gross draft of 830 cusecs continuous only is available under full regulation of both the reservoirs together. The total runoffs from Pamba and Kakki together for the years 1956-57, 57-58, 58-59 and 59-60 were 24600 Mcft, 28464 Mcft, 26369 Mcft and 32932 Mcft respectively. The average annual runoff of the years was 28091 Mcft.

The flood discharge has been calculated on Ryve's formula $Q= CM^{2/3}$

Where, Q= Flood discharge in cusecs, C=Ryve's constant,

M=Area of discharge.

The value for C for calculating the flood discharge of Pamba Dam Catchment of 28.00 Sq miles is 3500. The maximum flood discharge is calculated as 32,200 cusecs (911.8 m^3/s). The spill way is of solid gravity type with crest equation $x^2 = 40$ y. The downstream face is curved to conform to the flow characteristics of water. The clear water way required for the maximum discharge is 6 spans of 23 ft (7.01 m) each. The spillway for Pamba dam was finalized based on the model studies conducted by the Research Division, Peechi.

Hydrology review carried out in DRIP

As per BIS 11223-1985, Pamba Dam falls under the category of large Dams, i.e., Reservoir Capacity above 60 Mm^3 and Hydraulic head above 30 m. Hence the spillway is to be designed for Probable maximum Flood. Hence, as a pre requisite for DRIP, hydrological review was carried out based on the 1 day PMP value of 500 mm from PMP Atlas published by CWC even though the maximum rain fall for the last 15 years in the catchment area comes to 175 mm only. The revised Probable Maximum Flood is 1077 m^3/s and the spill way capacity is 912 m^3/s. Reservoir routing is carried out by the Modified Puls method (programme by CWC) and found that the

peak rate of outflow for the spillway comes to only 832 m^3/s and hence the existing spill way can safely negotiate the PMF.

2.2.3 Hoisting Arrangements for Radial Crest Gates

The spillway of Pamba Dam consists of 6 Nos. Radial gates made by M/s. Jessop & Company Ltd. Calcutta. The spillway for Pamba dam is 68.28 m high and consists of 6 nos. Radial gates of size 7.01 m x 4.87 m, for regulating the flood discharge of 911.8 m^3/s. The crest level of spillway is 981.46 m. The hoisting arrangements of shutter are installed over the top of Hoist Bridge at EL. 989.69 m. The hoisting arrangement consists of a central drive and two lateral drives coupled by a pipe shafts. The central drive has a spur type reduction gear, self-arresting worm-gear, a double shoe brake with electro hydraulic central device. The hoisting can be done either **electrically or manually**. The lateral drum consists of spur-type reduction gears and a rope drum. The mechanism also consists of indication needles and electrically controlled top & bottom position limit switches. A cross-section through the overflow portion of spillway of the dam is given in **Fig 2.5**. The details of spillway gate and hoisting system are shown in **Fig 2.5a.**

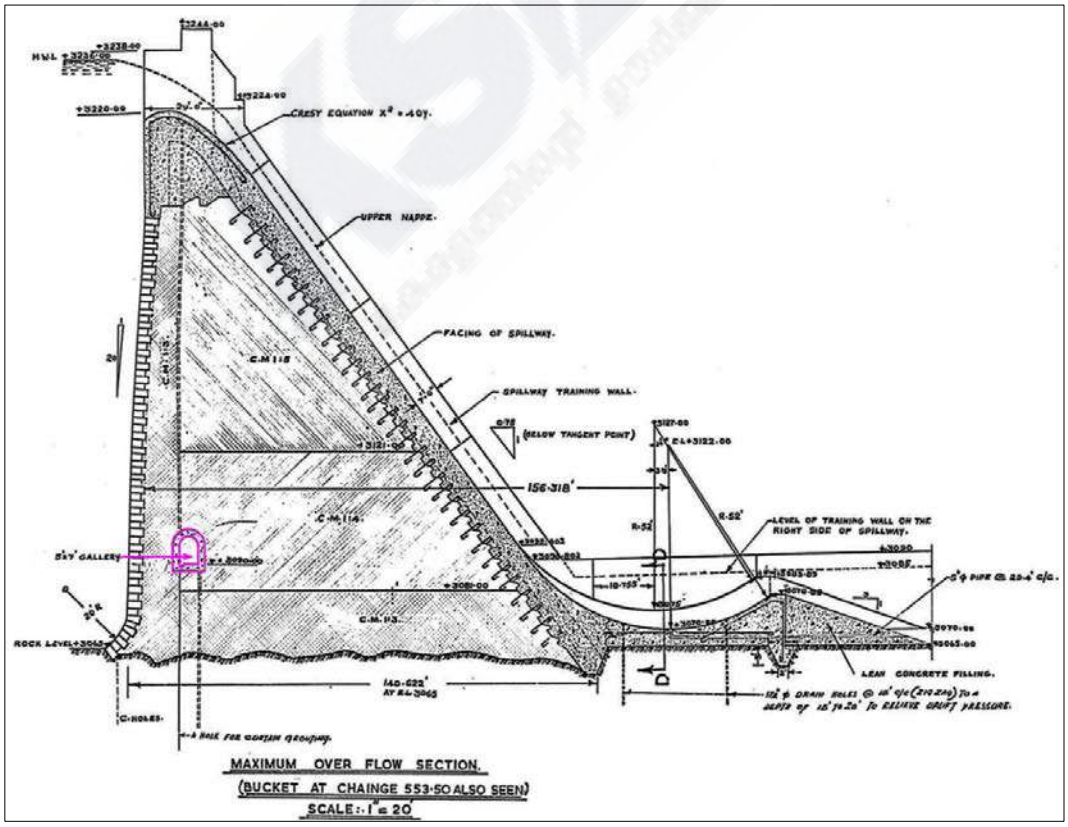

Fig 2.5 Cross-section through the overflow portion of Spillway

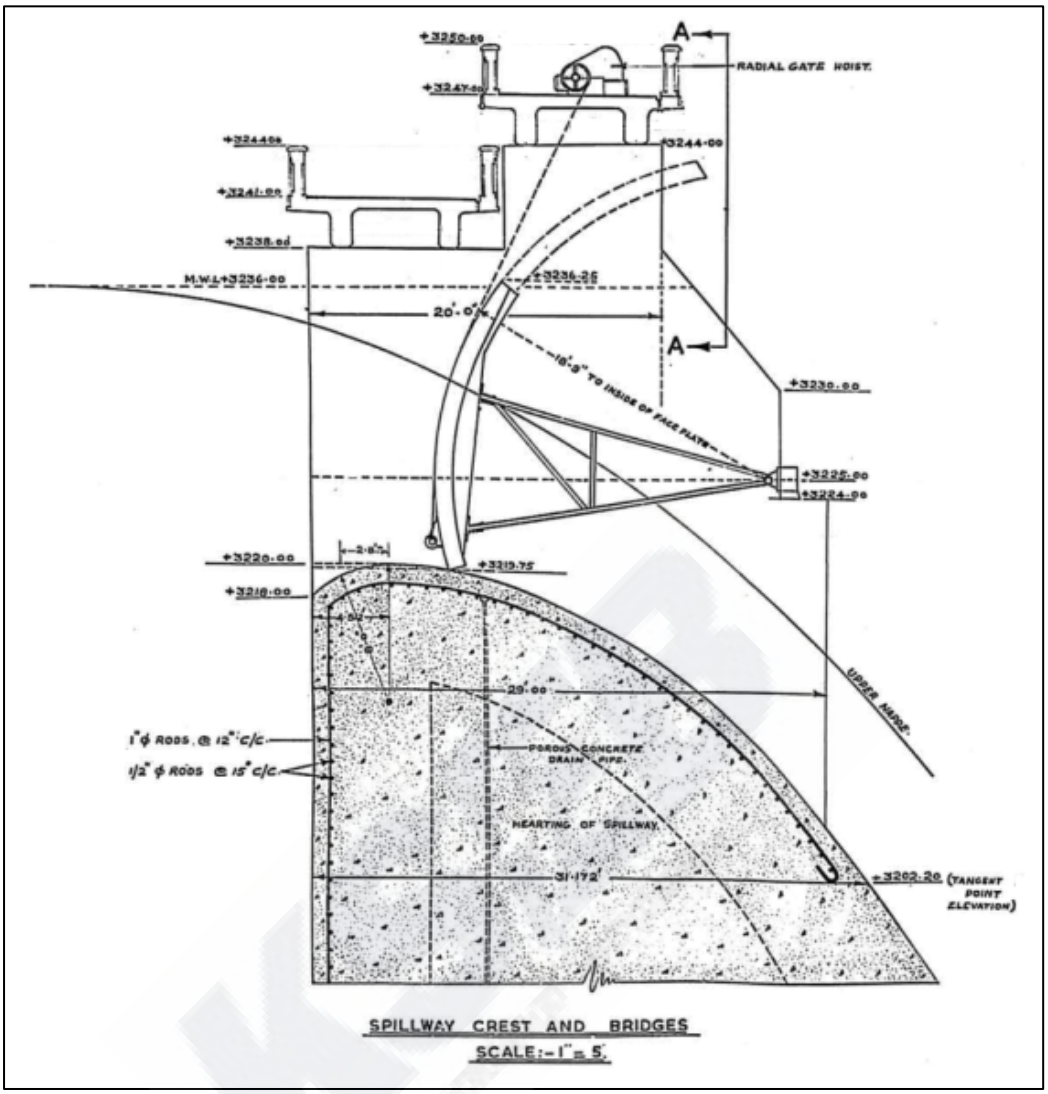

Fig 2.5a Details of spillway gate and hoisting system

Operation of radial gates:

The operation of the radial gates can be done either **electrically or manually**. After observing the parameters like, quantity of inflow on account of sudden rainfall or rainfall likely to happen, the height of gates to be raised is assessed first. This total height of opening is equally distributed to the all six gates. Gate No.3 is to be opened first to a unit height on the basis of requirement. Then Gate No.4 is operated to the same height as that of Gate No.3. The sequences of Gate operations are No.2, No.5 and finally No.1 & 6. The further increase in openings is also performed in the similar manner. The closing of the gates are being done in the reverse manner as that of opening. The manual system for operating radial gates is shown in **Fig 2.6.** The general arrangement of hoisting mechanism is given in **Fig 2.7.**

Fig 2.6 Radial Shutter Manual Operation

Fig 2.7 General View of Spillway Hoist Bridge

Raising and lowering of gates is done at a speed of 30 cm per minute, while operating electrically. The electric system consists of 3 phase synchronous motor, with short circuit motor 2.50 KW, 1400 rpm magnetic hydraulic brake unit, spindle, top & bottom position limit switches, etc. The electric control unit for the gates is shown in **Fig 2.8**.

The gates must be operated as per the instructions and detailed procedure as described in the gate operation manual included in **Annexure 2.**

The control panel arrangement of all the six radial gates is as given in **Fig 2.9**.

Fig 2.8 Electric Control system

Fig 2.9 Control panel arrangement of all the six radial gates

2.3 Normal Operation of the Reservoir

The operating procedures developed for normal or day to day operation of a dam shall include the following:

- Instructions for operating control mechanisms.

- Instructions for operating the reservoir in accordance with operation rule curve.
- General instructions for the safe operation of the dam and appurtenances.

The following aspects also need to be included:

- Releases to be made for various purposes round the year including releases to be made as per Inter-State Agreements/ MOU's with various States/Agencies/Projects, riparian releases etc.
- Rule curves.
- Inflow forecasting
- Flood release procedure

Site security is a matter of concern at all major dams. This includes terrorism implications and preventing structural damage by vandals and unauthorized operation of outlet or spillway gates. In most cases restricting public access is essential, and in some instances electronic security devices should be considered.

2.3.1 Operation of Control Mechanisms

The Operation manual of control mechanism and installation is attached as **Annexure 2.** The sectional elevation of spillway crest and hoist bridge of Pamba is given in **Fig 2.5a.**

Radial Gate Operations for flood release

The radial gates are being opened as per the direction of higher authorized officers. The gates are being opened only after intimating higher officials, District Disaster Management Authority, Police & Revenue Department. Mike announcement regarding the spill are being intimated to habitants on downstream sides of river course. Intimation to the public is also being given through News Paper & TV/Visual Medias. Also a control room is to be opened at the dam top itself during flood season on reaching Orange (second warning) Alert level for achieving better monitoring of water levels and gate operations.

As the dam site is in forest area, the electric power supply line to the dam is mostly through forest. During periods of heavy rain fall and storm, probability for power failure or lack of sufficient voltage is quite frequent. For obtaining uninterrupted three phase electric supply of sufficient voltage required for the operation of shutters, a 30 KVA Diesel Generator set is provided. The DG set will be kept ready, after checking its fuel quantity, circuits, and change over system, etc.

