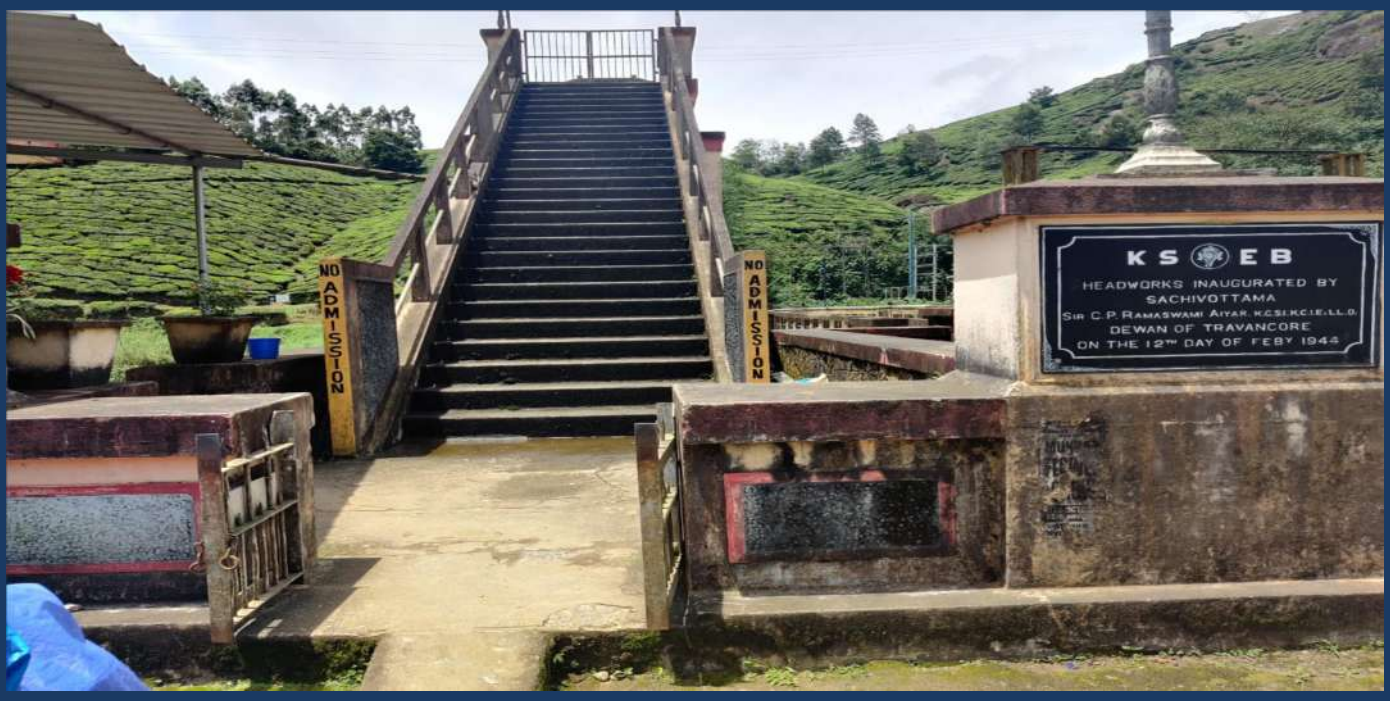
Operation and Maintenance Manual
For RA Head Works, Munnar
State of Kerala

Doc No. 19_DSO_O&M_ RA Head Works
Chief Engineer (Civil Dam Safety & DRIP)
Kerala State Electricity Board



Front Cover Photograph: Views of RA Head Works, Munnar.

Operation and Maintenance Manual

RA Head Works, Munnar

Approved

Chief Engineer (Civil)
Dam Safety & DRIP

Kerala State Electricity Board Ltd

Pallom, Kottayam.

August 2020

Kerala State Electricity Board Ltd

Dam Safety Organisation

Disclaimer

This *Operation and Maintenance Manual for* RA Head Works, Munnar in no way restricts the dam operators in digressing from her/his responsibilities. The Dam Operators must exercise appropriate discretion and good judgment 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, on-going 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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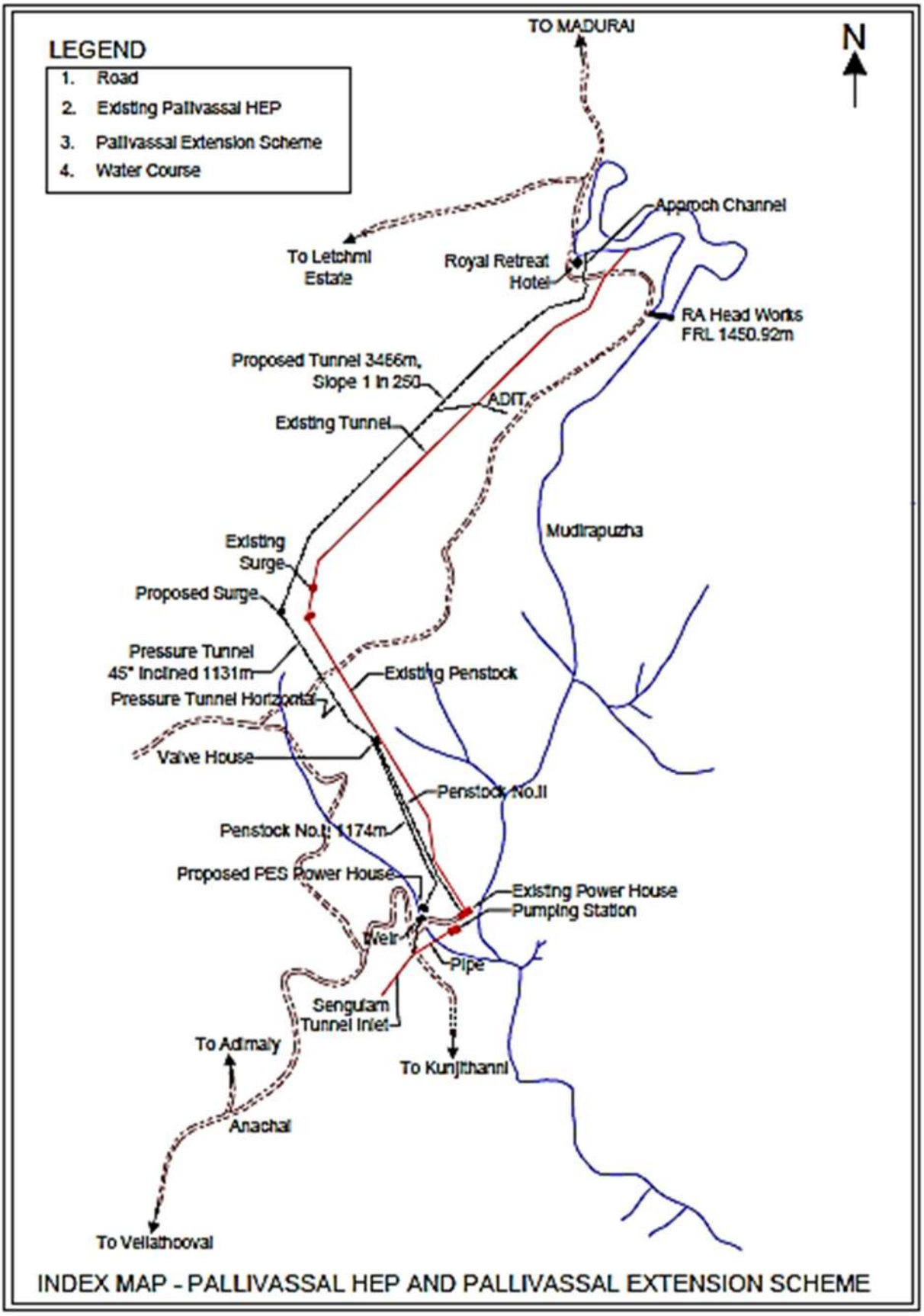
PREFACE

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.

RA Head Works 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 Pallivasal HEP of KSEBL commissioned in 1944 includes 2 main dams, one at Kundala and other at Madupetty. Both of them are storage dams and water is released as per requirements. The water released from Madupetty dam is diverted to the tunnel mouth of Pallivasal HEP by constructing a diversion weir named RA head works. The power house of the project is located at Pallivasal, on the right bank of Muthirapuzha River and generates 37.5 MW (3x5+3x7.5) under a net head of 572.08 m. A flow chart of Pallivasal HEP is given in the next page for reference.

This Operation and Maintenance Manual is prepared for the RA Head Works of PHEP.



Flowchart of Pallivasal Hydro Electric 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
FSCT	Federation of Societies for Coatings Technology
HCC	Hindustan Construction Corporation Ltd
IS	Indian Standard
KERI	Kerala Engineering Research Institute
KDSA	Kerala Dam Safety Authority
KSEBL	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
UAV	Unmanned Aerial Vehicle
USBR	United States Bureau of Reclamation
USACE	United States Army Corps of Engineers

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Chapter 1

General Information

1.1 Introduction

Pallivasal Hydro Electric Project is the first Hydro Electric project of Kerala. The Project is located in Munnar Village, Devikulam Taluk, of Idukki district. The latitude is $10^{o}04'00"$ N and longitude is $77^{0}04'00"$ E. The installed capacity of the Project is 37.5 MW. The project site is near to Munnar. There are two dams and one diversion weir as part of this project. They are Kundala Dam, Maduppetty Dam and R A Head works. R A Head works is located at 104 km from Kochi International Airport. Nearest Railway station is Aluva and is 105 km from R A Head works. The Maduppetty Dam is located at about 15 km upstream of R. A. Head works and Kundala Dam is further upstream and is about 12 km from Maduppetty Dam.

The Pallivasal Hydro Electric project utilizes the waters of Mudirapuzha River, a tributary of Periyar River having its source in the high range of Western Ghats. This stream is fed by several streams rising in the surrounding hills. The catchment area above head works of the project is about 235 sq. km, and most of this area experiences rains both during the North East and South West monsoons. The rain fall within the catchment varies annually from 5778.5 mm in certain areas to 1460.5 mm in the other areas with an average per sq. km of 1110.64 mm over the entire catchment area. The river flow varies from 849.38 m^3/s during abnormally heavy flood period to a recorded minimum of 1.22 m^3/s over a period of 3 days in the driest season of an exceptionally dry year. The minimum flow during an average dry year is 1.98 m^3/s. The retention level of the Diurnal Reservoir at the head works is RL 1450.47m.

The head works consists of a diversion weir, main intake and approach channel, subsidiary intake, Tunnel intake chamber and Tunnel portal. The power house and equipments were ready before the main weir, main intake and channel could be completed (mainly due to the delay in obtaining the gates of the main weir) and temporary dam was constructed across the river, 100ft downstream of the tunnel intake chamber (about 1500ft upstream of the main weir) and water was taken into the tunnel through a subsidiary intake. The temporary dam was dismantled after the main weir etc. was completed, and the head works inaugurated in 1944.

The tail race water from Pallivasal power house along with spill from RA head works and flow in river Mudirapuzha is tapped in the collecting tank by a pickup weir and fed to Sengulam Balancing Reservoir.

1.2 Purpose, Location, Description of the Project

Pallivasal Hydro Electric Project Location

Supply of cheap electric power for industrial and domestic purpose received the attention of the Travancore Durbar as early as 1929. The first Government owned supply was started at Thiruvananthapuram in 1928 from a diesel Generating Station. The rapid increase in load of the station, and the request for supply of power from the township in north Travancore decided the question of developing Hydro Electric Power with sufficient output for catering to the requirements of the whole of central and northern Travancore, where most of the important towns were situated. The first scheme taken up for development was the Pallivasal Project due to the existence of previous rainfall and river flow records, the cheapness of the scheme, the possibility of storage facilities for future extensions, the existence of a good tea factory located close to the Generation Station and the extreme convenience for access to the area with the opening of a good metaled road connecting the area to the plains.

Pallivasal Hydro Electric Project is located in Idukki District of Kerala State. The project site is near to Munnar. There are two dams and one diversion weir as part of this project. They are Kundala Dam, Maduppetty Dam and R A Head works. RA Head works is located by the side of Aluva – Munnar road just before Munnar and is about 104 km from Kochi International Airport. Nearest Railway station is Aluva and is 105 km from R A Head works. Maduppetty Dam is located at about 15 km upstream of R. A. Head works and Kundala Dam is further upstream and is about 12 km from Maduppetty Dam.

The upstream most dam of the project is Kundala. It is constructed in the upstream reaches of Mudirapuzha sub basin, downstream of the confluence of Chittuvarai, Ellappatti and Chunduvarai streams, in Periyar. It is a masonry dam having gross storage of 7.78 Mm3 and live storage of 7.65 Mm^3. FRL of the reservoir is 1758.69 m and the MWL is 1759.30 m. The water stored in the reservoir is released through the stream to Maduppetty dam located downstream. Maduppetty dam is a concrete Gravity dam having gross storage of 55.23 Mm^3 and live storage of 54.77 Mm^3. FRL & MWL of the reservoir is 1599.59 m. The water stored in the Maduppetty reservoir is released to downstream through a dam toe power house having a capacity of 2 MW. The controlled release from Maduppetty Dam reaches the diversion weir (R.A. Head works) and from there, the water is diverted through a water conducting system to the power house of Pallivasal HEP located on the right bank of Mudirapuzha river. After generating power, the tail water is pumped to the balancing reservoir of Sengulam Hydro Electric Project and the surplus water from the sump of pumping station is spilled to the Mudirapuzha River itself.

The index map and route map of Pallivasal HEP are given in **Fig 1.1 and Fig 1.2.**