River Outlets

The Howell Bunger valve is operated along with the emergency shutter. The operation of both can be done, either by **electrical/ manual** mode. Please refer **Cl.2.1.3.** In view of safety of valves, opening is done in ratio 1: 10. The emergency shutter at water side is opened first. The operation of sluice is followed by it to a height equivalent to 1/10 of the opening of emergency shutter (i.e., for having 1 inch opening of sluice valve, the emergency shutter has to be raised by 10 inches). Further openings are conducted in the same manner. The closing of the gates are being done in the reverse manner of that of opening.

IC Tunnel Operations

The tunnel has a control arrangement of shaft type with vertical lift gates sealed on upstream at a distance of 175' (53.34 m) from inlet face. The control shaft is elliptical in shape and size of control shaft is 17' x 12' 3" (5.18 m x 3.73 m). The shutter of IC tunnel is 12' 3" x 9' 6" (3.73 m x 2.90 m), having total weight of 13 Tons. The gear system of hoisting winch can be operated either by electric power or manually. The lifting and lowering speed by electric power is 2' in 20 seconds (0.61 m / 20 sec). The lifting speed of shutter by manual operation is 1"/min (25 mm/min) and lowering speed by gravity is 8'/minute (2.44 m/minute). The hoisting mechanism consists of 6.25 H.P motor with 750 rpm which requires an un-interrupted power supply of 400 - 440 volts, 3 phase 50 cycles supply for electrical hoisting of shutter. The braking system is operation solenoids and hand release lever brake.

Sluice gates of Kochu Pamba Weir Operations

The scour sluice of the dam is made by a couple of Gate Valves, placed at a distance of 1.20 m between them, located in a slot on the left bank downstream side. The operation of the same is done by turning the wheels.

While getting directions for releasing water to Pamba River, the sluice gates of Kochu Pamba Weir will be opened. The operation of the both the gates are done by rotating the fly wheel in anti-clockwise direction. The ratio of opening is done in 1:1. The gate at water side is opened first to a unit height. The operation of the gate at downstream is followed by it to the same height. Further openings are also conducted in the same manner. The operation can only be done **manually**. The opening vent is 60 cm dia. It will take 120 rotations of wheel for the getting the gate fully opened. The closing of the gates is done in the reverse manner as that of opening.

2.3.2 Operation of the Reservoir

Pamba reservoir was being operated as per 'Guidelines for Operation of Storage Reservoirs (IS 7323:1994), no spilling of water over the spillway will normally be permitted until FRL is reached. Hence no rule curve was prepared for this dam.

The reservoir water is released through spillway gates on reaching the Full reservoir Level i.e. **986.33 m level**. The spillway crest level is EL. 981.46 m. The total spillway discharge (free discharge) through spillway gates (6 Nos) for different reservoir levels under full opened condition is tabulated in **Table 2.5** and is given in **Fig 2.10**. Discharge (Rating) curve through single spillway for different reservoir levels with different gate openings is given in **Fig 2.11** and tabulated in **Table 2.6**.

Reservoir Level in m	Spillway discharge through one gate in m^3/s	Total Spillway discharge (6 gates) in m^3/s
981.46	0.00	0.00
981.50	0.09	0.55
982.00	4.70	28.23
982.50	12.94	77.66
983.00	23.99	143.93
983.50	37.55	225.29
984.00	53.27	319.65
984.50	71.11	426.68
985.00	90.69	544.11
985.50	112.17	673.03
986.00	135.54	813.24
986.33	151.98	911.89

Table 2.5 Spillway Discharge

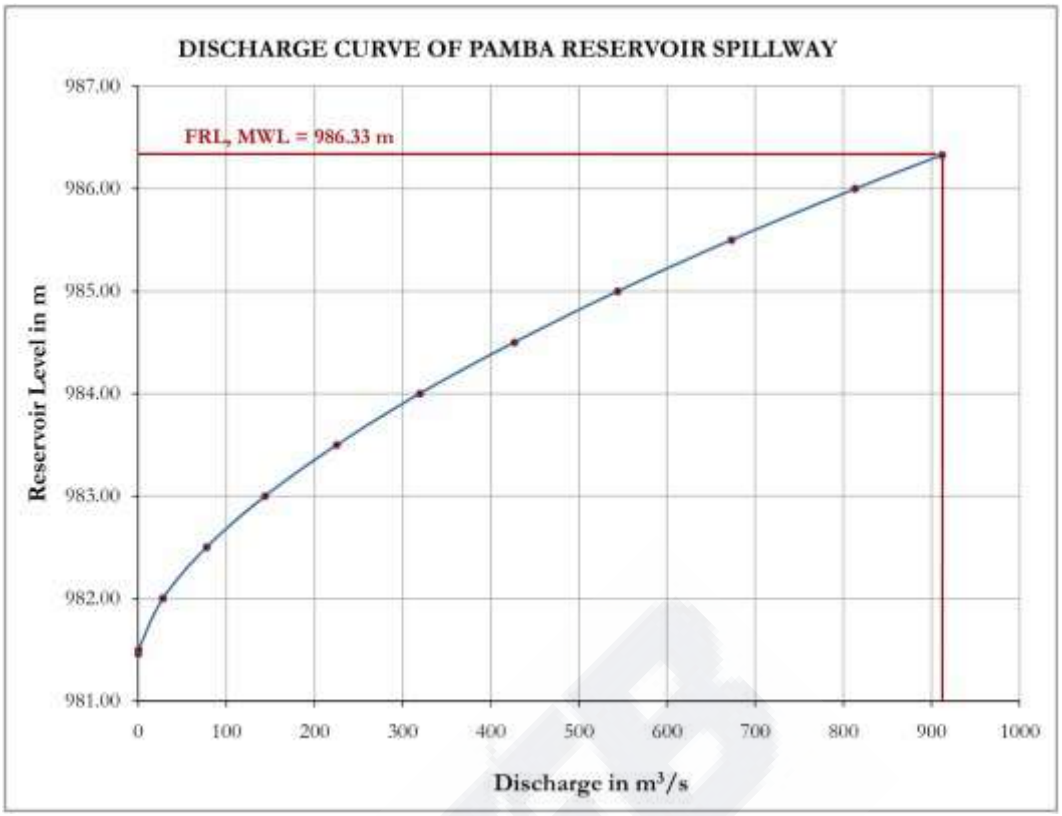

Fig 2.10 Discharge curves for Spillway Gates

Pamba-Discharge through a single spillway gate for different gate openings and reservoir levels													
Reservoir Level (m)	Gate opening (+m)/Elevation of bottom of spillway gates (in m)												
	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00	3.30	3.60	4.88
	981.76	982.06	982.36	982.66	982.96	983.26	983.56	983.86	984.16	984.46	984.76	985.06	986.34
981.46 (Crest Level)	0.00												
982.50	7.30	13.62											
983.00	8.69	16.57	23.55										
983.50	9.88	19.05	27.47	35.05									
984.00	10.93	21.23	30.86	39.78	47.91	55.18							
984.50	11.88	23.19	33.90	43.97	53.35	62.01	69.85						
985.00	12.76	24.99	36.67	47.76	58.25	68.08	77.22	85.60	93.14				
985.50	13.58	26.66	39.23	51.26	62.73	73.61	83.87	93.46	102.34	110.44			
986.00	14.34	28.22	41.61	54.51	66.88	78.71	89.97	100.64	110.66	120.01	128.62	136.43	
986.33	14.82	29.20	43.11	56.54	69.47	81.89	93.76	105.07	115.78	125.87	135.27	143.95	151.98

Table 2.6 Discharge through single spillway

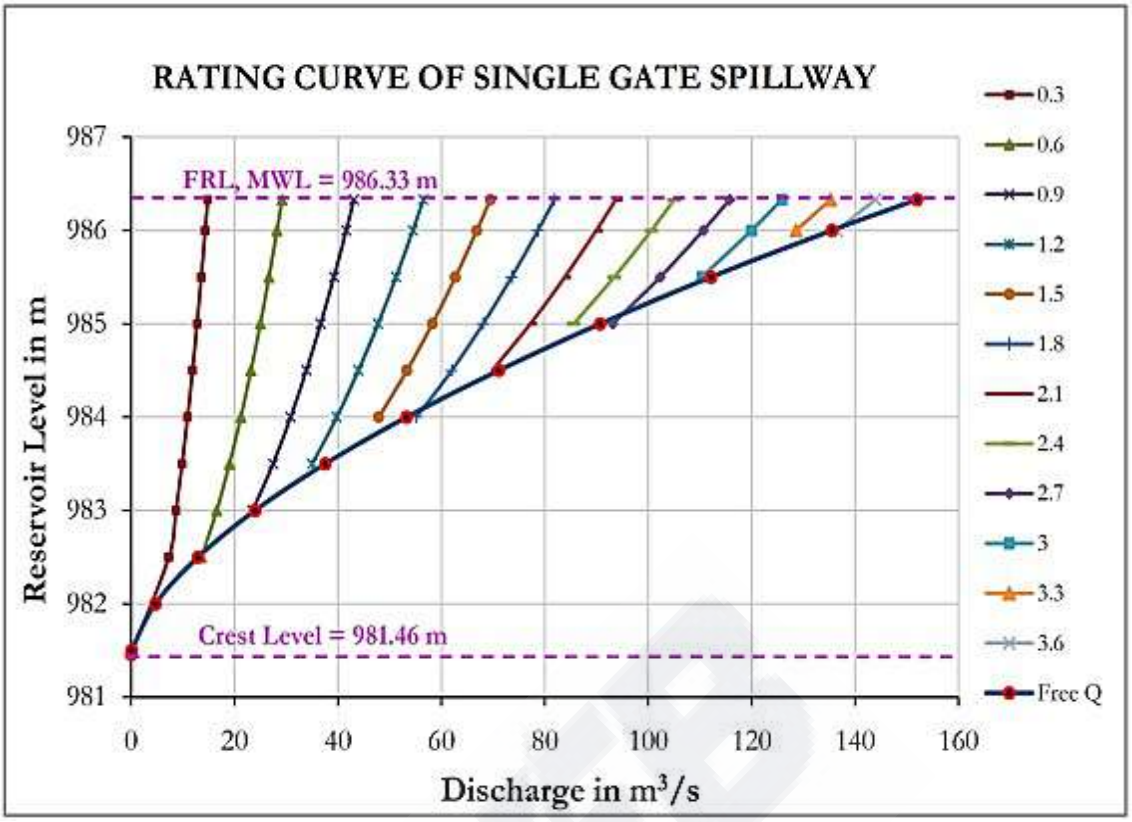

Fig 2.11 Discharge curves for Single Spillway Gate

2.3.3 Rule Curve

As per the Kerala flood study report of August 2018, CWC has recommended for reviewing the rule curves of all the reservoirs in Kerala. The rule curves need to be formulated for both conservation as well as operations during the flood, in case of storage reservoirs also, particularly for the reservoirs having the live storage capacity of more than 200 Mcm in order to create some dynamic flood cushion for moderating the floods of lower return periods particularly in the early period of monsoon. Accordingly, rule curve for major reservoirs under KSEB Ltd considering the historic inflow after the filling of reservoir and the power demand during respective months are being prepared.

The live storage capacity of Pamba dam is only 31.15 Mm^3 and water is being release to Kakki - Anathodu reservoir through I C Tunnel for power generation at Moozhiyar Power house. Hence considering the rainfall, inflow and power generation of the Project from 2010 to 2018 as in **Table 2.7**, an average reservoir water level pattern is arrived. The peak level is proposed at FRL 986.33 m during November 15th considering the NE Monsoon of October to November. A rule curve arrived accordingly is shown in **Fig 2.12a** and **Fig 2.12b** and the maximum (storage) water levels of the respective months in **Table 2.7.** The reservoir water

exceeding the rule curve level beyond crest level will be spilled or adjusted with power generation. This rule curve can be used till further revision.

2.3.4 Safety Aspects

The spillway gates are operated step by step after assessing the reservoir water level and inflow and the sequencing is defined in **Cl.2.3.1**.

2.3.5 Flood Release Procedure

The flood water is released through spillway gates based on the operation manual of gates and flood routing studies given in the hydrology review**.** There are six spillway gates in Pamba dam. The sequence of operation of spillway gates is Gate no. **3, 4, 2, 5, 1, 6**. ie. Gate No.3 is to be opened first to a unit height on the basis of requirement. Then Gate No.4 is operated to the same height as that of Gate No.3. Further sequences of operations are No.2 & 5 and finally No. 1 & 6. The further increase in openings is also performed in this manner.