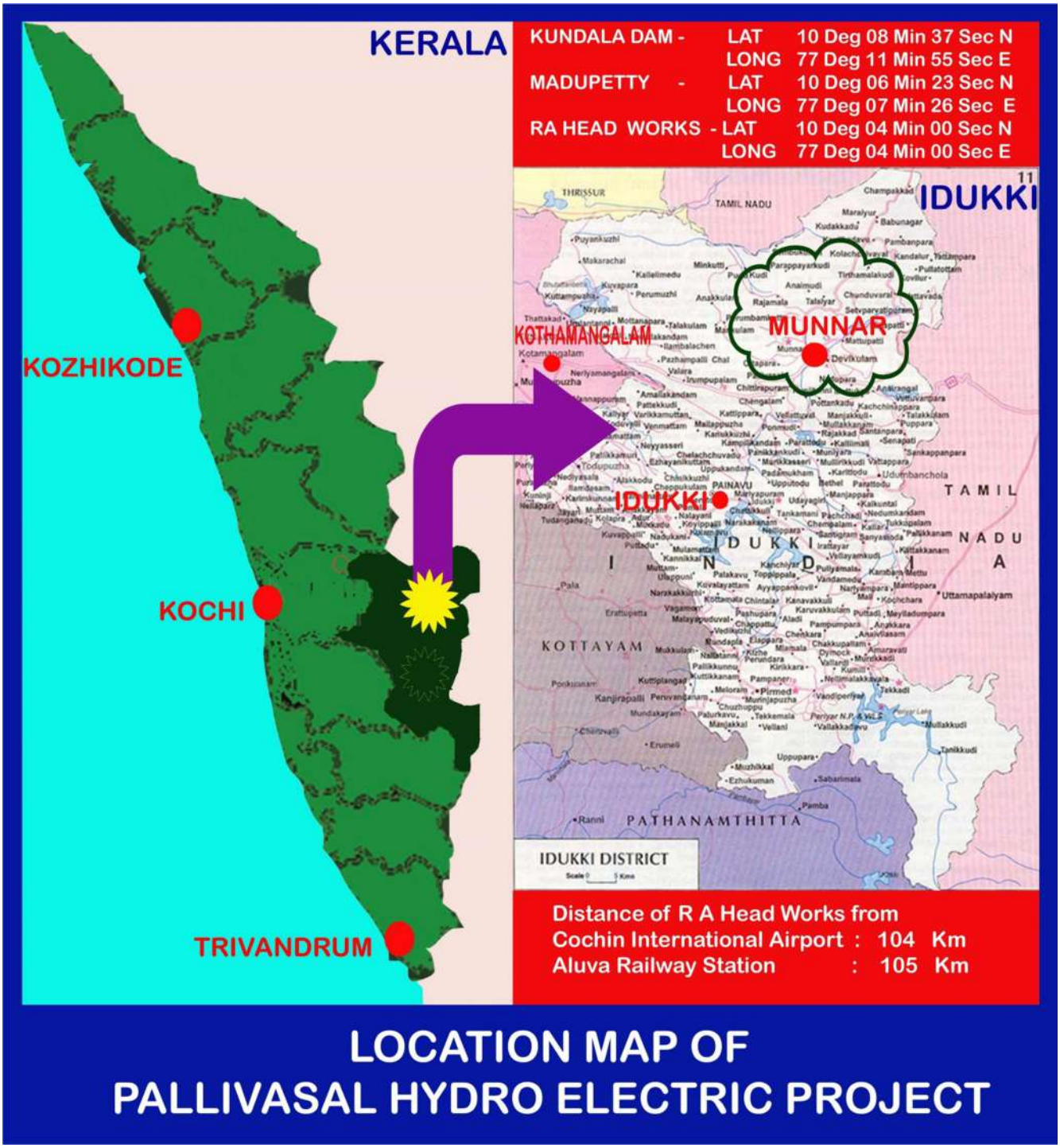

Fig 1.1 Index Map

Fig 1.2 Index Map District wise

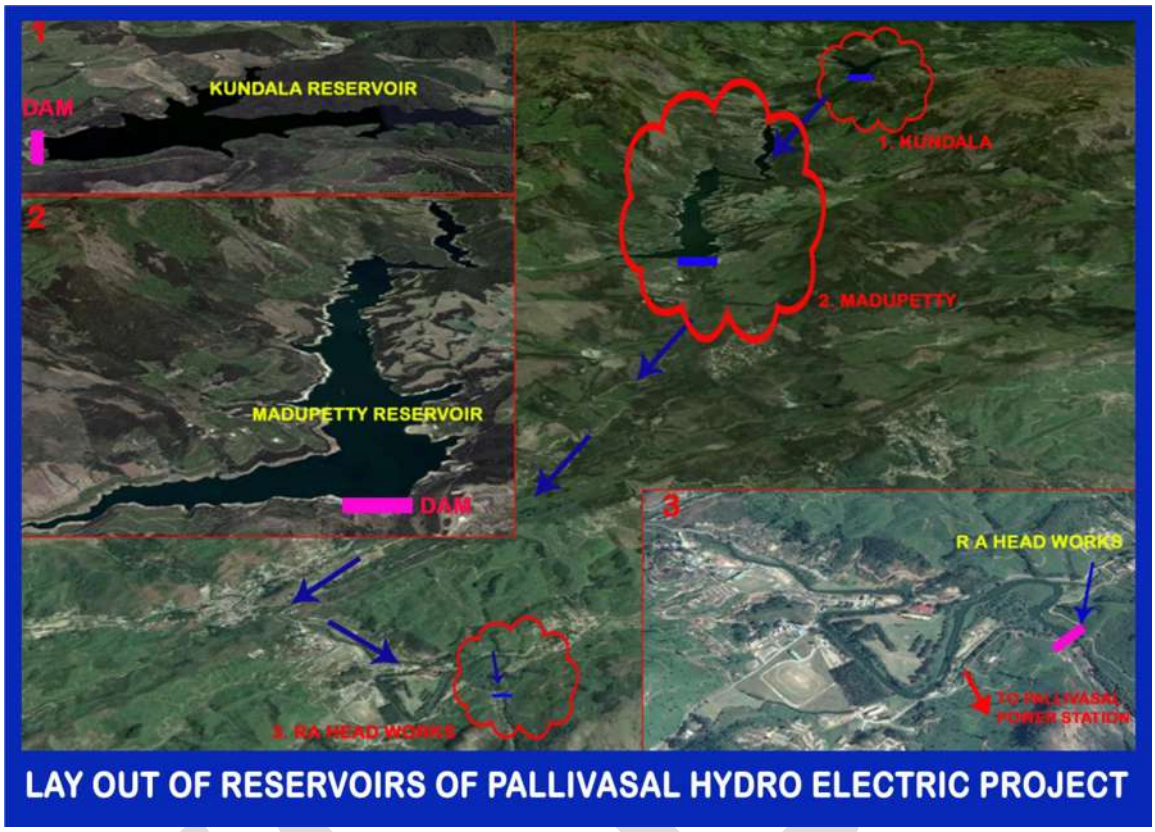

Fig 1.3 Lay out of reservoirs of Pallivasal HEP

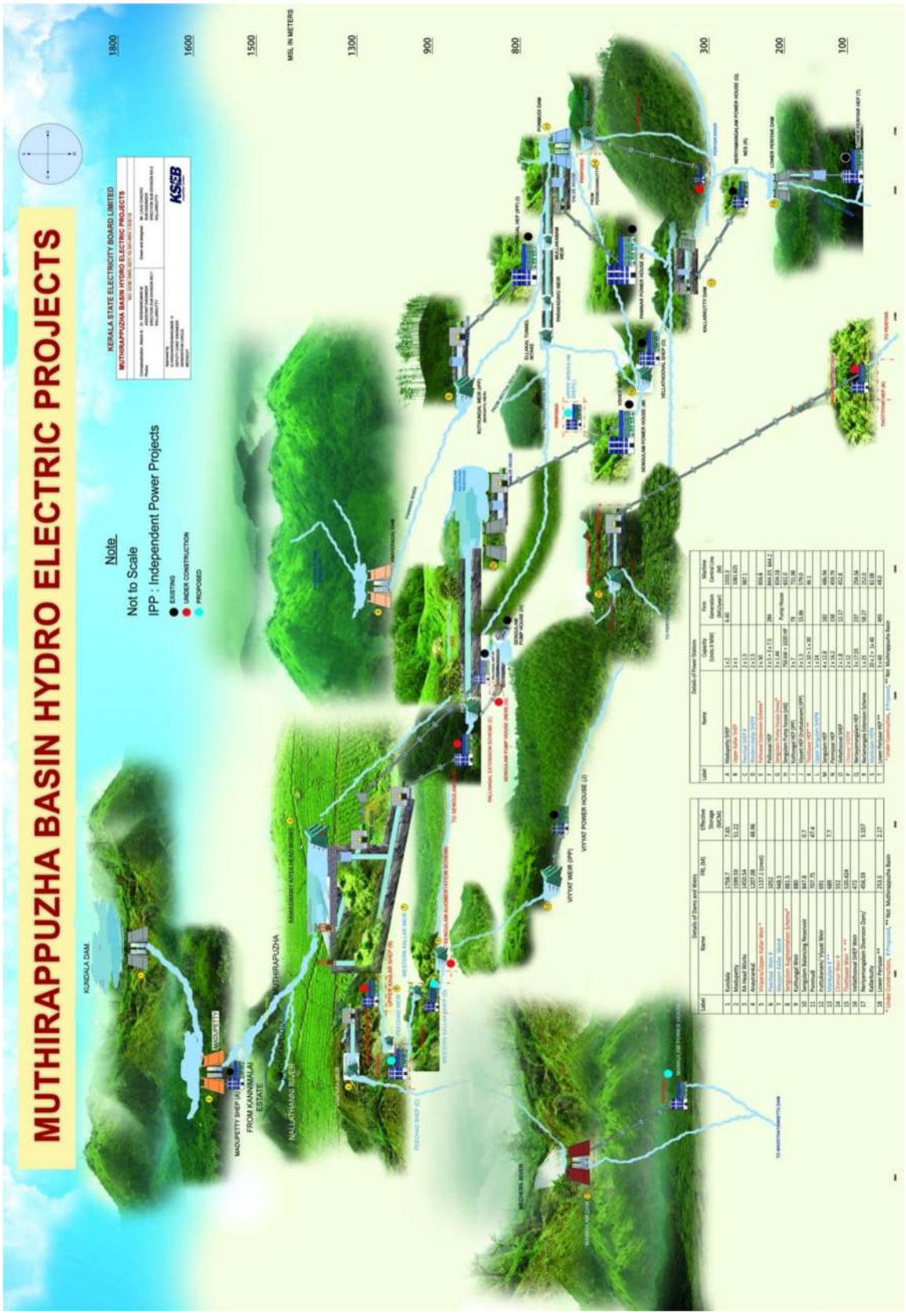

Fig 1.4 Schematic Diagram

PRINCIPAL FEATURES OF PALLIVASSAL HYDRO ELECTRIC PROJECT- RA HEADWORKS		
I	**MAIN WEIR**	
	Catchment Area	235 sq.km including CA for Kundala & Madupetty
	Live Storage	0.223 Mm^3
	Bed Level	1444.45m
	Sill level of Spillway	1444.75 m
	FRL	1450.54m (4759 ft.)
	MWL	1450.54m (4759 ft.)
	Deepest Foundation Level	1439.26m (4722 ft.)
	Water Spread area at MWL	0.01 sq.km
	Length of Dam	130 ft.(39.62m) between abutments
	Type of Dam	Gated Structure
	No of Gates	3 Nos
	Type of Gate	Vertical lift, Chain and Sprocket
	Size of Gate	11.60x5.79m(38' x 19')
	Spillway	Stilling Basin
	Flood discharge Capacity	1275 m^3/s
II	**Main Intake and Approach Channel**	
	Approach Channel length	499.85m(1640 ft.), Trapezoidal shape, base width 0.88m(2'9") and side slope 30^o
	Capacity	7.92 m^3/s (280 cusecs)
	Intake level	1447.95m (4750.5 ft.)
III	**Tunnel**	
	Length	3177.24m (10424 ft.)
	Shape & Size Unlined Portion	Horse Shoe 2.74x2.44m(9ft x 8ft)
	Shape & Size Lined Portion	Circular 2.44m dia(8ft)
	No. of ADITs	Three
	Invert level at inlet	1447.95m (4750.5ft)
	Invert level at exit	1438.47m
	Fall	"3:1000"
	Lining	30.48 cm tk. Cement concrete
	Maximum flow	7.93 m^3/s
	Velocity	1.83 m/s (6ft/sec)
IV	**Surge Shaft**	
	Sill Level	1439.04m
	Top of the Shaft	1452.30m
	Floor of Surge chamber at inspection Gallery	1452.50m
	Floor of inspection Gallery	1456.26m
	Height	13.26m
	Diameter	3.05m

V	**Valve House**	
	Dimensions	9.16×3.89× 3.65m
	Valves	Four Nos of Automatic Butterfly valves
VI	**Penstock**	
	No. of Line	Four
	Size	Three Nos of 76.2 cm dia and One No. of 106.68cm
	Flow	0.99m^3/s
	Total length	2327.14m(7635.33 ft.) & 7300ft
	Shell thickness varying from	8mm to 24mm
	No. of Anchors	18+ 1 above valve house
VII	**Power House**	
	RCC Structure	Size 49.07x11.58x 10.51m with concrete hollow block walling
	Generator floor level	2765ft
	Gross Head	1994ft
	No and capacity of generating set	3x5.55 KW and 3x9.33 KVA
	No and capacity of Turbine	3x4.535 KW and 3x7.95 BHP
	Generated Voltage	11 kv