During flood season, various alerts as mentioned in **Chapter 1** were issued for opening of spillway gates. But in the light of the Kerala Flood 2018, the flood release operations of Pamba reservoir is revised by the KSEB Ltd vide B.O (FTD) No. 444/2019(DGC/AEE-II/Dam Safety/2019 dt 03.06.2019. Accordingly, Alerts for spilling of water are fixed as first warning **Blue 983.00 m**, second warning **Orange 983.5 m** and third warning **Red 984.5 m**. The gate of the interconnecting tunnel will be kept open during the monsoon period and spill will be resorted to when the reservoir water level crosses 985 m. After giving first warning, further warning is given in local media including TV etc., regarding the possible opening of spillway gates continuously. Also intimations are given to Disaster Management, District Administration, and Police Department etc. before opening the Spillway gates.

2.3.6 Reservoir Capacities

The Gross storage of the reservoir 39.22 Mm^3 and the Live Storage is 31.15 Mm^3 at FRL of +986.33 m and the details are given in **Table 2.1.**

PAMBA DAM - WL FROM 2010-2018								
Month / Year	June		July		August		September	
	1 F	2 F	1 F	2 F	1 F	2 F	1 F	2 F
2010-11	965.18	966.10	965.40	966.05	966.95	971.03	974.43	974.25
2011-12	965.23	965.43	965.55	966.40	968.78	974.15	977.93	978.05
2012-13	963.53	963.95	964.40	964.58	964.95	965.60	965.25	964.30
2013-14	965.10	967.30	969.85	975.05	980.05	981.18	981.68	982.60
2014-15	967.30	966.80	966.95	968.20	967.40	971.60	975.58	974.88
2015-16	963.68	965.03	965.53	964.70	965.30	965.15	964.43	964.55
2016-17	964.03	965.60	966.85	967.45	968.45	969.85	970.60	970.08
2017-18	963.85	965.45	965.58	964.50	964.70	966.00	967.50	970.43
2018-19	967.80	968.75	971.00	980.00	984.95	982.63	978.18	976.25
Average	965.70	966.41	967.45	968.93	970.79	974.49	976.04	976.49
Rule curve	973.99	974.70	975.74	977.22	979.08	982.78	984.33	984.78

Month / Year	October		November		December		January	
	1 F	2 F	1 F	2 F	1 F	2 F	1 F	2 F
2009-10							952.50	976.15
2010-11	975.65	976.65	976.75	978.08	979.25	978.73	977.53	976.25
2011-12	976.78	976.78	977.73	978.38	978.58	977.58	976.13	975.03
2012-13	964.18	965.90	967.80	968.53	968.53	967.40	966.75	965.95
2013-14	981.35	979.75	979.13	978.35	977.18	975.28	973.28	972.03
2014-15	973.70	974.28	975.55	975.35	975.20	975.15	974.93	974.53
2015-16	965.33	966.70	968.73	971.33	973.40	974.25	974.00	972.90
2016-17	969.63	969.20	968.75	968.30	967.93	967.18	966.03	965.40
2017-18	973.50	974.45	975.40	977.35	978.68	978.23	977.58	976.80
2018-19	975.55	975.48	974.68	973.70	973.28	973.00		
Average	976.87	976.91	977.29	978.04	977.78	976.68	975.46	974.46
Rule curve	985.16	985.20	985.58	986.33	986.07	984.97	983.75	982.75

Month / Year	February		March		April		May	
	1 F	2 F	1 F	2 F	1 F	2 F	1 F	2 F
2009-10	974.60	973.15	971.03	967.73	964.55	963.65	964.40	964.18
2010-11	975.25	974.05	971.73	968.25	964.88	963.53	963.48	963.95
2011-12	973.98	972.78	970.83	967.30	964.25	963.45	963.50	963.40
2012-13	964.53	963.73	963.38	963.35	963.35	963.40	963.45	963.58
2013-14	970.20	967.85	965.45	963.68	963.15	962.98	964.30	965.75
2014-15	973.58	972.23	970.43	967.28	964.58	963.83	963.88	963.83
2015-16	971.43	970.03	968.50	966.43	964.50	963.65	963.50	963.60
2016-17	964.80	963.98	963.60	963.55	963.38	963.23	963.15	963.30
2017-18	976.05	975.25	973.55	970.63	967.40	964.68	963.55	963.95
Average	973.25	971.73	969.61	966.63	964.21	963.44	963.79	964.23
Rule curve	981.54	980.02	977.90	974.92	972.50	971.73	972.08	972.52

Table 2.7 Rule Curve - Reservoir Level in Previous Years

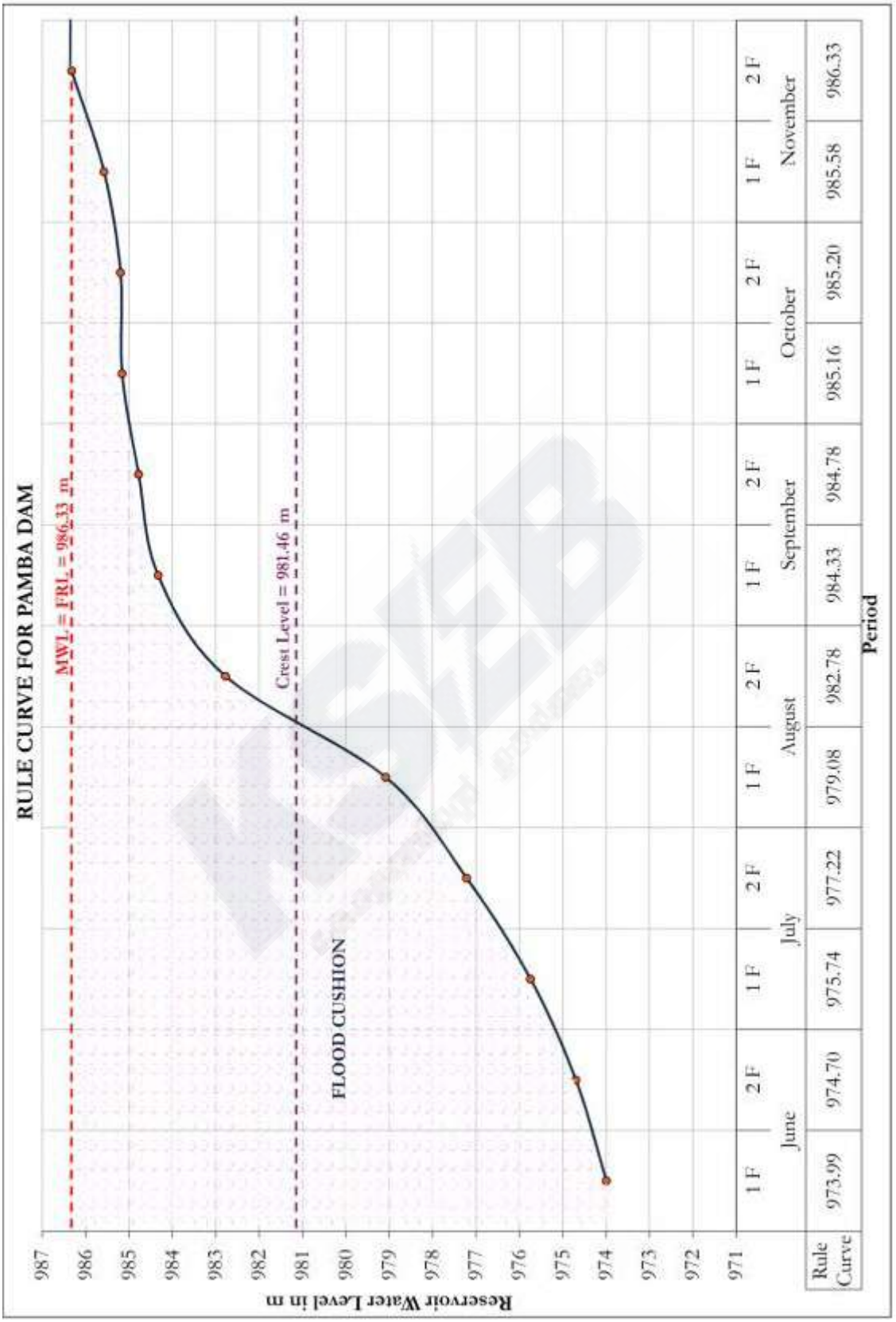

Fig 2.12a Rule Curve for Pamba Reservoir SW Monsoon period

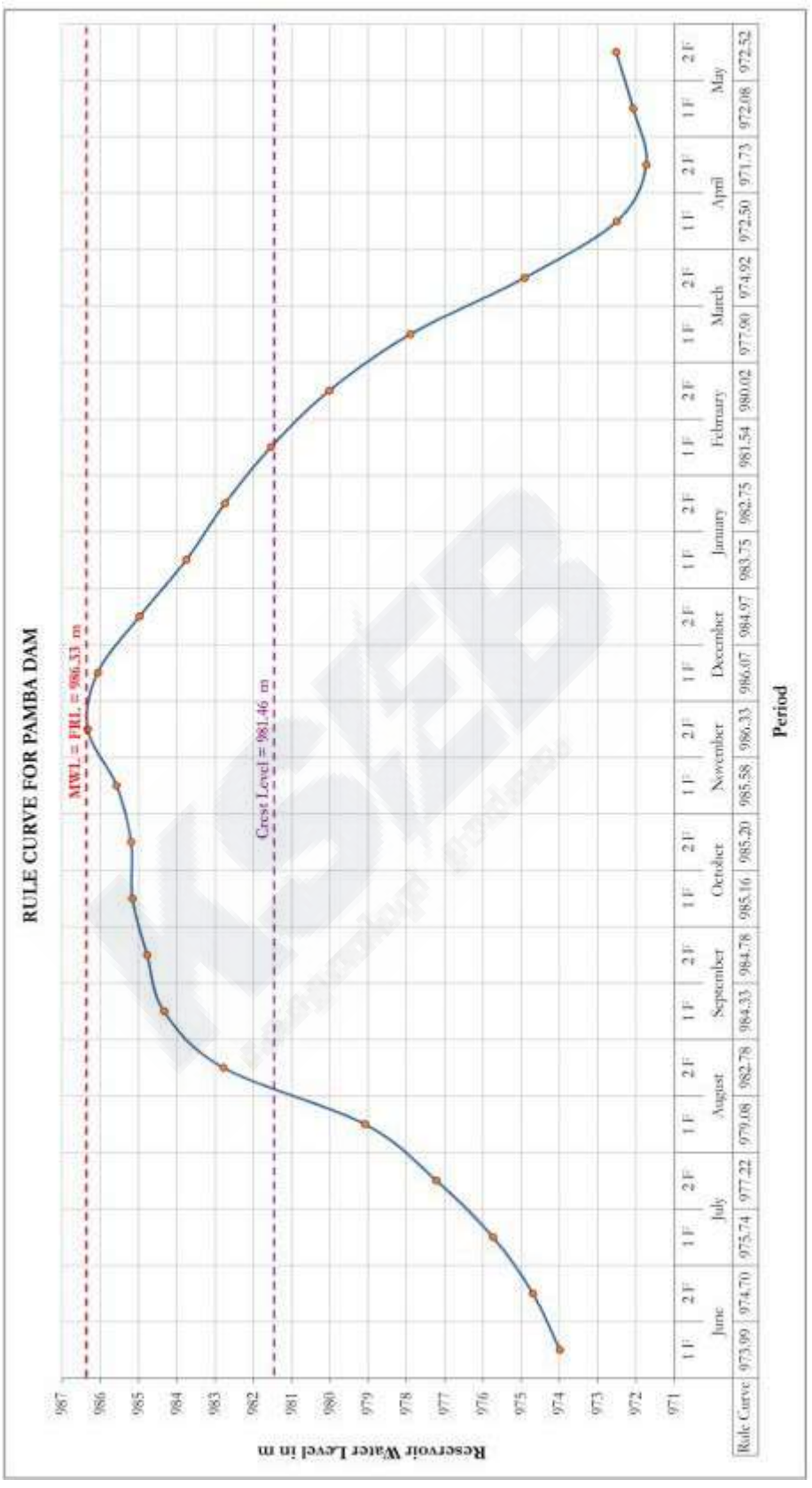

Fig 2.12b Rule Curve for Pamba Reservoir for full year

2.3.7 Climate

Pamba catchment receives comparatively good rains almost throughout the year. It is observed that the rains contributed by South-West monsoon are comparatively heavier than the rain precipitation during North- East monsoon. The average annual rainfall as per the completion report of the project is 4572 mm and the average annual runoff is estimated at 824 Mm^3.

2.3.8 Inflow forecasting/Methodology

There is no inflow forecasting system at present in Pamba dam. The methodology followed for working out the inflow is given in **Cl.2.3.8.1.**

2.3.8.1 Inflow Computation

Inflow into reservoirs is normally estimated by the reservoir gauging method (also called the rise and fall method or inflow-outflow method). All the outflows are added together and to it the rate of rise in storage (Positive if the level rises, and negative if it falls) is added. Expressed as an equation, this will be.

Inflow (cumecs) = Total outflow (cumecs) + Rate of increase in storage (cumecs)

The rate of increase or decrease in storage can be determined from the observed rate of increase or decrease in reservoir level and the elevation capacity tables. For easy computation a table can be developed showing the rate of change of storage in the Pamba reservoir for a rate of rise in reservoir level of 1 cm/hour. This table can be put to use for easy interpolation. Once the inflow is known the outflow and gate opening required to maintain the water level can be computed.

2.3.9 Summary of Flood Regulation Procedure

The flood regulation procedures at Pamba can be summarized in the following 5 steps:

1. Observe the reservoir level at 1 hour intervals.
2. Determine the total outflow occurring at all outlets (including river sluices, spillway, IC Tunnel etc.)
3. Estimate the inflow
4. Determine the gate opening as the case maybe.
5. Open the required number of gates to the extent required to maintain constant reservoir level. i.e., release is equal to the inflow.

2.3.10 Emergency Operation

The Emergency operation will be carried out following the Emergency Action Pan (EAP). The Emergency conditions are outlined in Chapter 4 under clause 4.2.1 on Immediate Maintenance. The EAP together with this Manual will be available at site at all times. Summary of alert conditions during Emergency are given in **Annexure 4**.

2.4 Power Generation

SGHEP Power House is located in Moozhiyar, Seethathodu village, Konni Taluk around 60 km from Pathanamthitta. The Power Station was commissioned during 1967 with Six Generating units of 50 MW each coupled to vertical shaft Pelton turbine. After power generation, water from the power station is released to the Moozhiyar reservoir. RMU works were undertaken in the Power Station from 2005 to 2009. Capacity of 4 units was enhanced by 5 MW each and 2 units were enhanced by 10 MW. Thus the total installed capacity of the station is 340 MW.

[*Since Pamba is a component dam of SGHEP contributing water to the storage reservoir Kakki - Anathode; the power intake, power tunnel, surge, penstock (L.P.P and H.P.P.) are one and the same for SGHEP- details are given below as in the O&M Manual of Kakki- Anathode Dams.***]**

2.4.1 Power Outlets

Since Pamba is a component dam of SGHEP contributing water to the storage reservoir Kakki-Anathode, the intake structure is the same located on the left bank of the reservoir upstream of Kakki dam as shown in **Fig 2.13(a) & (b).**

The intake arrangement consists of a shaft of excavated section 20'-3" x 15' elliptical with sectional area of 238.5 Sq ft. Total height of shaft is 237 ft between level 3208' and 2971'. The flow through the tunnel is regulated or controlled by one Vertical Lift Gate of size 15' x 11' 3" sealed on the upstream and operated inside the above shaft. The average lining thickness of the shaft is 1'6" with reinforcement ½" dia. at 12" c to c both ways. An elliptical wall from level 3208' to 3235' has been constructed, over which the hoist platform and other arrangement have been erected. The shaft location is 353 ft from the inlet face of the tunnel. Details of intake and control shaft are given in **Drg 2.10 & Drg 2.11** of **Annexure 1.**

The intake control arrangement salient features are tabulated below;

Control Arrangement (Intake)		
Type	:	Shaft with vertical lift gates sealed on upstream
Operation		
a. Lifting and lowering by electric power	:	5 ft /min
b. Lowering by gravity	:	8 ft /min
c. Lifting by hand power	:	1 inch/min
Total weight	:	32 T
Maximum design head	:	263.3 ft
Gear operation	:	Electrically and manually
Brake	:	Operation solenoids and hand release lever brake
Motor		
a. Speed	:	1350 rpm
b. HP	:	60 HP
c. Supply	:	400-440 Volts, 3 phase 50 cycles.
Trash Racks	:	Arranged in semi-circular pattern around the power tunnel mouth in semi-circular pattern
Hoist Capacity	:	118 T

(a) **(b)**

Fig 2.13(a) Power Intake Structure of Kakki-Anathodu, (b) Wire Rope Drum of Intake Gate

Trash-rack structure

Trash rack arrangements are provided at the inlet face of power tunnel, in a semicircular pattern around the tunnel mouth supported by R.C.C. columns and ribs. There are 5 nos. R.C.C. columns 13'3½" c/c (4.05 m) connected by R.C.C. arch ribs at 10' (3.05 m) c/c vertically which forms the structure for the trash rack. The trash rack sill level is 896.97 m and centre line of inlet is 902.80 m. Height of the columns is 50 ft (15.24 m) over which there is a covering slab of 2'0" (0.61 m) thickness. The trash rack is in submerged condition and do not require frequent cleaning. No cleaning mechanism is provided here. Trash-rack was manufactured with 20 no's panels of size 11'10 ½" x 10' (3.62 m x 3.05 m). 5 no's have been erected vertically one over the other between each column. The panels having frames welded with 8" x 3" double channel with 7 nos. vertical and across 'I' section girders 7" x 3 ½" (0.18 m x 0.09 m) and trash bars with 2" x ½" flats are welded at 2 ½" (0.064 m) c to c was fabricated by Kerala Allied Engineering Co. (Pvt.) Ltd., Kundara. Welding for fabricating the trash rack was done by electric arc method. Precautions were taken to minimize stress due to expansion and contraction and also distortion due to heat. One coat of red lead painting has been done to the panels of the trash rack. Permanent hoisting arrangements for lifting and re-erecting the trash racks have been provided over the column. For this purpose 5 nos. columns 12 ft (3.66 m) height with connecting beams 2' x ½' (0.61 m x 0.15 m) have been constructed on which the hoist arrangements are located. The elevation and sectional plan of trash-rack arrangement is shown in **Drg 2.12** of **Annexure 1**.

2.4.2 Power Tunnel

The power tunnel 18274 ft (5570 m) long and 15' (4.57 m) diameter is designed for a maximum discharge of 1920 cusecs (54.37cumec). The tunnel was constructed from seven working faces provided by three Adit tunnels. Adit-1 at Ch. 3323ft, Adit - 2 at Ch. 12677 ft and Adit-3 at Ch. 17731 ft. The surge shaft is located at Ch. 16858. Gradient for the first section of tunnel is 1 in 250 from Inlet to Adit No.1, 1 in 310 from Adit No.1 to Adit No.2 and 1 in 110 from Adit No.2 to a point X (1044 ft behind the surge shaft). The slope from point X to surge is 1 in 100 and this slope continuous up to the exit face.

2.4.3 Surge Shaft

Sabarigiri HEP surge shaft located at the end of a 16858 ft (5138.32 m) long head race tunnel is of the simple type with expansion chambers at top and bottom. The design features of the surge shaft have been finalized after checking their suitability and efficiency by model

studies conducted at CWPRS, Pune. The construction of the surge shaft was completed, and made ready for use early in February 1966. The main shaft is 25 ft (7.62 m) in dia and has a height of nearly 350 ft. The expansion chamber at top which controls the maximum upsurge level is 45 ft dia and has a height of 85 ft (25.9 m) (**Drg 2.13** of **Annexure 1**). The gallery at bottom is in the shape of an arc of circle of radius 125 ft (38.10 m) and is connected to the main shaft by two connecting spokes (**Drg 2.14** of **Annexure 1**). This ring type gallery is a unique and novel feature in the design of the surge system and has been evolved as a result of detailed studies made by the KSEBL engineers and by model studies.

2.4.4 Penstocks

The Sabarigiri HEP penstocks run down from the inside of power tunnel at about elevation 2980 ft running for a length of about 8500 ft along the hill slopes on the Vettilappara valley and ends at about elevation +641 ft where it is connected to the turbine of the power station. The penstocks are designed to convey a maximum of 1920 cusecs through a drop of 2581 ft (786.685 m) to the power station to feed six turbo generators with an overall installed capacity of 300,000 KW. The penstock consists of (a) L.P.P. and (b) H.P.P.

2.4.4.1 Low Pressure Pipe Line (L.P.P.)

Starting at the upstream face of the bell mouth at the surge shaft at elevation +2881ft till the portal point at the exit, the power tunnel has been lined with M.S. Plates, ASTMA 285 Grade-C Firebox quality having yield points stress of 21 kg/mm^2. This lining forms part of the L.P.P. The L.P.P. continues till the 'Trifurcation' point. The total length of the L.P.P. is 410.252 m having a constant external diameter of 375 mm and shell thickness 1", 1-1/16" and 1-1/8". 20" internal diameter drain pipe has been fixed to the L.P.P. at a point 147.502 m from the 'Trifurcation' on the upstream and laid along the Adit. The total length of the drain pipe is 136 ft and leads into the Vettilappara valley. The drain pipe system is controlled by a sluice valve and disperser at the downstream end.

2.4.4.2 High Pressure Pipe Line (H.P.P.)

The L.P.P. terminates at the trifurcation to be connected to the 3 nos. High Pressure Penstocks each line controlled by 78 inch – Horizontal shaft Servomotor – operated and counter weighted – Butterfly valves. The valves are located at 24.384 m below the Trifurcation point. The three surface penstocks are from the Trifurcation point to the power

house. The H. P. P is made of special type of high- tension steel viz. Lukens 36 carbon steel.

There are, on the whole 18 bends in the penstock alignment of which 10 are compound bends having both vertical and horizontal bends. One expansion joint each is provided immediately downstream of all the anchors except the last anchor. From the last surface anchor, the penstocks are taken through three diverging inclined tunnels. This last anchor being situated on a steep incline called fort for a load distribution technique involving heavy reinforcements. At the lower ends of the inclined tunnel, each penstock bifurcates and the six branches are taken through six short independent tunnels spaced at 48 ft centre to centre, to the turbines.

2.4.5 Initial Filling of Reservoir

Partial storage of water in Pamba reservoir commenced followed by the plugging of construction sluice on 06.05.1965 ahead of the scheduled. Reservoir is gradually impounded up to 3218.90 ft on 01.01.1966. Then reservoir level was reduced by operating the disperser valve. By 01.04.1966 water was let out through I C Tunnel to Kakki reservoir. A maximum water level of 3233.60 ft was attained by 01.09.1967. A water level indicator was installed on the left bank upstream face of dam.

2.5 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details are kept at the field office. Essential documents as per the dam safety guidelines are kept at the dam site office. Also the Rainfall data and Reservoir level are available. Following records of reservoir operations are being maintained:

1. Rainfall record on daily basis throughout the year.
2. Reservoir levels on daily basis during non-monsoon and hourly basis during monsoon.
3. Depth of outflow over the spillway on hourly basis during monsoon.
4. Estimated spillway outflows during monsoon on hourly basis.
5. Power releases / releases through IC Tunnel.
6. Water audit register to be maintained for estimating the inflows on hourly basis during monsoon and daily basis during non-monsoon by accounting all the releases/outflows and the incremental change in storage in the reservoir.
7. All operating procedures

Chapter 3

Project Inspection

An effective inspection program is essential to identify problems and to keep a dam in a good and healthy condition. Inspection details and suggestions are kept at field office and reports send to higher offices. The current practice of Inspection at Pamba dam envisages the Deputy Chief Engineer in presence of Executive Engineer at site to carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC (**Annexure 5)**. The Deputy Chief Engineer will submit the inspection report to the Chief Engineer for onward transmission to CWC. The Executive Engineer at site will conduct quarterly inspections and will prepare health reports. The format followed as per CWC is now revised during January 2018 and new guidelines issued vide Doc No. CDSO_GUD_DS_07_v1.0, CWC 2018 for Safety Inspection of Dams. Now since the health reports are to be uploaded in DHARMA, the inspection reports are prepared in the new format incorporated in DHARMA. Detailed description on project inspections is available in the Guideline for Safety Inspection of dams. However an overview of the various types of inspections to be carried out at Pamba dam is given below. Note that for uploading Inspection Data into DHARMA, the Inspection Instructions & Forms given in the above mentioned Guideline for Safety Inspection of Dams must be used. This Chapter provides guidance on carrying out other inspections.

3.1 Types of inspections

Four different types of dam safety inspections are to be carried out at Pamba Dam. These include, but not limited, to the following:

1. Comprehensive evaluation inspections
2. Scheduled inspections (Pre & Post monsoon inspections & other scheduled inspections)
3. Special (Un scheduled) inspections
4. Informal inspections.

The frequency of each type of inspection depends on the condition of the dam and State DSO regulations, etc. Typical inspection elements and the detail of the safety inspections are provided below. More detailed descriptions are given in the 'Guideline for Safety Inspection of Dams' (CWC 2018). A comprehensive health checklist **(Annexure 6)** for recording the status of each item being inspected and the overall condition of the equipment along with any consequential risks on the health of the dam is required to be maintained.