Table 1.1 – Main Features of Pallivasal Hydro Electric Project

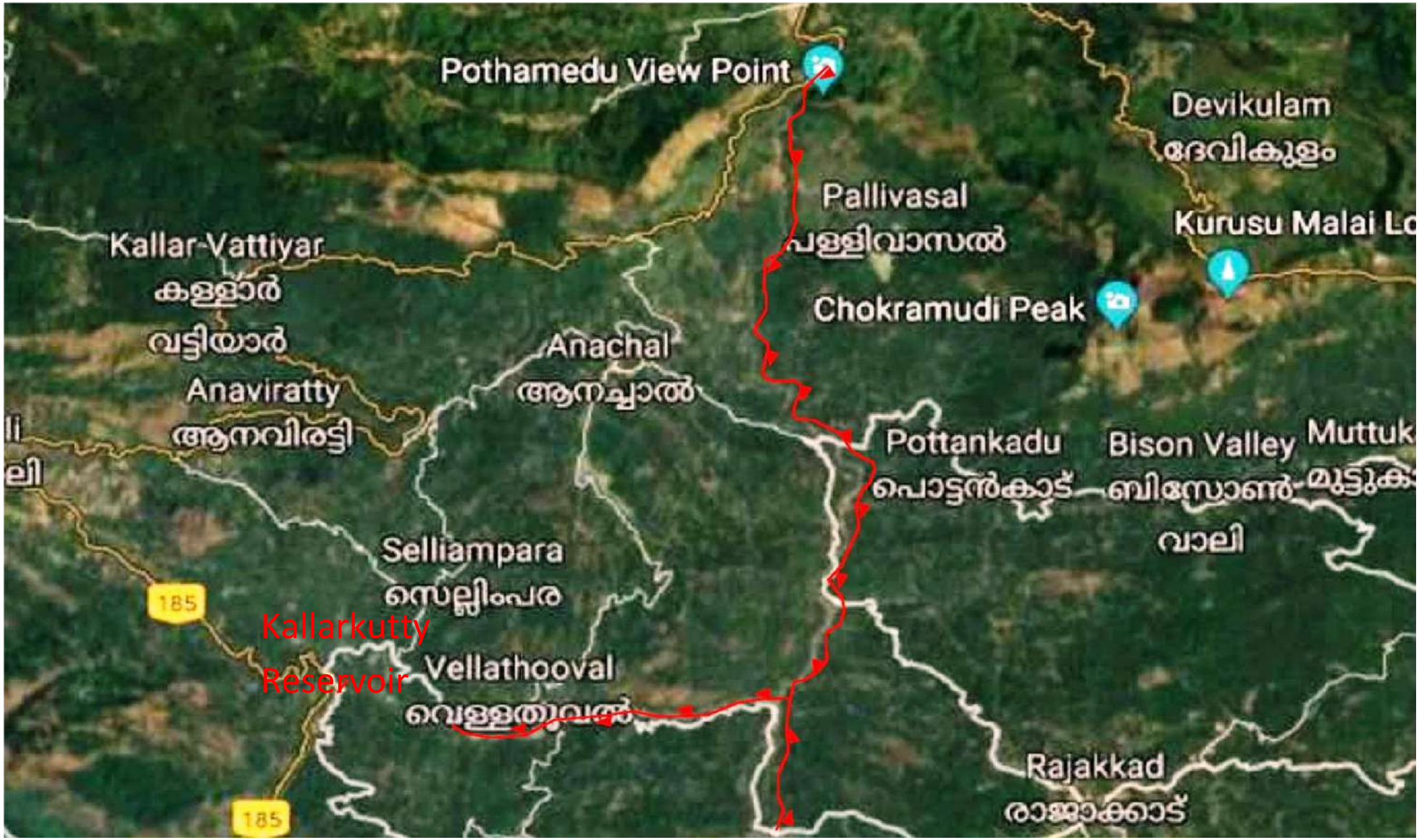

Fig 1.5 Spillway Water from RA Head Works – Flowing Route

Main Components of the Project

1.2.1 Reservoir

There are two dams and one diversion weir as part of this project. The upstream most dam is Kundala. The water stored in the reservoir is released through the stream to Maduppetty Dam located downstream. The water stored in the Maduppetty reservoir is released to downstream through a dam toe power house. The controlled release from Maduppetty Dam reaches the diversion weir (R.A. Head works) and from there, the water is diverted through water conducting system to the power house of Pallivasal HEP located on the right bank of Mudirapuzha river. After generating power, the tail water is pumped to the balancing reservoir of Sengulam Hydro Electric Project and the surplus water from the sump of pumping station is spilled to the Mudirapuzha River itself.

This RA Head Works diverts the regulated release from upstream storage reservoir Madupetty to the power house of Pallivasal Hydro Electric Project. The RA Head Works is a diversion weir having a pondage of 0.223 Million Cubic Meter. It is a gated structure with hydraulic head 5.17 m. There is no obstruction to the water way except the sill of height about 30 cm to rest the gate. The spillway is having three bays. The head works consists of a main weir, main intake and approach channel.

1.	Water Spread Area	0.01 sq. km
2.	Catchment Area	235 sq. km
3.	Maximum Annual Rainfall recorded	5778.5 mm
4.	Full Reservoir Level (FRL)	+1450.54 m above MSL
6.	Effective Storage at FRL	0.223 Mm^3
7.	Net head at power house	572.08 m

Table 1.2 – Hydrology Details of PHE Project

Fig 1.6 RA Head Woks and Reservoir - Google view

Fig 1.7 RA Head Woks Reservoir

1.2.2 Head Works

The head works consists of a diversion weir, an intake arrangement with trash rack in front of approach channel, Tunnel intake chamber with trash rack and control gate and Tunnel portal. Head works is designed as s spillway tank forebay.

Main Weir

The main weir consists of three "stoney" pattern sluice gates each 11.60 m wide and 5.79 m deep. The top 0.91 m of each gate being an automatic tilting flap provided to take charge of the rapid rises to which this river is subject, and prevent flooding of the recreation grounds upstream used by Messers Kannan Devan Hills Produce company as polo ground, cricket field etc. The gates were supplied by Messers Glenfield and Kennedy Ltd. The layout of the head works is given in **Annexure 1**. The weir is designed to pass 1275 m^3/s under flood conditions. The shutters are operated by electric motors mounted on an operating platform above. They can also be operated by hand at time of emergency. The weir is located 487.66 m downstream of the tunnel inlet chamber in a narrow gorge where the river runs out of the Munnar valley. The site on which the weir is built consists mainly boulders of varying sizes in mud on the left flank and an outcrop of sheet rock on the right. The sill level of the weir is at 1444.75 m, the upstream curtain wall being taken down to a maximum depth of RL 1444.75 m. Pressure grouting up to 7.02 kg/cm^2 pressure has been done down to RL 1433.1 m for this curtain wall and for 6.1m below for all foundations generally. The abutments and piers are of mass concrete and are ashlar faced. The left bank upstream river training wall is taken down sufficiently deep to act as a cut off wall, while the right bank wall of the main intake chamber nearest the river is also taken down to form a cut off wall. This cut off wall is extended towards the road way from the weir for a distance of approximately 18.29 m into sound ground. The right bank cut off wall is designed to relieve the intake chamber of excessive uplift under the floor when empty.

A low wall bout 24.38 m upstream of the sluice gates forms a sand trap and an ashlar paved apron is provided from this wall approximately 24.38 m downstream. The paving is 23 cm thick down to the piers, and 34.30 cm thick over the sill.

The Weir carries single line Road Bridge designed to Indian Standard loadings. There is a road on the left bank of the river.

The layout, plan and elevation of weir are appended in **Annexure 1, Drgs. 2, 4 and 5.**

Fig 1.8 RA Head Works - Google view

Fig 1.9 RA Head Works - Photograph

1.2.3 Water Conductor System

The water conductor system of the Pallivasal HEP consists of a main intake and approach near to RA Head works, a Tunnel from Intake to Surge Shaft, Surge, Valve House and Penstocks. These are described below.

1.2.3.1 Main intake and approach channel

The main intake and approach channel is situated upstream of the weir on the right bank almost at right angles to the weir. There are three sluice gates each giving a free opening of 3.04 x 2.13 m with a trash rack in front of each gate. The masonry work is similar to that of the main gate, being of mass concrete. The sill level of this intake is EL 1447.88 m and is the same as the sill level of the tunnel portal gate. The floor of the intake chamber is sloped towards the scour chamber. The intake chamber has been designed to withstand an uplift pressure of 25.29 kg/m^2 under the floor which is considered as the worst condition that can arise presuming the chamber to be empty and river in high flood. The chamber is built in reinforced concrete.

Fig 1.10 RA Head Works- Photographs of Main Intake and Approach Channel

The scour chamber is rectangular in cross section, which changes to trapezoidal cross sections for the approach channel proper. It is fitted with 0.91x1.22 m scour gate which discharges through a concrete duct through the abutment to a point below the weir. The sill level of the scour gate is EL 1445.60 m. No decantation chamber has been provided as the river base has not been founded to carry heavy silt or sand at the level of take-off i.e. EL 1447.88 m. The fine silt carried cannot be decanted by any known type of decantation chamber. It was anticipated that any fine silt suspended would settle along the approach channel, and this anticipation has proved correct.

The approach channel is 499.85 m long with an upgrade of 0.61 m from the end of the transition section to the scour chamber to the tunnel chamber. It is constructed with continuous RC floor 0.84 m wide and 20.32 cm thick and side slopes of about 30 degree to the horizontal. The sides are paved with concrete slabs 10.16 cm. 3.8 cm thick cast in position on the natural earth surface of the excavation, or on a layer of 3.8 cm metal with open joints between the slabs. The channel has been designed for a flow of 7.93 m^3/s with a draw down in water level of 1 in 40,000. The open joint method construction was adopted as the channel runs parallel with and close to the river. The water level in the channel can therefore never be higher than the water level of the river. But the worst condition will arise when the channel is empty say for de silting and to make it water tight would involve an unwarrantably heavy expenditure with no corresponding benefit, since during normal working there is no point in making the

channel water tight.