3.2 Comprehensive Evaluation Inspections

For comprehensive dam safety evaluation for each dam an independent panel of experts known as Dam Safety Review Panel (DSRP) needs to be constituted for determining the condition of the dam and appurtenant works. The panel will undertake evaluation of the dam once in 10 years or on occurrence of any extreme hydrological or seismic event or any unusual condition of the dam or in the reservoir rim. The terms of reference of the comprehensive dam safety evaluation shall include but not be limited to;

- General assessment of hydrologic and hydraulic conditions, review of design flood, flood routing for revised design flood and mitigation measures.
- Review and analysis of available data of dam design including seismic safety, construction, operation maintenance and performance of dam structure and appurtenant works.
- Evaluation of procedures for operation, maintenance and inspection of dam and to suggest improvements / modifications.
- Evaluation of any possible hazardous threat to the dam structure such as dam abutment slope stability failure or slope failures along the reservoir periphery.

A comprehensive evaluation inspection of Pamba dam consists of five major parts:

1. Review of project records (i.e. study of all design / construction records/drawings, history of the dam's performance, previous inspection notes/reports, notes on distress observed/ any rehabilitation measures undertaken earlier, instrumentation data and its interpretation.
2. Inspection of the dam and its appurtenant works.
3. To review the results and reports of additional field investigations & laboratory testing.
4. Review of design studies, review of design flood, checking of the adequacy of Spillway capacity, freeboard requirements, dam stability and any special study.
5. Preparation of a detailed report of the inspection.

3.2.1 Details to be provided to DSRP before inspection

All relevant details / data / drawings for the dam project to be examined by the DSRP shall be provided at least 3 months in advance of the proposed visit. This will include

- General information and Scope of the Project
- Emergency preparedness
- Details of key personnel

- Hydrology Original and reviewed
- Reservoir operation and regulation plan
- Basic data and Issues related to safety of dam
- Problems if any during construction
- Drawings of dam, spillway, gates and appurtenant structures
- Seismicity aspects & details
- Status of the instrumentation
- Construction History
- Geological Report including Special problems at site and their treatment
- Field Inspection- Observation & recommendation regarding Remedial Measures
- Dam Incidents and Reservoir filling details

Dam Incidents and Reservoir filling

During construction of Pamba dam, while the foundation was being prepared in Block No.2, some loose materials were noticed in a particular portion. This was wedged out and removed. It indicated a dip or small fissure in the region and hence filled with cement concrete up to general foundation level. Additional holes are drilled in this portion and grouted. Partial storage of water in Pamba reservoir commenced followed by the plugging of construction sluice on 06.05.1965 ahead of the scheduled date.

Some abnormal discharge was noticed in the dam right abutment gallery system as an indicative of higher porosity of masonry after completion of the dam. Grouting through embedded pipes was recommended by the experts as drilling and grouting from crest may damage the face drains.

3.3 Scheduled Inspections

Scheduled inspections shall consist of Pre-monsoon & Post-monsoon inspection and any other inspections carried out by the State Dam Safety Organisation/any Expert panels constituted by the dam owner. These inspections are performed to gather information on the current condition of the dam and its appurtenant works. This information is then used to establish needed repairs and repair schedules, and to assess the safety and operational adequacy of the dam. Scheduled inspections are also performed to evaluate previous repairs.

Scheduled inspections include the following components as a minimum:

- Review of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required

- Visual inspection of the dam and its appurtenant works
- Preparation of a report or inspection brief, with relevant documentation and photographs. The report should be filed in the dam owner's project files

3.3.1 Pre- and Post-Monsoon Checklist and Example of Report Proforma

Detailed checklists are required to ensure the health of the dam and to ensure that it continues to operate in satisfactory and safe condition. The Proforma to be used for inspection should be the one enclosed in the Doc No. CDSO_GUD_DS_07_ v1.0, CWC 2018 on the Guidelines for Safety Inspection of Dams.

Pre-monsoon Inspection to be carried out during	:	April - May
Post-monsoon Inspection to be carried out during	:	December - January
Inspecting Officers	:	Deputy Chief Engineer along with SPMU Executive Engineer, Field Executive Engineer, Concerned field Assistant Executive Engineer and Assistant Engineer
Preparation of Inspection Report	:	Executive Engineer, Field (Dam Health Engineer)
Submission of Pre-monsoon Inspection Report	:	Before June 30th
Submission of Post-monsoon Inspection Report	:	Before January 15th
Checking and approval of report	:	Deputy Chief Engineer, SPMU
Uploading corrected document in DHARMA	:	Executive Engineer, Field

3.4 Special (Unscheduled) Inspections

Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections are not regularly scheduled activities, but are usually made before or immediately after the dam or appurtenant works have been subjected to unusual events or conditions, such as an unusually high flood or a significant earthquake. These inspections are to be carried out by teams to be constituted by state DSO after an initial assessment based on informal inspection carried out by project personnel reveal dam safety related concerns like cracking in the dam, damages, erosion/ scour, undermining/

piping/ sink holes/ liquefaction or any such undesirable feature. A special inspection may also be performed during an emergency, such as an impending dam breach, to evaluate specific areas or concerns. They are also made when the ongoing surveillance program identifies a condition or a trend that appears to warrant a special evaluation. Special inspections should focus on those dam components that are affected by the unusual event and should include at least three elements:

1) Review of available relevant files or data
2) Visual inspection of all components of the project and surroundings
3) Report preparation covering status of project and recommendations

More detailed site investigations / studies may be required (such as drilling, surveys, or seepage flow estimates) if the special inspection reveals the need for the same. Photographic documentation is to be included as part of the inspection.

3.5 Informal Inspections

An informal inspection, is a continuing effort by on-site personnel (dam owners/operators and maintenance personnel) performed during their routine duties. Informal inspections are critical specially to keep an eye on the proper operation and maintenance of the dam. These inspections consist of frequent observations of the general appearance and functioning of the dam and appurtenant structures.

Operators, maintenance crews, or other staffs who are posted at Pamba dam site are supposed to conduct informal inspections on routine basis. These people are the 'first-line of defense' in assuring safe dam conditions, and it is their responsibility to be familiar with all aspects of the dam. Their vigilance while walking across the dam for inspection / surveillance, checking the operating equipment, and noting changes in conditions may prevent serious mishaps or even dam failures.

Informal inspections are important and are performed at every available opportunity. These inspections may only cover one or two dam components as the case may be, or they may cover the entire dam and its appurtenant structures in one go. The informal inspections are not as detailed as comprehensive evaluation, scheduled, and special inspections and will only require that a formal report is submitted to the dam owner's project files if a condition is detected that might endanger the dam. Report is to be submitted detailing the condition discovered along with photographs, time, reservoir water level, other features etc.

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Chapter 4

Project Maintenance

A good maintenance program is required to protect a dam against deterioration, prolong its life and greatly reduce the chance of failure. Maintenance program for a dam should be developed primarily based on systematic and frequent inspections. Nearly all the components of a dam and its materials are susceptible to damage and deterioration if not well maintained. Moreover, the cost of a proper maintenance is small compared to the costs of major repairs, loss of life, property and litigation. If maintenance of a dam is neglected the consequences and costs could be enormous.

4.1 Maintenance Plan

A basic maintenance schedule for the various monitoring components prepared for Pamba dam based on manual of operating parts, frequent inspections, priority, and interval for Pamba dam is attached as **Annexure 8**. This shows tasks to be performed and how frequently that is to be inspected/observed and repaired.

4.2 Maintenance Priorities

Maintenance activities need to be prioritized. In order of priority they need to be clarified under the heads immediate maintenance & preventive maintenance.

4.2.1 Immediate Maintenance

The following conditions are critical and call for immediate attention & reservoir lowering, if warranted. These conditions may include, but are not limited to:

- The dam is about to be overtopped or being overtopped during high flood.
- The dam showing signs of piping or internal erosion along faults, weak zone etc. indicated by increasingly cloudy seepage or other symptoms.
- The spillway being blocked or with some inoperable gates.
- Evidence of excessive seepage as seen in the gallery/on downstream face of the dam.

An EAP is to be activated when any of the above conditions are noted.

4.2.2 Preventive Maintenance

This can be further classified as Condition based Maintenance and Routine Maintenance.

4.2.2.1 Condition Based Maintenance

The following maintenance works are to be undertaken as soon as possible after the defective condition is noted. These include but are not limited to:

- Remove all vegetation and bushes by roots from the dam surfaces, restoring any eroded areas.
- Repair of defective gates, valves, and other hydro-mechanical equipment.
- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/ foundations in concrete / masonry dams.
- Repair any damages on spillway glacis, piers, energy dissipaters, training/divide walls, downstream areas etc.
- Repairs on u/s face of masonry dams in case the pointing of masonry joints is damaged resulting in increased seepage
- Controlling any heavy seepage in the foundation/ inspection galleries in Concrete / masonry dams from drainage holes.
- Repairs of any cracks/cavities/joints in concrete /masonry dams/structures.
- However many of these works will require the services of experienced engineers/expert panels.

4.2.2.2 Routine Maintenance

Several tasks should be performed on a continuous basis. These include but are not limited to the following:

- Any routine repair to concrete or metal component.
- Observation of any springs or seepage areas in shear zones, faults etc., comparing quantity and quality (clarity) with prior observations.
- Monitoring of downstream development which could have an impact on the dam and its hazard category.
- Maintenance of Electrical & Hydro-Mechanical equipment and systems e. g. Servicing of spillway gates, hoisting arrangements and gates/hoist of outlet works/sluices & stand by generator.
- Maintaining proper lighting at dam top, galleries, etc.

- Monitoring of seepage in galleries of the dam.
- Monitoring/ cleaning & removal of leached deposits in porous concrete / formed drains in dam body and foundation drainage holes.
- Maintenance of all dam roads & access roads.
- Operation of electrical and mechanical equipment and systems including exercising gates & valves.
- To keep the gate slots clear of silt/debris.
- Maintenance/testing of monitoring equipment (instruments) and safety alarms.
- Testing of security equipment.
- Testing of communication equipment.
- Any other maintenance considered necessary.

4.3 Procedures for Routine Maintenance

4.3.1 Controlling Damage from Vehicular Traffic

Vehicles, except for maintenance, are restricted on the dam top and kept out by fences or barricades. Any damages are repaired as soon as possible**.** Also vehicles are permitted after security checking at check posts.

4.3.2 Controlling Vegetation

Removal of vegetation around the dam and adjoining premises is done 3 times in a year.

4.3.3 Masonry / Concrete dams & spillways

The following important issues / aspects need to address while undertaking the periodic maintenance, but are not be limited to:

- Cracking in concrete (potential causes are alkali – aggregate reaction, thermal stresses because of heat of hydration or temperature variations, foundation problems).
- Damages on spillway glacis, spillway piers, training/divide walls, energy dissipaters, downstream areas (probable causes are cavitation, abrasion, un-symmetrical flows, unfavorable down-stream conditions)
- Vegetation growth in spillways, spill channel, approach channel etc.
- Seepage in Galleries and on d/s face of the dam.

- Cleaning and removal of leached deposits from choked drainage holes in the dam body/foundations.
- Repair to upstream face of masonry dams in case the pointing is damaged, leading to increased seepage.
- Status of rectification works undertaken from time to time need to be assessed during periodic maintenance.
- To ensure proper access & lighting in galleries.
- To ensure that the dam is behaving as designed based on instrumentation programs.
- Periodic maintenance should be performed on all concrete surfaces to repair deteriorated areas. Repair of deteriorated concrete at the earliest following the standard specifications for repair of concrete surfaces and re-pointing of masonry joints etc.; it is most easily repaired in its initial stages. Deterioration can accelerate and, if left unattended, can result in serious problems or dam failure.

For remedial measures of problems of special nature advice of experienced engineers/ Panel of Experts needs to be obtained.

4.3.4 Outlet Works

The outlet works of Pamba dam are detailed in **Cl.2.1.3**. The conduits should be inspected thoroughly once a year. Circular conduits that are of dia 1.5 m or more can be manually inspected. Common problems are improper alignment (sagging), separation and displacement at joints, cracks, leaks, surface wear and loss of protective coatings, corrosion and blockage. Problems with conduits occur most often at the joints. Further collars at joints used may also lead to inadequate compaction. Hence, special attention should be given to them during inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause leakage of water to the embankment during pressure flow. The outlet should be checked for signs of water seepage along the exterior surface of the pipe.

As regards to Hydro-mechanical works, intake gate at I C tunnel appropriate paragraphs in this chapter may be referred. If routine inspection of the Hydro-Mechanical Equipment shows the need for maintenance, the work should be completed as soon as possible.