Three drainage flumes of RC construction cross the channel. Two of these are of 13.56 m clear span. The approach channel leads into the tunnel intake chamber with a suitable transition section. The tunnel intake chamber is rectangular in shape, 17.07 m long, 4.88 m wide and 3.89 m high from the floor to the top of the wall. Floor level is RL 1447.42 m. At the entrance to the channel to the tunnel chamber a pier 0.61 m thick and 3.66 m long has been constructed. There are grooves on either side of the pier, as well as on both walls of the tunnel chamber opposite.

A river training wall consisting of RC piles and slabs runs 54.86 m upstream from the intake. The river bank has been properly trained and amply protected with rip rap dumping and dry rubble waling at all weak points for a distance of about 0.8 km upstream of the main weir.

At the entrance to the tunnel from the tunnel inlet chamber, a sluice gate of clear opening 2.59 x 2.44 m channel take off and the one at the tunnel portal are operated by electric motors. Emergency hand operation with safety cut off electrical circuit when hand operating gear is used has also been provided.

Fig 1.11 Photograph of Tunnel Inlet

1.2.3.2 Tunnel

The Tunnel is designed to carry a maximum flow of 7.93 m^3/s at a velocity of 1.83 m/s. The total length is 3177.08 m of which 57.7 m at the entrance is cut and cover. The general shape of the unlined portion is horse shoe 2.74 x 2.44 m and lined portion is 2.44 m circular. At points where changes in section occur, splays have been formed to prevent turbulence. Tunnel driving was commenced from ADITS I, II and exit face. ADIT No. III was opened later to accelerate the progress. The cut and cover portion at entrance was also started simultaneously. The invert level of the tunnel portal is 1447.88 m and exit is 1438.47 m. The fall is 3:1000. The type of ground encountered in driving was granite gneiss, sound in the centre (i.e. only one fault from RD 1193.54 m to RS 1917.1 m) but shattered at each end (i.e. from RD 0 to RD 1193.54 m and RD 1917.10 m to exit) with exception of small reaches. Considerable loose ground bearing a large quantity of water was also encountered in the shattered portion. This made the driving very difficult in these portions, and resulted in the formation of two chimneys. Driving back from adit II to portal, very bad ground was encountered at RD 614.75 m together with heavy inflow of water necessitating a deviation of the tunnel at this point through sounder ground. This resulted in the 3 angles shown in the **Drg No. 3 in Annexure 1** between RD 85.64 m and RD 629.99 m. The bad portion was plugged and abandoned. Where the rock is shattered, the tunnel is lined with 30.48 cm thick concrete lining and pressure grouting to 7.02 kg/cm^2 has been done above the lining. For pressure grouting alone, 393 tons of cement was used. In portions where the ground was very poor, a reinforced gunite mantle was formed. This consists of 16 mm steel bars in the form of a spiral at 15 cm pitch with 15 cm longitudinal bars of 16 mm dia in 10.16 cm of gunite over 30.48 cm plain cement concrete lining. The 57.70 m cut and cover at the entrance is lined with 50 mm of reinforced gunite over 45.7 cm plain concrete. BRC fabric 15.24 cm x 15.24 cm x 4.76 mm is used for reinforcement in guniting.

The total length of plain concrete lined section is 1450.17 m and lined and reinforced gunite 213.35m. The unlined portions have been given 50 mm of plain gunite facing to fill up irregularities and prevent excess turbulence when water flows. Silt traps have been formed in the inverts of the tunnel at adits I&II, and 45 cm scour pipes have been provided through adit plugs. Sluice valves 45 cm size (hand operated) have also been provided at the outer end of the pipes for scouring purposes. These silt traps are of cement concrete 10.67 m long with a fall of 2.54 cm in the first 61 cm of length and then a fall of 2:100 to the bell mouth of the scour pipes.

1.2.3.3 Surge Shafts

The surge shaft is located at Ch. 2933.86 m in the tunnel. It is 13.26 m high from the invert of the tunnel to the floor of the surge chamber, and 3.04 m in diameter. The junction of the tunnel and the shaft is lined with 15 cm of reinforced gunite. 22 mm steel bars at 15 cm centers in two spiral rows, with 16 mm vertical distribution bars have been used as reinforcements. The layer of reinforced gunite is placed inside plain cement concrete 30.48 cm thick. The lining is carried to 5.94m height from the bottom of the shaft, 6.09 m along the tunnel towards portal end, and in to the tunnel exit plug on the downstream side. The surge chamber is 19.35 m long of horseshoe section, 4.27x4.57 m high, and lined with 30.48 cm thick cement concrete. The floor of the chamber has a slope of 1:100 from each end to the centre of the shaft. Connected to the same chamber is an inspection gallery which opens on to the hill side. It is of horseshoe section 2.13 x 2.44 m high and 25.14 m long. Access to the different chambers is by iron ladders. The different elevations are given below.

Bottom of Shaft	-	RL 1439.040
Top of Shaft	-	RL 1452.30
Floor of Surge chamber at Inspection gallery	-	RL 1452.50
Floor of Inspection gallery	-	RL 1456.26

This surge shaft is designed to take care of upward surges due to the rejection of full load capacity at the power house, and negative surges for the sudden increase in load from 75% to 100% of the full capacity i.e. a rejection of 240 cumec comparatively slowly due to the setting time for closing of turbine needles (2 min 45 seconds to 3 min) or a sudden increase in demand to mount a surge pipe on each of the penstocks immediately below the valve house to relieve the tunnel connecting pipe and the butterfly valves from excessive water hammer under worst conditions of operation. These have been installed under the second stage which is also nearly complete.

A 1.70 m internal diameter steel pipe connecting the tunnel to the pipe line commences immediately downstream of the surge shaft. The three adits and the tunnel exit have been plugged with cement concrete, each plug being poured in two sections from the outer ends. The first section of approximately one half of the plug was poured longitudinally, and 50 mm of gunite was shot on the face and on the perimeter for a distance of 61 cm. The second half of the plugs was then poured and gunited on the faces up and down stream inside the tunnel jointing the gunite previously applied. This method has proved very effective and no signs of leakage have appeared in service.

The tunnel pipe is 132.58 m long and has a vertical bend of 4°10'51" at 119.78 m from the surge shaft. Shell thickness is 8 mm. A special branch piece 8.20 m long made up in two sections, carrying four outlets to the main valve house is bolted to the main pipe at its out-let end. An anchor has been cast on the vertical bend and branch pieces above the valve house. The space between the 1.7 m diameter pipe and the tunnel has been filled with concrete, and mass concrete protection wall provided along the toe of the cutting at the tunnel exit to guard the pipe lines from any danger of falling rocks etc., from the hill side above this point.

1.2.3.4 Valve House

The valve house is a concrete structure with walls of hollow concrete blocks. The main dimensions are 9.30 m long top of the pipe track, 3.89 m wide, 3.66 m height from the floor to roof is a 12.5 cm thick RC slab. Entrance of the valve house is from the pipe track. The valve house accommodates two automatic butterfly valves, each set to trip on a pre-set flow of water through the pipe it controls. The valves can also be tripped electrically from the power house through a solenoid tripping mechanism on each valve operated by push buttons on the control desk. Automatic air valves are installed on each pipe immediately below the butterfly valves. Provision is made for four penstocks, three 762 mm dia. each and forth of the 1067 mm dia. For the first stage development, two penstocks alone were laid. The downstream flanges at the third and fourth penstocks were kept blanked off initially. Under the roof slab, a 3.2 m RS girder carries a 4 ton chain block and tackle for handling future extension pipes etc. The penstock No. 3 and 4 (one no 762mm dia. and one No. 1067mm dia. was erected later. These penstocks were also equipped with a bypass arrangement for air relief as shown in fig. below.

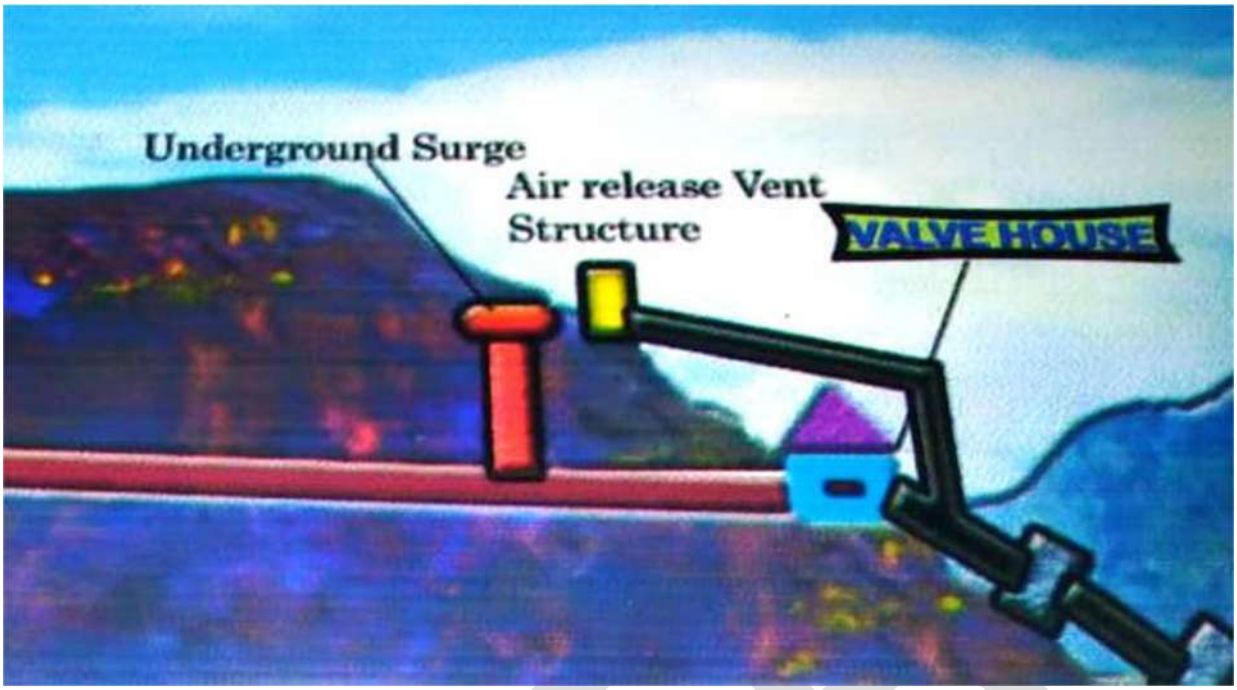

Fig 1.12 Air release arrangements for Penstocks 3 and 4

Fig 1.13 Penstocks, Valve House and Air Release Chamber of PHEP

1.2.3.5 Penstocks

Two penstock lines each 2327.12 m long were installed in the first stage. The pipes vary from 762 mm internal diameter at the top sections to 559 mm dia. at bottom. Details are given below.