4.3.5 Trash Racks

Trash racks provided in front of the Pamba dam outlet may become clogged with debris or trash which reduces their discharging capacity. The head losses through clogged trash racks also increase. Maintenance of trash racks includes periodic inspections for rusted and broken sections and repairs are made as needed. Trash racks should be checked during and after floods to en-sure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

Trash racks provided in front of the I C Tunnel of Pamba reservoir are submerged as MDDL of Pamba dam and inlet sill of IC Tunnel are the same and frequent cleaning is not necessitated. The trash rack cleaning is possible only after depleting the reservoir. No trash rack cleaning mechanism is provided.

4.3.6 Spillway Radial Gates & Hoisting Equipment

The safe and satisfactory operation of a dam depends on proper operation of its Gates & Hoisting Equipment. Maintaining spillway gates in working condition is critical for dam safety and is to be assigned the highest priority. If routine inspection of the Hydro-Mechanical Equipment reports the need for maintenance, the work should be completed as soon as possible.

The gates are to be operated through their full range twice annually (before monsoon & after monsoon keeping a gap of at least six months). Because operating gates under full reservoir pressure can result in large discharges, exercising of gates should preferably be carried out during dry conditions or lean times of the year.

The aspects to be inspected and maintained periodically for ensuring proper operation of gates in general are given below. The O&M manuals of the gates manufacturer's would however govern the overall maintenance of Gates & Hoists whenever there is any contradiction with the instructions given in the Manual.

a) The gate slot and bottom platform/sill beam should be cleaned periodically. Scales formed over the embedded parts should be removed. Second-stage concrete should be checked for any development of cracks / leakages and repairs should be attended to immediately.

b) The gate leaf should be thoroughly cleaned and repainted as and when necessary according to the procedure or guidelines- indicated in IS: 14177 or as per the recommendations of the paint manufacturer. All drain holes provided in the gate

assembly should be cleaned.

c) Rubber seals should be smoothed, if required, for proper alignment. All nuts and bolts fixing the seal to the gate should be tightened uniformly to required torques. Seals, if found damaged or found leaking excessively should be adjusted, repaired or replaced as considered necessary.

d) The wheel shall be rotated to check their free movement. Gate roller bearings and guide roller bushes should be properly lubricated. Whenever necessary these should be opened for rectifications of defects, cleaning and lubrication and should thereafter be refitted. These may be replaced if repairs are not possible.

e) Hoisting connection of the gate leaf should be lubricated where necessary and defects if any should be rectified.

f) All nuts, bolts, check nuts and cotter pins of the lifting devices should be checked periodically.

g) All components should be greased and lubricated. Recommended and approved oils and grease only should be used.

h) All welds shall be checked for cracks/ damages. Any weld that might have become defective should be chipped out and redone following the relevant codal provisions. Damaged nuts, bolts, rivets, screws etc. should be replaced

i) The guide-assemblies, wheel-assemblies and sealing-assemblies shall be cleared off grit, sand or any other foreign material.

j) The wheel pin shall be coated with corrosion resistant compound.

k) All nuts and bolts shall be tightened.

The aspects to be inspected and maintained periodically for ensuring proper operation of these gates are as under:

a) **Rubber Seals**: i) Seals shall be inspected for leakages. Locations of excessive leakages shall be recorded for taking remedial measures. Weeping or slight flow in localized area will not require immediate remedial measures. However, measures like tightening of bolts are carried out. Further adjustment is carried out during annual maintenance.

b) **Trunnion block assembly and anchorages:**

i. All the nuts and bolts of Trunnion block assembly and its anchorages shall be checked for tightness.

ii. Check all the welds for soundness and rectify defects.

iii. Check whether the Yoke girder and thrust block is covered or not. If not, cover it with mild steel plates.

iv. Cover the trunnion pin with anti- corrosive jelly.

v. Remove all dirt, grit etc. from trunnion assembly and lubricate trunnion bearings of the gate with suitable water resisting grease as recommended by bearing manufacturers.

c) **Gate structures:**

i. Check all the welds for soundness and rectify defects.

ii. Check welds between arms and horizontal girders as well as between latching bracket and skin plate with the help of magnifying glass for cracks/defects and rectify the defects.

iii. Clean all drain holes including those in end arms and horizontal girders.

iv. Check all the nuts and bolts and tighten them. Replace damaged ones.

v. Check upstream face of skin plate for pitting, scaling and corrosion. Scaling may be filled with weld and grinded. Corroded surface shall be cleaned and painted.

d) **Embedded Parts:**

i) All the sill beams and wall plates shall be inspected for crack, pitting etc. and defects shall be rectified.

ii) The guide roller pins shall be lubricated.

e) **General Maintenance:**

Defective welding should be chipped out and it should be re-welded duly following the relevant codal provision (IS: 10096, Part-3).

i) Damaged nuts, bolts, rivets, screws etc. should be replaced.

ii) Any pitting should be filled up by welding and finished by grinding if necessary.

iii) The gate leaf, exposed embedded metal parts, hoists and hoist supporting structure etc., should be thoroughly cleaned and repainted when required keeping in view the original painting system adopted and as per the guidelines contained in IS: 14177.

iv) Trunnion bearing should be greased as and when required. Keeping trunnion bearings in perfect working condition is very important. All other bolted connections should also be checked up for proper tightness.

v) Bolts and trunnion bearing housing should be tightened wherever required.

vi) The seals of the gate should be checked for wear and tear and deterioration. These should be adjusted/replaced as and when necessary.

vii) The wall plates, sill beams shall be checked and repaired if necessary

viii) Wire ropes should be properly lubricated.

ix) Oil level in the worm reduction unit should be maintained by suitable replenishment. Oil seals should also be replaced if required. Lubrication of other parts of hoists such as chains, position indicators and limit switches should also be done.

x) The stroke of the brake should be reset to compensate for lining wear. Worn out brake linings should be replaced in time.

xi) Flexible couplings should be adjusted if required.

xii) Repairs and replacements of all electrical relays and controls should be attended to.

xiii) Maintenance of alternative sources of Power such as Diesel Generating sets and alternative drives wherever provided should be carried out.

xiv) The list of essential spare parts to be kept available should be reviewed and updated periodically. The condition of spares should be checked periodically and protective coating given for use. . Ensure availability of essential spare parts at site as per the list of essential spares.

4.3.7 Maintenance of Electrically operated fixed hoists

For obtaining uninterrupted three phase electric supply of sufficient volts required for the operation of shutters, a 30 KVA Diesel Generator set is provided.

a) General Instructions:

i. Never open any bolt or nut on motor, gear boxes, rope drums and other load carrying hoist components when the gate is in raised position. The gate should be fully closed or rested on the gate latches before carrying out any work on hoist components including motor brake and other electrical equipment.

b) Inspection and Maintenance

The aspects to be inspected and maintained periodically for ensuring proper operation of Rope drum hoists are as under;

i. Entrance to all hoist platforms shall be kept locked. All keys shall remain with the shift supervisor.

ii. A cursory daily inspection shall be made of hoist and gate to ensure that there is no unusual happening.

iii. Clean all hoisting equipment and hoist platform.

iv. Check oil level in gearboxes and replenish as and when required with oil of proper grade.

v. Apply grease of suitable grade by grease gun.

vi. Lubricate all bearings, bushings, pins, linkages etc.

vii. Check all the fuses on the power lines.

viii. All bolts and nuts on gear boxes, hoist drum and shaft couplings should be checked for tightness.

ix. Check the supply voltage.

x. Drain sample gear oil from each of the gear boxes. If excessive foreign particles or sludge is found, the gear box shall be drained, flushed and filled with new oil.

xi. All the geared couplings shall be greased.

xii. Raise and lower the gate by hoist motor and check for smooth, and trouble free operation of gate without excessive vibration.

xiii. Observe current drawn by motor at the time of lifting and check if it is more than normal. If so, stop the hoist and investigate the cause and rectify.

xiv. Check the condition of painting of various components and remove rust wherever noticed and repaint the portion after proper cleaning as per painting schedule.

xv. All trash, sediments and any other foreign material shall be cleared off the lifting rope and lifting attachment.

xvi. All ropes shall be checked for wear and tear and if broken wires are noticed, the rope shall be replaced.

xvii. All the wire ropes shall be checked and all visible oxidation shall be removed.

xviii. All wire ropes shall be greased with cardium compound.

xix. Check the overload relays for proper functioning.

xx. Check all the nuts, bolts, rivets, welds and structural components for hoisting platform and its supporting structure for wear, tear and damage. All damages shall be rectified. All bolts shall be tightened. The portion with damaged painting shall be touched up.

xxi. Check the pulleys, sheaves and turn-buckles.

xxii. Raise and lower the gate for its full lift several times (at least three to four) and observe the following:

a) Check the limit switches and adjust for design limits.

b) The effectiveness and slip of the breaks shall be checked by stopping the gate in raising and lowering operations. The brakes shall be adjusted if needed.

c) When the gate is operated, there should not be any noise or chatter in the gears.

xxiii. Adjust the rope tension of wires if unequal. Check for all gears and pinions for uneven wear and adjust for proper contact. Grease the gears.

xxiv. Repaint the hoist components, hoisting platform and its supporting structures as per requirement.

xxv. The periodic maintenance of commercial equipment like motors, brakes, thrusts etc. shall be carried out as per manufacturers operation and maintenance manual.

4.3.8 Maintenance of Electrical components of Fixed Rope Drum Hoists

a) The Electrical components to be inspected and maintained periodically are as under;

i) Starters should be cleaned free of moisture and dust.

ii) Each individual connector should be tried by hand to make sure that it operates freely.

iii) All wearing parts should be examined in order to take note of any wear which may have occurred during operation.

iv) If the connector hums, the contact faces should be cleaned.

(v) Examine all connections to see that no wires are broken and no connections are loose.

vi) Clean the surface of the moving armature and magnet core which comes together when the connector closes, free of dust or grease of any kind.

vii) Examine the mechanical interlocks between the reversing connector and see when the contact tips of one of the connector units are touching, it is impossible to get the contact tips of the other unit to touch.

viii) The contact tips should be kept free from burns or pits by smoothening with fine sand paper or emery paper.

ix) Replace the contact tips which have worn away half-way.

x) Do not lubricate the contacts.

xi) Examine earth connections and motor leads.

xii) Examine motor windings for overheating

xiii) Blow out windings thoroughly by clean and dry air to clear air passage in the stator and the rotor of any accumulated dirt. The air pressure shall not be

too high to damage the insulation.

xiv) Examine control equipment

xv) Examine starting equipment for burnt contacts

xvi) Check and tighten all nuts and bolts

xvii) Clean and tighten all terminals and screw connections all contact surfaces shall be made clean and smooth.

xviii) Lubricate the bearings

xix) Overhaul the controllers

xx) Inspect and clean circuit breakers.

xxi) Wipe brush holders and check bedding of brushes.

xxii) Blow out windings thoroughly by clean and dry air. The pressure shall not be so high that insulation may get damaged.

xxiii) Check the insulation resistance of the motor between any terminal and the frame. If the measured resistance is less than the prescribed value, then steps shall be taken

to dry- out the motors either by passing a low voltage current through the windings or by placing the stator and rotor only in a warm dry place for a day or so.

WARNING: The complete motor shall never be put in an oven for drying as that may melt the grease out of bearings.

xxiv) Coat the windings with an approved high temperature resisting insulation enamel or varnish.

xxv) Over haul the motor, if required.

xxvi) Check the switch fuse units and renew, if required.

xxvii) Check resistance or earth connections.

xxviii) Check air gap.

b) Solenoid Operated Brakes

i) All fixing bolts shall be checked and tightened at least once in three months.

ii) The magnet stroke should be reset to compensate for wear.

iii) Re-adjust the brake when the magnet stroke reaches the value given on the instruction plate.

iv) Brake lining should be checked and replaced when required.

v) Examine all electrical leads and connections.

vi) Rubber bushes or couplings should be checked and replaced if defective.

vii) The pins should be tightened.

viii) Brake drum shall be cleaned to remove any dust or grease.

4.3.9 Electrical System

Electricity is typically used at a dam for lighting and to operate the gates, hoists, recording equipment, and other miscellaneous equipment. It is important that the Electrical system be well maintained, including a thorough check of fuses and a test of the system to ensure that all parts are properly functioning. The system should be free from moisture and dirt, and wiring should be checked for corrosion and mineral deposits.

All necessary repairs should be carried out immediately and records of the works kept. Maintain generators used for auxiliary emergency power - change the oil, check the batteries and antifreeze and make sure fuel is readily available.

Monitoring devices usually do not need routine maintenance. Open areas are particularly susceptible to vandalism. As such all electrical fittings like bulbs, lights, loose wires etc. in open areas should be checked routinely and replaced/repaired where needed. The recommendations of the manufacturer should also be referred to.