505.91m	762mm internal dia	8 and 9.5mm	thickness
635.41m	711mm internal dia	11.5, 14.5 and 16mm	thickness
779.34m	660mm internal dia	16, 17.5 and 21 mm	thickness
261.07m	610mm internal dia	22.5 and 24 mm	thickness
145.39m	559mm internal dia	24 mm	thickness
Total 2327.12m			

These diameters were chosen mainly to facilitate nestling of pipes for shipment.

Excluding the top anchor above the valve house there are 16 main anchors on bends in the lines and two subsidiary anchors on long lengths of the straight sections. Between the valve house and anchor No. 12 lap welded pipes are used with riveted joints and below anchor No.12 to the power house the pipes are of cast steel with riveted joints. There is one pipe support below each individual pipe, between the joints and an expansion joint below each anchor. Each of these pipe lines is designed for a flow of 0.99 m^3/s with a loss of head of 31.27 m or 1.13 m^3/s with 40.38m loss of head. Below the last anchor there is 87.12 m of 559 mm diameter distribution pipes supplying water to the three machines in the power house through 457 mm dia. branch pipes. The pipes are interconnected through Y pieces so that No.1 pipe line, No.3 machine from No.2 pipe line and No.2 machine either from No.1 or No.2 pipe line. Two hand operated valves are installed one on the branch from No.1 pipe line and the other on the branch from No.2 pipe line to facilitate running No.2 machine from one or other of the penstocks. There is strict instruction to the operating staff to open the valve only after closing the other to prevent paralleling the pipe line at the bottom end since this is not advisable. The 1.12 m pipes leading in to the power house through ducts in the floor have each a hydraulically operated sluice valve control supply to each turbine. The closing times of these valves have been adjusted to suit the pipeline characteristics. The operation of these valves is controlled by a hand operated pilot valve on each main valve. The closing time of the valve as it is set is between 2 min and 3 minutes.

Drain sluices and drain pipes are provided at the power house end of each penstock. The drain pipes discharge through the turbine pit in to tailrace. These are to be used only for emptying the pipe line when it became necessary.

Each main valve has got a by- pass arrangement controlled by a hand operated valve to enable

pressure on both sides of main valves to be equalised before is closed. Instructions have been issued that when a main valve is closed under normal conditions, the bypass valve is to be closed only after the closure of the main valve and before main valve is opened, its bypass valve must be opened first and pressure equalised on both sides. The valves however according to the makers have been designed to be closed under full flow conditions.

1.2.4 Power House

The power house is located on the right bank of the Mudirapuzha River at RL 842.73 m floor level. It is a RCC frame structure with hollow concrete block walling between columns and beams.

The main hall housing the turbines and generators is 49.07 x 11.58 x 10.52 m to the bottom of the flat RC roof slab. An overhead electrically operated travelling crane of 30 tons capacity traverses the main hall longitudinally 6.86 m above floor level. A 7.62 m wide annex of the east side of the building extending for 34.59 m from the north end contains the battery room, oil filtering room, the house service transformer room and the 11 KV cellular switch gear on the ground floor and the main control plat form on the first floor. The annex is also RC frame construction continuous with the frame of the main hall with hollow concrete block walling. The ground floor of the annex is 3.20 m high to ceiling, and the first floor is 3.96m high to the underside of the flat RCC roof slab. A reinforced concrete double stair case gives access to the control platform from the main hall. The machines are all within the range of vision of the operator from the control floor.

The building is founded on sound rock. The frame columns being founded on individual footings benched into the rock. The beams connect the columns at ground level, at control floor level and at roof level. The control floor is carried on these tie beams and the roof on these and the main supporting beams across the main hall. All columns, beams and the roof and control room floor are RC construction. The control floor slab is 159 mm thick and the roof slab 114 mm.

Flooring inside the main hall and oil filtration room is of special marble mosaic tiles over a leveling course of concrete. Battery room has been provided with asphalt flooring to prevent damage due to acid fumes and any spilled acid. The other rooms on the ground floor are finished with special hand paving tiles. The walls of the main hall are finished with a height of 3 m with marble mosaic dado with a black border and above that polished chunnam plastering 3 coats. The interior of the battery and oil filtration rooms are tiled to 1.83 m height above floor. The battery room walls and ceiling are treated with special anti-sulphuric paint above the tiling. The underside of the roof slab and the beams are all finished with chunnam plastering. The exterior of the building is cement washed. The flat roof is given a good drainage slope and finished with paving tiles over asphalt to prevent dampness. Cement asbestos drain pipes are provided down the outside of the building.

The overhead travelling crane moves on rails fixed to RC girders on the main columns. The main hall has a main door 6.09 x 4.88 m at the southern end for taking in machinery. This door has hand operated rolling type shutter. There are two doors one on each side for use of the operating personnel.

Ducts have been provided below ground level for taking in cool air into the generator pit, and for releasing the hot air on the eastern side of the power house. Suitable cells have also been provided below ground level for housing protective current transformer and neutral earthing resistances. A pit 4.88 x 3.66 x 2.13 m has been provided in the power house to facilitate repair works to be done on the transformers.

TAILRACE: No. 3 machine discharges into an open channel running straight out to the river, while the tailrace of No.1 and 2 machines are cut and cover culverts of RCC box construction curving into the main tail race to permit a smooth outflow. A tank 4.57 x 3.66 x 2.13 m is constructed at the river bank close by for accommodating a water resistance for use in testing the machine. This water resistance tank is fed with water through a pipe controlled by a small sluice valve, taking its supply from the tail race. The river bank near tail race exit is amply protected against slips and erosion.

COOLING WATER: a cooling water tank for supply of cooling water to water cooled machine bearing is constructed at high level on the hill side north of the power house. This tank gets water from the nearby river by gravity flow through 75 mm main pipe.

Fig 1.14 Name plate of Turbine and Generator (Unit IV, V & VI)

Fig 1.15 Name plate of Turbine and Generator (Unit I, II& III)

Fig 1.16 Pallivasal Power House

1.3 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, KSEBLtd.
Authority of Spillway operations and Flood releases	Chief Engineer Generation, Moolamattom, KSEB Ltd
Operation and safety of the dam	Deputy Chief Engineer, Generation Circle, Meencut, KSEB Ltd.
Controlling / Operation Officer at dam site	Executive Engineer, Generation Division, Chithirapuram.
Reservoir operations, inspection & maintenance	Executive Engineer, Generation Division, Chithirapuram.
Dam Health Engineer	Executive Engineer, Generation Division, Chithirapuram
Recording reservoir data, inspection, monitoring and maintenance at site	Assistant Executive Engineer, Generation Sub Division, Chithirapuram
Handling Dam operations, inspection, monitoring and performing duties as Maintenance Officer at dam	Assistant Engineer, Generation Sub Division, Chithirapuram

Table 1.3 Details of Controlling Officers

1.3.1 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. Observe the gates and to see that floating debris is not deposited in the gate components.

9. Monitor the condition of the, 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.

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 and ensure that the dam top, 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 EE/ Dy CE /CE in case of any untoward incidents or malfunctioning of the gates of excessive seepages, leakages etc.

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

14. 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.

1.3.2 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. 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.

9. Observe the dam top, approach roads are well maintained by housekeeping personnel.

10. 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.

1.3.3 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 KSEBL regarding the power generation requirement.

1.4 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.
- Weather related data
- Water quality

MWL (m)	FRL (m)	Crest Level (m)	Present Water Level (m)	Previous Year Water Level (m)	Storage (Mm3)	Rainfall (mm)	Generation (Mu)	Spill (Mm^3)	Gate Operation Details

Table 1.4 Inflow and Outflow Report

Instruction is given to the Executive Engineer for daily collection and reporting of inflow and outflow data in a standard Proforma as in **Table 1.4** above to the Deputy Chief Engineer.

Date	Water Level (m)	Previous Year Same day Water Level (m)	Rainfall (mm)	Previous Year Rainfall (mm)	Storage (Mm^3)	Generation (Mu)	Gross Inflow (Mm^3)	PH discharge + Losses	Spill (Mm^3)	Net Inflow (Mm^3)	Remarks

Table 1.5 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 1.5**.