4.3.10 Maintenance of Metal Gate Components

All exposed, bare ferrous metal of an outlet installation, whether submerged or exposed to air, will tend to rust. To prevent corrosion, exposed ferrous metals must be either appropriately painted (following the paint manufacturer's directions) or heavily greased in respect of moving parts & on surfaces like guides & track seats on which there is movement of gates. When areas are repainted, it should be ensured that paint is not applied to gate seats, wedges, or stems (where they pass through the stem guides), or on other friction surfaces where paint could cause binding. Heavy grease should be applied on friction surfaces to avoid binding. As rust is especially damaging to contact surfaces, existing rust is to be removed before periodic application of grease.

Surface Preparation and Painting of HM Works

i) Protection of painted surfaces is considered essential for protection & enhancement of service life. Gates, their embedded parts, gate leaf, hoists and its supporting structures need to be protected against corrosion due to climatic condition, weathering, biochemical reaction and abrasion etc. This equipment is likely to deteriorate or get damaged to any extent that the replacement of parts may become necessary and such replacement may become difficult

and costly.

ii) Surface preparation & Painting requirements:

Painting for hydro-mechanical works is to be carried out as prescribed in IS 14177 for both newly manufactured as well as old & used gates, hoists and associated works after proper surface preparation. The preparation includes thorough cleaning, smoothing irregular surfaces, rusted surfaces, weld spatters, oil, grease, dirt, earlier applied damaged layers of primers/ paint by use of mechanical tools, by use of solvents, wire brush etc. The sand / grit blasting process is used for surface preparation to a level of Sa 2½ of the Swedish standard.

iii) Surfaces not requiring painting & their protection during surface preparation, painting & transportation process:

a) The following surfaces are not to be painted unless or otherwise specified:

- Machine finished or similar surface
- Surfaces which will be in contact with concrete
- Stainless steel overlay surfaces.
- Surfaces in sliding or rolling contact
- Galvanized surfaces, brass and bronze surfaces.
- Aluminum alloy surfaces

b) The Surfaces of stainless steel, nickel, bronze and machined surface adjacent to metal work being cleaned or painted shall be protected by using sticky protective tape or by other suitable means over the surfaces not to be painted.

c) All embedded parts which come in contact with concrete shall be cleaned as detailed above and given two coats of cement latex to prevent rusting during the shipment while awaiting installation.

iv) Application of primer &finish coats on embedded parts and gates:

a) Embedded Parts:

- The prescribed primer shall be applied as soon as the surface preparation is complete and prior to the development of surface rusting and within the specified time prescribed by Indian Standards or the Paint Manufacturer. In case there is lapse of considerable time beyond the prescribed time limit, the surfaces shall be again cleaned prior to priming.
- Two coats of zinc rich primer with epoxy resin shall be applied to all embedded

parts surfaces which are not in contact with concrete and shall remain exposed to atmosphere or submerged in water to obtain a dry film thickness of 75 microns.

- This shall be followed by three coats at an interval of 24hours of coal-tar blend epoxy resin so as to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall not be less than 300 microns.

b) Gates:

Primer Coat:

Over the prepared surface one coat of inorganic zinc silicate primer giving a dry film thickness of 70 ± 5 microns should be applied. Alternatively two coats of zinc rich primer, which should contain not less than 85% zinc on dry film should be applied to give a total dry film thickness of 75 ± 5 microns.

Finished paint:

Two coats of solvent less coal tar epoxy paints. These shall be applied at an interval of about 24 hours. Each coat shall give a dry film thickness of 150±5 microns. The total dry film thickness of all the coats including primer coating shall not be less than 350 microns.

v) Hoist and supporting structure:

a) Structural components:

- Primer coats of zinc phosphate primer shall be applied to give a dry film thickness of 40±5 microns.
- Final Coats: One coat of alkalized based micaceous iron oxide paint to give a dry film thickness of 65 ± 5 microns followed by two coats of synthetic enamel paint confirming to IS 2932 – 1974 to give a dry film thickness of 25 ± 5 microns per coat. The interval between each coat shall be 24hours. The total dry thickness of all coats of paint including the primer coat shall not be less than 175 microns.

b) Machinery: Except machined surfaces all surfaces of machinery including gearing, housing, shafting, bearing pedestals etc., shall be given:

- Primer coats: One coat of zinc phosphate primer paint to give minimum film thickness of 50 microns. Motors and other bought out items shall be painted if necessary.
- Finished coats: The finished paint shall consists of three coats of aluminum paint confirming to IS2339 – 1963 or synthetic enamel paint confirming to IS 2932 – 1977 to give a dry film thickness of 25±5 microns per coat to obtain a total

minimum dry film thickness of 125 microns.

c) Machined surfaces:

All machined surfaces of ferrous metal including screw threads which will be exposed during shipment or installation shall be cleaned by suitable solvent and given a heavy uniform coating of gasoline soluble removable rust preventive compound or equivalent. Machined surfaces shall be protected with the adhesive tapes or other suitable means during the cleaning and painting operation of other components.

vi) Application of paint:

- Mix the contents thoroughly as directed by paint manufacturer before and during use.
- Painting at shop can be done by any of the three methods namely Brush / roller, Conventional spray, Airless spray etc.

The paint can be made to suit the adopted method. But once the gate and equipment is in erected position the general method adopted is only brush / roller. In case of spray lot of precautions are to be taken.

For More details: Refer IS: 14177 Part (II) – 1971.

Appendix A – Brushing of paint

Appendix B – Spraying of paint

Appendix C – Spray painting defects: Causes and remedies.

Removal of old paint / rust and carrying out fresh painting:

The carrying out of fresh painting is to be considered under the following conditions:

- The rusting is noticed all over the surface or
- Rusting is severe or
- Cracking and blistering has damaged the primer coat exposing the metal and is noticed all over the surface or
- The paint film has eroded badly, the scrap of entire paint film to the base metal

Note: In case of maintenance and renovation: Refer IS 14177 (Part II) – 1971 for checking and repainting.

vii) Removal of old paint for repainting:

Caution should be exercised while removing the old paint. The surfaces shall be de-rusted and descaled by either mechanically by one or more of the methods, namely:

a) Wire brushing, Scraping, and chipping. Sand papering or cleaning with steel wool or abrasive paper

b) Power tool cleaning

c) Flame cleaning

d) Sand blasting or shot blasting and

e) Chemical rust removal.

Note: The method of application shall be decided based on conditions existing. After cleaning, painting is to be carried out as originally proposed.

Some are painted without removal of old paint and rusting this will amounts to no painting and deteriorate faster than the original one.

viii) Inspection and testing of painting of H. M works:

a) The following steps are involved in inspection of painting:

- General inspection before and during painting
- Viscosity test of paints
- Paint thickness test – using Elco-meter.
- Inspection of general appearance of finished work.

b) General:

The aim of inspection and testing is to ascertain whether the recommended practice is being employed correctly during every stage of application and whether the final results fulfill the object of painting. Any test carried out should be of non – destructive nature or, if it is of destructive nature, it should be either restricted to areas which can be restored without marring the general appearances or be such that it is possible to restore easily without necessitating a complete repetition of the work.

c) Inspection of surfaces prior to painting:

Inspection methods will depend on whether it is to be painted for the first time or is to be repainted.

d) New Works (Not previously painted): The following shall be decided by inspection:

- The method of pre cleaning feasible or recommended;
- The intermediate protective treatments to be applied, if found necessary;
- The final painting schedule and the specifications for the paint for ensuring the particular performance;
- The method of application, whether by brush, roller or spray.

e) Old Work (Which requires repainting):

The following shall be decided by inspection:

- Whether the entire existing paint requires removal; and/or

- Whether repainting without paint removal would be adequate.

4.3.11 Access Roads

Access road surfaces must be maintained to allow safe passage of automobiles and any required equipment for servicing the dam in any weather conditions. Routine observations of any cut and fill slopes along the sides of the road should be made. In case of unstable conditions/slopes developing blockage of the road, protective works including retaining walls shall be provided as remedial measures. Drains are required to be provided and maintained along roads to remove surface and subsurface drainage. This will prolong the life of the road. Road surfacing should be repaired or replaced as necessary to maintain the required traffic loadings. The maintenance of all access roads is executed under DRIP.

4.3.12 General Cleaning

For proper operation of spillways, outlet valves, inlet and outlet structures, stilling basin / energy dissipation arrangements, IC Tunnel dam slopes, trash racks, debris control devices etc., regular and thorough cleaning and removal of debris is necessary. Cleaning is especially important after large floods, which tend to send more debris into the reservoir. The dam has two transverse galleries meeting to the foundation gallery. The dam top road and these galleries are to be cleaned regularly.

4.4 Materials and Establishment Requirements during Monsoon

Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked in adequate quantities for emergency situations that may arise. At Pamba Dam, round the clock patrol is to be carried out during monsoon period. Additional manpower including operating staff (gate operators, workers, electrician etc.) will be provided based on requirement during monsoon period. Details of manpower / organizational structure are given in Chapter -1.

Following materials are required for handling the situations during monsoon period:

- Gunny Bags
- Sand, Boulders/Wire crates
- Bamboos/ Balli's
- Baskets, ropes

- Petromax Lamps with Spares
- Torches with spare cells
- Kerosene Oil
- Match Boxes
- Rain Coats
- Gum Boots
- Warning sign indicator
- Danger zone lights

4.5 Preparation of O&M budget

The O & M budget for Pamba dam should essentially include but not be limited to the following items:

i) **Establishment Cost of Regular Staff** - Salaries and allowances, Bonus, Medical reimbursement, LTC, Leave encashment, pension benefits, etc. (as applicable).

ii) **Establishment Cost of Work charged Staff** - Salaries and allowances, Bonus, Medical reimbursement, LTC, Leave encashment, Pension benefits, TA and DA , etc. (as applicable).

iii) **Establishment Cost of Daily wage Staff** - Salaries and allowances, TA and DA etc. (as applicable)

iv) **Office Expenses** - Telephone/Mobile/any other Telecommunication bills, Electricity bills, water bills, Office stationery, Day to day office requirements.

v) **Motor Vehicles** - Running and Maintenance cost of inspection vehicles, Cost of hiring of vehicles as required

vi) **Maintenance of Colony** - Maintenance of staff quarters, colony roads, Electricity, Sanitary and Water supply systems etc

vii) **T&P** - The T&P requirements for offices, colony, works etc. as applicable.

viii) **Works**- Painting, oiling, greasing, overhauling of HM equipment's, Repair/replacement of gates seals & wire ropes, POL for pumps & generator sets, Electricity charges and maintenance of Electric systems of dam site, specific requirements for all Civil, H.M & Electrical maintenance works, vegetation removal, maintenance/cleaning of drains in dam, maintenance of lift/elevators in dam (as applicable), maintenance of access roads & basic facilities, provision for

flood contingency works during monsoon, unforeseen events/items (about 10% of the cost of works) etc.

A summary table for the O & M budget is given below in **Table 4.1**.

Sl. no.	Budget item	Previous year cost (Rs)	Current year budget (Yr ____) (Rs)	Remarks
a.	**Establishment**			
1	Salary of regular staff including all other benefits			
2	Travel expenses			
3	Office expenses			
4	Vehicle expenses			
5	Maintenance of office & colony complex			
	Sub-total - a			
b.	**Works**			
1	**Civil works**			
1.1	Concrete / masonry dam			
1.2	Sluices in concrete / masonry dams			
1.3	Approach / inspection roads within dam area			
2	**Hydro-Mechanical works**			
2.1	Spillway gates & hoists			
2.3	Sluices in concrete/masonry dams – service/emergency gates & hoists			
3	**Electrical works**			
3.1	Electrical fittings, motors, controls for all gate hoists			
3.2	Power supply lines			
3.3	Electrical fittings on dam top, dam galleries, etc.			
3.4	Standby power / diesel generator			
3.5	Remote control			
4	**Instrumentation**			
5	**Miscellaneous works**			
6	**Salary of work charged staff including all benefits**			

7	**Materials to be stored before monsoon**			
	Sub-total - b			
c.				
1	**contingency (10%) on sub-total of a & b**			
2	**tools & plants**			
	Sub-total - c			
	Total Annual Cost			

Table 4.1 Summary Table for Annual O&M Budget

4.6 Maintenance Records

Maintenance records are of utmost importance. A record shall be kept for all maintenance activities, both immediate and preventive maintenance works. Information that must be recorded includes, but not limited to, the following:

- Date and time of maintenance,
- Weather conditions,
- The type of maintenance,
- Name of person or contractor performing maintenance,
- Description of work performed,
- The length of time it took to complete the work with dates,
- Equipment and materials used, and
- Before and after photographs.

The data should be recorded by the person responsible for maintenance.

Chapter 5

Instrumentation and Monitoring

A dam's instrumentation furnishes data for deciding if the structure is functioning as intended and provides continuous monitoring to warn of any unsafe developments or phenomena that can lead to dam failure by drawing information from a wide spectrum of instruments and procedures, ranging from simple to complex. The program must be based on prevailing geotechnical conditions at the dam, and must include consideration of the hydrologic and hydraulic factors present before and after the project is in operation. The extent and nature of the instrumentation depends not only on the complexity of the dam and the size of the reservoir, but also on the potential for threat to life and property losses downstream. The involvement of personnel with experience in the design, installation, regular monitoring, and evaluation of an instrumentation system is of prime importance to the success of the program.

Instruments installed at a dam can indicate occurrence of any anomalous or problematic behavior. They can show that whether the dam behavior is as per design or otherwise. Actual measurements of uplift pressure in a Gravity dam and comparison with the uplift pressure assumed in original designs is an example.

5.1 Instrument Types and Usage

A wide variety of instruments and procedures are used to monitor dam behavior. The parameters often monitored by instruments include:

- movements (horizontal, vertical, rotational and lateral)
- pore pressure and uplift pressures
- water level
- seepage flow
- water quality
- temperature
- Crack width
- seismic activity
- weather and precipitation data
- stress and strains

Pamba dam is not instrumented with Pendulum, Pore Pressure meter, Joint meter, Resistance Thermometer etc. But minimum instrumentation is proposed under DRIP.

Instruments are not installed for Pamba dam except V notch. The modernization of instrumentation is being arranged under DRIP. It is proposed to install Tilt sensors, Joint meters, Thermo meters and accelerographs in the dam under DRIP. The status of instrumentation in Pamba dam is given in the **Table 5.1.**

There are 31 Vertical drain holes in the Pamba dam gallery and are connected with GI caps. In the unplugged condition, the drained water flows to the drains. When the uplift pressure is to be measured, the top opening is plugged and pressure gauge fitted on to the side opening through 1" dia pipe on the 3" side of the T connection. Then the pressure gauge works and gives the static head corresponding to the reservoir level. After measuring the maximum head, the pressure is released by removing the plug. Refer **Drg 5.1** of **Annexure 1.**

STATUS OF INSTRUMENTATIONS IN PAMBA DAM			
Sl. No.	Name of Instruments	Total No installed	Functioning
1	Single V – notch	1	1
2	Joint Meter	0	0
3	Tilt Meter	0	0
4	Uplift Pressure Gauge	0	0
5	Thermometer	0	0

Table 5.1 Instrumentation Present Status

5.2 Parameters monitored

5.2.1 Pore Pressure and Uplift Pressure

Uplift pressure meter (removable) are available for measuring the uplift pressures.

5.2.2 Water Level

Water level gauge is provided at the left bank of the dam. Daily water levels are taken two times. During monsoon, hourly readings are taken and recorded.

5.2.3 Seepage Flow

Seepage is measured with V notches.

Seepage assessment

In Pamba dam the porous drains and foundation drain holes are connected to the common drain in foundation gallery. Drain culvert is located at level 3090' in Block no.8. The collected water is drained to the downstream side over the right bank of spillway. The drainage holes in the foundation gallery are subjected to uplift pressure test at regular intervals. Total seepage is measured using a V notch established in 9th block in bottom gallery. Seepage details for the period 2013 to 2019 are given in **Table 5.2**.

Observation date	Water Level in m	Discharge through V-Notch in Litres/minute
21.01.2013	965.55	0.88
25.02.2013	963.55	0.88
22.03.2013	963.25	0.88
23.04.2013	963.35	0.88
24.05.2013	963.35	0.88
25.06.2013	970.65	7.06
23.07.2013	977.20	94.85
26.08.2013	980.55	135.65
26.09.2013	986.30	185.48
26.10.2013	980.30	94.85
25.11.2013	978.30	65.35
23.12.2013	975.35	44.45
05.01.2014	973.65	20.50
28.02.2014	967.15	2.43
27.03.2014	963.45	0.88
29.04.2014	962.95	0.88
27.05.2014	965.70	1.70
28.06.2014	965.00	6.32
16.07.2014	970.85	2.43
28.08.2014	970.50	2.43
26.09.2014	974.60	37.83
25.10.2014	973.65	28.18
20.11.2014	975.50	49.22
29.12.2014	975.10	31.83
23.01.2015	974.35	28.18
21.02.2015	972.40	12.61
19.03.2015	968.55	2.43

17.04.2015	963.85	0.88
19.05.2015	964.35	0.88
07.06.2015	963.70	0.88
09.07.2015	966.30	0.88
19.08.2015	965.40	0.88
21.09.2015	965.10	0.88
30.10.2015	966.20	0.88
27.11.2015	972.15	13.73
22.12.2015	974.35	28.18
26.01.2016	972.70	28.18
24.02.2016	969.95	4.98
26.03.2016	965.95	4.98
25.04.2016	963.45	2.43
20.05.2016	963.50	0.88
25.06.2016	964.65	0.88
26.07.2016	966.60	0.88
25.08.2016	970.40	2.43
19.09.2016	970.30	2.43
17.10.2016	969.40	2.43
27.11.2016	968.20	2.43
20.12.2016	967.70	0.88
11.01.2017	965.90	4.98
13.02.2017	964.70	0.88
05.03.2017	963.45	2.43
02.04.2017	963.50	0.88
02.05.2017	963.20	2.43
25.06.2017	964.95	0.88
30.07.2017	964.50	0.88
22.08.2017	967.75	0.88
30.09.2017	972.70	28.18
20.10.2017	974.35	28.18
30.11.2017	976.00	77.50
06.12.2017	978.70	62.47
16.01.2018	977.20	94.85
07.02.2018	976.10	77.50
02.03.2018	974.60	28.12
05.04.2018	968.05	28.12
23.05.2018	963.50	0.88
24.06.2018	965.50	2.43
22.07.2018	984.00	159.08
09.08.2018	984.35	159.08
21.09.2018	976.00	77.50
24.10.2018	976.00	77.50

19.11.2018	973.75	8.68
12.12.2018	973.10	8.68
30.01.2019	970.20	4.97
14.02.2019	968.85	0.88
13.03.2019	967.70	0.88
19.04.2019	973.10	2.43
22.05.2019	963.00	2.43
16.06.2019	963.75	0.88
20.07.2019	966.60	2.43
27.08.2019	966.60	4.97

Table 5.2 Seepage details of Pamba dam from 2013 to 2019

5.2.4 Water Quality

The quality of water including pH value is tested monthly at Analytical laboratory, Thiruvananthapuram. A sample Analytical report is included in **Annexure 9.**

5.2.5 Seismic Activity

The project area falls in zone no III of the seismic zone map of India. The maximum intensity felt by the Pamba Dam site has ranged from 5 to 7 on M.M. Scale. The dam is required to be safe using the appropriate seismic coefficients in the BIS code and as approved by NCSDP. Historical significant earthquake events in the near vicinity are as under

- Event 1: Date: 12/12/2000, Epicenter: Erattupetta, Magnitude: 5 and
- Event 2: Date: 1/7/2011, Epicenter: Erattupetta, Magnitude: 4.8

The Seismic observatory installed at Pamba is not working. Hence new digital seismic observatory as well as accelerographs for the Dam galleries for measuring local tremors is included under DRIP.

5.2.6 Weather Conditions

Now the rainfall data are measured with rain gauges. But a full equipped weather station can sense all weather conditions. Automated weather station is proposed.

5.3 Frequency of Monitoring

Water levels monitored daily, the seepage data monitored on fortnightly basis and water quality on monthly basis.

5.4 Data Processing and Evaluation

The steps required to process and evaluate data, whether collected manually or automatically, are the same. Instrument data should be processed and evaluated according to the procedures established by the monitoring program. Accumulation of instrument data by itself does not improve dam safety or protect the public. Interpretation of data, so collected, needs to be carried out judiciously. Help of experienced personnel from the concerned field from Institutes / manufacturers / instrument suppliers could prove to be useful.

5.4.1 Data Collection

On daily, fortnightly and monthly basis, as the case may be.

5.4.2 Data Presentation

On monthly basis. A monitoring report is included in **Annexure 9.**

5.4.3 Data Interpretation

As per standard practice & on monthly / six monthly / yearly basis or as decided by design authorities.

5.4.4 Dam Performance Evaluation

Performance evaluation is conducted for safe normal operation involving all concerned engineers / officers before and after monsoon.

In case, the data deviates from expected behavior or design assumptions, action should be taken. The action to be taken depends on the nature of the problem, and should be determined on a case-by-case basis

5.5 Methods of Behavior Prediction

5.5.1 Visual Observations

Observations by on site personnel (dam owners/operators and maintenance personnel) may be the most important and effective means of monitoring the performance of a dam. An inspector should examine visually walking along the dam alignment for any leakages, any distress, wet spots on d/s face of dam, seepage from foundation gallery etc.

5.5.2 Monitoring Results

Analysis and observation of the instrument readings on water level, leakages, uplift and other parameters can ascertain the visually observed behavior. Any deviation from the normal behavior needs to be resolved critically by taking required remedial measures in consultation with senior / experienced engineers.

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Chapter 6

Previous Rehabilitation Efforts

6.1 Issues with the dam

The dam was commissioned long back and no major rehabilitation works were carried out. The Dam was inspected by experts from CWC and DSRP, recommendations given for works/remedial measures to be attempted for improving the structural safety and security performance of the Dam. Accordingly the following works were carried out under DRIP I.

- Special repairs to radial gates of Pamba dam
- Repairs to valves & gates of Pamba dam:
- Maintenance of road to galleries, Dam top, IC Tunnel inlet etc of Pamba Dam
- Replacing damaged wearing coat of Pamba dam top road
- Monitoring cabin at Pamba Dam Left bank
- Protective roofing to the hoist machine of Pamba dam
- Steel doors to Gallery entrance of Pamba Dam
- Reaming Foundation and body drain holes
- Improving dam top lighting
- Supply and commissioning of High Mast lights
- Upstream epoxy painting - Yet to be undertaken.

The photographs showing the DRIP works are given below:

Before - Dam Top Wearing coat

After - Dam Top Wearing coat

Before - Special repair to Hoist mechanism

After - Special repair to Hoist mechanism

Monitoring cabin – Construction

Monitoring cabin – Final stage

Before –Supply and Erection of Roofing to hoist of Pamba Dam radial gate

After – Supply and Erection of Roofing to hoist of Pamba Dam radial gate

Dam Top Lantern–Before

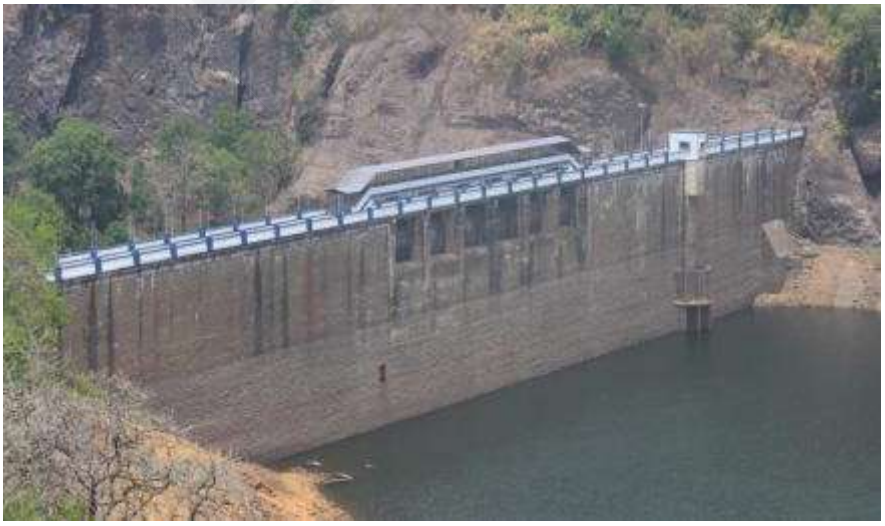
Dam Top Lantern–After

High mast light

Reaming of drain holes

Construction of Generator room

Before Painting



After Painting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Chapter 7

Updating the Manual

Whenever features of the dam and appurtenant structures change, the O & M Manual must be edited and portions rewritten to reflect these changes. This task is often ignored. Updating information in the O & M Manual should be done whenever major changes like construction of an additional spillway, construction of dam on the upstream etc., take place.

Aspects to be considered when updating the Manual must include: Increase/decrease in the frequency of an inspection or the maintenance routine based on additional data/ experience acquired, Changes in the operation and/or maintenance procedures based on additional data/experience acquired, Alterations to the project data because of changes/modifications in the dam by way of additional spillway etc.

It is recommended that the O & M Manuals may be reviewed/ updated after every 10 years by the respective Dam Owners.

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