Records/Logbooks of the operations for the following activities at RA Head Works 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	This is collected daily
Reservoir inflow	This is calculated daily
Spillway outflow	This is calculated during spill
River releases	The tail water is released to Mudirapuzha
Weather related data	Collected and reported daily
Surveillance/Security arrangements	Provided at one security cabin at right bank of dam.
Water quality	The quality of water is to be tested every six months.
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 $1132 m^3/s$. The spillway is free overflow type. The sizes of gates are of 11.60 m x 5.79 m. The vertical lift gates of chain and sprocket arrangement is provided over the spillway.
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 i s available at Dam site.
Safety and special instructions	Safety equipment are available
Names and addresses of official visitors	Record of inspections maintained at office

1.5 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. KSEB Inspection Bungalow facilities are available at Munnar. The National Highway NH 89 Passes along the sides of RA Head Works. The RA Head Works is about three km from Munnar Town. Frequent bus services are available on day night basis in this route.

Distances to the nearest medical assistance is available at Munnar Town (3 km) and Adimaly (28 km). Police station is located at Munnar Town. Two nos. of main private hospitals with almost all medical facilities are also available at Kothamangalam which is around 80 km from Weir site. Safety equipment like safety shoe, helmet, safety belt, first aid kit and fire extinguisher are available at the dam site.

1.6 Restricted Areas

Certain areas of the Weir 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. Warning boards showing the restricted area are placed at the dam premises. Dam premises is protected with all around compound wall and gates and warning and information boards are also provided at various locations

1.6.1 Dam safety surveillance including instrumentation

Security arrangements are provided near dam at security check post at the dam top on left bank.

Security Arrangement Existing - 3 Shifts per day

1.7 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 RA Head Works is outlined below in **Fig 1.15.**

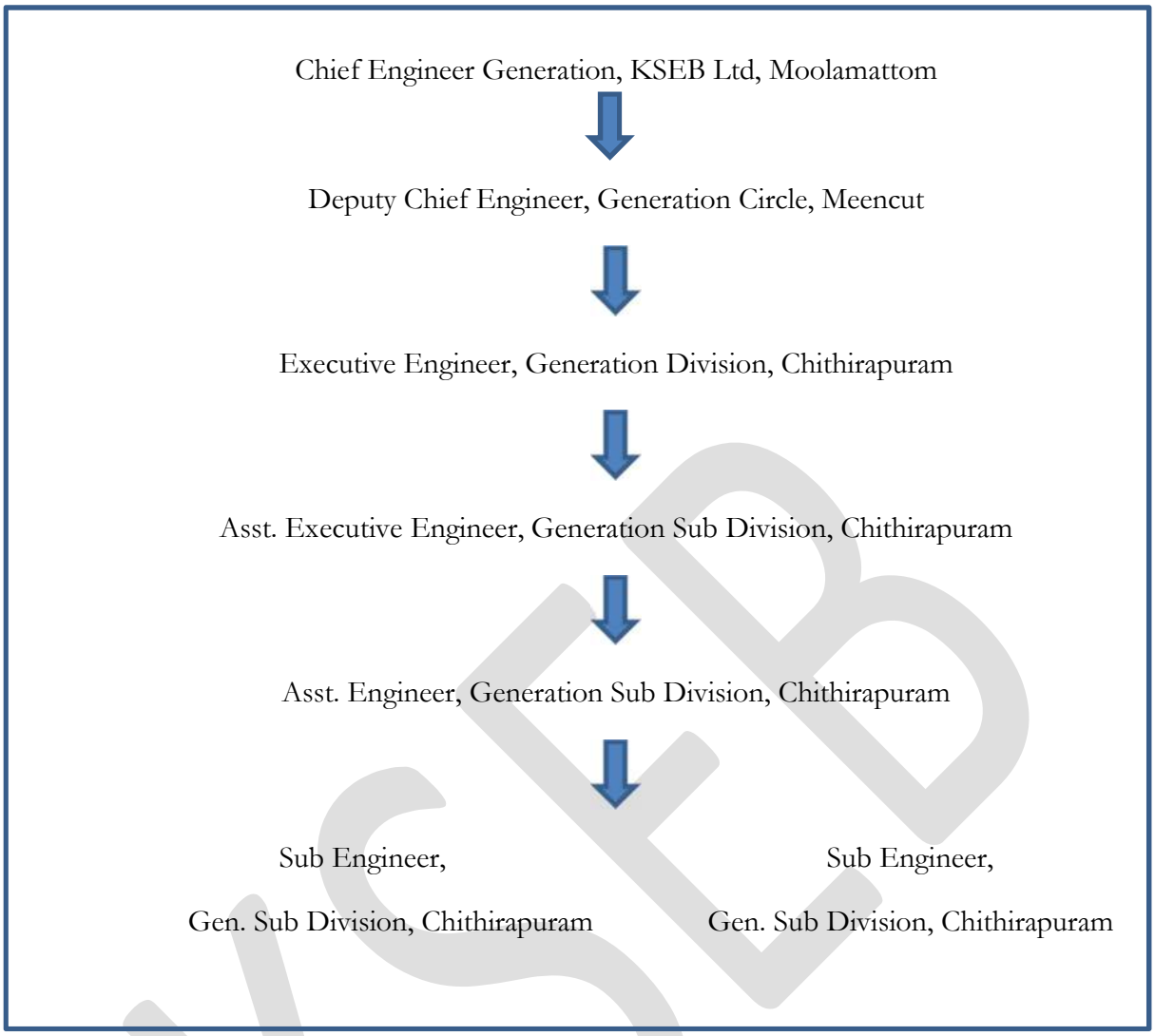

Fig. 1.17 Dam Safety Organisation Structure for RA Head Works

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

Designation and office address	Contact number and e-mail
Chief Engineer, Generation, KSEB Ltd, Moolamattom	Ph: 9446008203, 9496009370 0486 2252273 e-mail: cegenkseb@gmail.com
Deputy Chief Engineer, Generation Circle, Meencut	Ph: 9446008443, 9496009378 04865 263229 e-mail: dycegmct@gmail.com
Executive Engineer, Generation Division, Chithirapuram	Ph: 9446008445, 9496009379 04865 263226 e-mail: eegdchpmkseb@gmail.com
Assistant Executive Engineer, Generation Sub Division, Chithirapuram	Ph: 9446008449 e-mail: pvslhep@gmail.com
Assistant Engineer, Generation Sub Division, Chithirapuram	e-mail: pvslhep@gmail.com
RA Head Works	04865230344 9496009380

Table 1.6 Hierarchy of Controlling Officers

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

Spillway flood releases

RA Head Works is being operated as per 'Guidelines for Operation of Reservoirs' (IS 7323:1994). RA Head works is a gated diversion structure having a live storage capacity of 0.223Mm^3 and is not treated as a storage reservoir. Hence it is proposed to have a single stage/colour (Red) alert system. Red Alert is given for opening of spillway gates considering the inflow to the reservoir by closely monitoring the reservoir levels. Disaster Management, District Administration, Police Department etc. shall be informed prior to the operation of gates. Warnings shall be given to the people downstream through media, mike announcement, siren etc. regarding the opening of spillway gates to discharge excess water

in advance as per the guide lines issued by Disaster Management Authority. Also. Sanction shall be obtained from DDMA before opening the gates.

. The Weir is equipped with three nos. of Chain and sprocket type vertical lift gate of size 11.60 x 5.79 m. The spillage is released to Mudirapuzha River itself. The spill flowing route is shown in **Fig 1.5** given above.

The alert level is fixed considering the normal rainfall intensity and for general guidance. In the case of extreme rainfall event or identifying any distress, appropriate protective action shall be initiated by the managers of R A Head Works as per the Emergency action plan. Release from the head works will be contained in the river course in normal monsoon releases.

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

The tail race water from the Pallivasal Power House along with the spillover from RA Head Works and inflow from its own catchment between RA Head Works and Pallivasal Power House seems the main source of water to the Sengulam Hydro Electric Project.

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, Intake gate, outlet gates (Sluice). Details are given under the Chapter Project Maintenance.

1.8 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
- Power station operation plan
- Administrative procedures
- Maintenance schedules
- Regional communication directory

1.9 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 1.7.**

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, Spillway and its energy dissipation arrangements, Power 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 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, Spillway and its energy dissipation arrangements, Power Intake	Weekly	Assistant Engineer
7	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements, Power Intake	Fort nightly	Assistant Executive Engineer
8	Check security and safety devices, logbook and site register which include the above information.	Fort nightly	Assistant Executive Engineer
9	Measuring devices, communication devices, vegetation growth	Fort nightly	Assistant Executive Engineer
10	Check Sign/Warning display boards near vulnerable locations	Fort nightly	Assistant Executive Engineer
11	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements, Power Intake	Monthly	Executive Engineer
12	Check measuring devices, Security and safety devices, Communication Devices, Status of Vegetation growth, – rectification, if needed.	Monthly	Executive Engineer
13	Check Sign/Warning display boards near vulnerable locations	Monthly	Executive Engineer
14	Replace fuse light bulbs, Inspect to maintain ventilation system, cleaning of control panel boards.	Monthly	Assistant Engineer
15	Check outlet works, updating operating instruction, check gate air vents, gate control switchboxes, check operation of gates, grease gate hanger/dogging	Quarterly	Executive Engineer
16	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

17	Check condition of spillway, Check for debris in inlet channel, Check operation of gates, Check for damages in spillway glacis, energy dissipation arrangement, d/s area etc., Check spillway bridge drains, inside of motor control cabinet.	Quarterly	Executive Engineer
18	Record pertinent information in Operation of Gates, Check hydro mechanical components.	Quarterly	Executive Engineer
19	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
20	Submission of Inspection report to State DSO, CWC and uploading into DHARMA.	Half yearly	Chief Engineer/ Deputy Chief Engineer
21	Comprehensive inspections	Annually	Dam Safety Authority along with Dam Owners
22	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
23	Comprehensive inspection of performance of the dam and gate structures and reservoirs, trash racks and stilling basin /energy dissipation arrangement.	Ten Yearly	DSRP

Table 1.7 Schedule of duties/inspections

1.10 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.

Chapter 2

Project Operation

The operation of a weir 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 RA Head Works 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.

2.1.1 Diversion Weir

This is a barrage like structure with gate arrangements with small pondage which diverts water to the tunnel of Pallivasal Hydro Electric Project. The weir is located 487.66 m downstream of the tunnel inlet chamber in a narrow gorge where the river runs out of the Munnar valley.

The weir consists of three "stoney" pattern sluice gates each 11.60 m wide and 5.79 m deep. The water is impounded by the gates. The sill level of the gate is almost at the bed level of the stream. The weir is anticipated to pass 1275 cumec.

The Weir carries single line Road Bridge designed to Indian Standard loadings. There is an existing track on the left bank of the river leading to extensive cardamom plantations to the east of Munnar. This road will be useful when communications to this cardamom area are improved.

2.1.2 Spillway

Spillway is free overflow type with 3 bays. Three "stoney" pattern sluice gates each 11.60 m wide and 5.79 m deep are installed. The top 91 cm of each gate being an automatic tilting flap provided to take charge of the rapid rises to which this river is subject, and prevent flooding. The gates were supplied by Messers Greenfield and Kennedy Ltd. Chain and sprocket type gate hoisting arrangement is provided. The gates are operated by electric motors mounted on an operating platform above. They can also be operated by hand at time of emergency.

Crest level of spillway is +1444.75 m. The Spillway is designed for a maximum discharge of 1275 cumecs. Dissipation of energy of the water falling from spillway is effected by providing hydraulic jump type stilling basin.

Fig 2.1 Spillway Arrangements at RA Head Works

Fig 2.2 Spillway Arrangements at RA Head Works – View from Downstream

2.1.3 River Outlet arrangements

The scour chamber provided is rectangular in cross section, which changes to trapezoidal cross sections for the approach channel proper. It is fitted with 0.91x1.22 m scour gate which discharges through a concrete duct through the abutment to a point below the weir. The sill level of the scour gate is Rl 1445.60 m. No decantation chamber has been provided as the river base has not been founded to carry heavy silt or sand at the level of take-off i.e. RL 1447.88 m. The fine silt carried cannot be decanted by any known type of decantation chamber. It was anticipated that any fine silt suspended would settle along the approach channel, and this anticipation has proved correct.

2.1.4 Elevation Capacity Curve

The area and capacity curve of RA Head Works Reservoir has not much significance because the storage in this reservoir is only about 0.223 Mm^3 and is only a spillway tank forebay.

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 15-17, August 2018 near to RA Head Works was 640.90 mm. The 4 –day rainfall of 15-18, August 2018 near to RA Head Works site was 746.10 mm.

2.3 Normal operation of the Reservoir

2.3.1 Design Flood and Features Related to Safety

This RA Head Works diverts the regulated release from upstream storage reservoir Madupetty to the power house of Pallivasal Hydro Electric Project. The RA Head Works is diversion weir has a pondage of 0.223 Million Cubic Meter. It is a gated structure with hydraulic head 5.17 m. Hence the design flood is the one result from the storm with 100 year return period. The revised design flood of the diversion weir, RA Head Works (Pallivasal HEP) is estimated as per FER 5 (a) & (b) published by Central Water Commission and IS - 11223. The revised design flood is estimated as 1301 m3/s. The revised design flood has been reviewed and approved by the State Level Committee with Members Sri. M. K. Parameswaran Nair, (Member (Retd.), KSEB), Dr. Komalavalli (Chief Engineer (Retd.), Sate Water Resource Department), Director, KSEB Ltd. (Generation – Civil), Chief Engineer (Dam Safety, KSEB Limited) and Chief Engineer (Civil – Construction & Design, South, KSEB Limited).

The original design flood of R A Head Works was 1275m^3/s. The revised design flood is increased by a small margin of 2 %. About 35 m^3/s of water is diverted to the power station and net flow over the weir will be less than 1275 m3/s. Hence no improvement is required for RA Head Works in view of the revised design flood.

2.3.2 Hoisting Arrangements for Vertical lift Spillway Gates

The main weir consists of three "stoney" pattern sluice gates each 11.60 m wide and 5.79 m deep. The top 0.91 m of each gate being an automatic tilting flap provided to take charge of the rapid rises to which this river is subject. The gates were supplied by Messers Greenfield and Kennedy Ltd. Chain and sprocket type gate hoisting arrangement is provided. The gates are operated by electric motors mounted on an operating platform above. They can also be operated by hand at time of emergency.

Fig 2.3 Hoisting Arrangements of main shutter at RA Head Works

Fig 2.4 Hoisting Arrangements of Main Gate

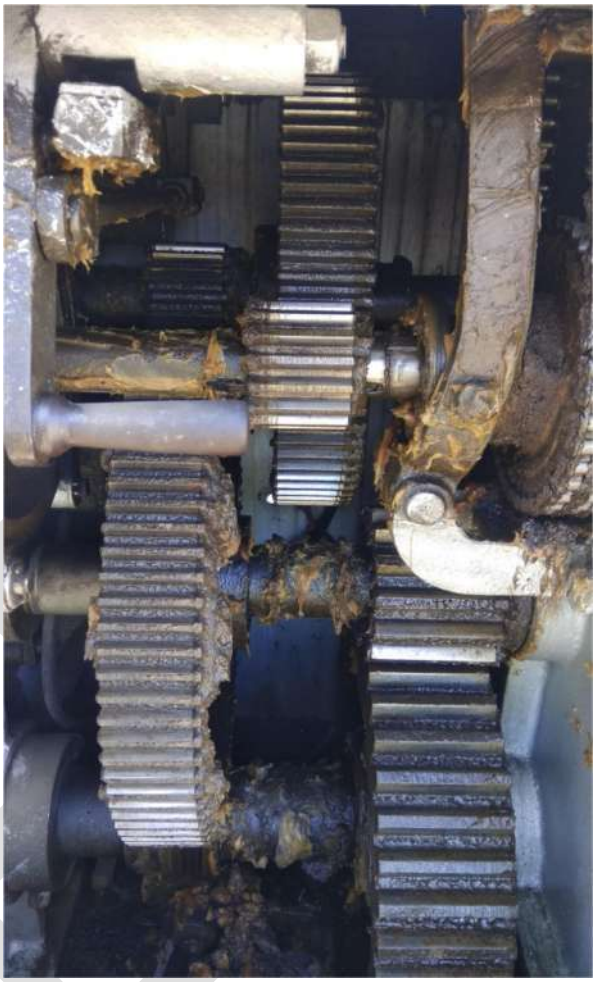

Fig 2.5 Central Gear Assembly

Fig 2.6 Central Control unit

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.
- General instructions for the safe operation of the dam and appurtenances.
- 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.

2.3.3 River Outlets (Sluice Vents)

The scour chamber is rectangular in cross section, which changes to trapezoidal cross sections for the approach channel proper. It is fitted with 0.91x1.22 m scour gate which discharges through a concrete duct through the abutment to a point below the weir. The sill level of the scour gate is RL 1445.60 m. No decantation chamber has been provided as the river base has not been founded to carry heavy silt or sand at the level of take-off i.e. RL 1447.88 m. The fine silt carried cannot be decanted by any known type of decantation chamber. It was anticipated that any fine silt suspended would settle along the approach channel, and this anticipation has proved correct. The gate provided for scour chamber can be operated manually.

Fig 2.7 Sluice Gate Operating arrangements

Fig 2.8 Sluice Inspection Chamber

2.3.4 Power Outlet

The main intake and approach channel is situated upstream of the weir on the right bank almost at right angles to the weir. There are three sluice gates each giving a free opening of 3.04m, 2.13m with a trash rack in front of each gate. The masonry work is similar to that of the main gate, being of mass concrete. The sill level of this intake is RL 1447.88m and is the same as the sill level of the tunnel portal gate. The floor of the intake chamber is sloped towards the scour chamber. The intake chamber has been designed to withstand an uplift pressure of 25.26kg/m^2 under the floor which is considered as the worst condition that can arise presuming the chamber to be empty and river in high flood. The chamber is built

in reinforced concrete. The gates are both operated electrically or manually.

Fig 2.9 Main Intake Arrangements

Fig 2.10 Main Intake Operating Arrangements

Fig 2.11 Main Intake – Hand Operating Arrangements

The approach channel is 499.85 m long with an upgrade of 0.61 m from the end of the transition section the scour chamber to the tunnel chamber. It is constructed with continuous RC floor 0.84 m wide 20.32cm thick, and side slopes of about 30 degree to the horizontal. The sides are paved with concrete slabs 10.16cm thick cast in position on the natural earth surface of the excavation, or on a layer of 1.5 inch metal with open joints between the slabs. The channel has been designed for a flow of 7.93m^3/s with a draw down in water level of 1 in 40,000. The open joint method construction was adopted as the channel runs parallel with and close to the river. The water level in the channel can therefore never be higher than the water level of the river. But the worst condition will arise when the channel is empty say for de silting and to make it water tight would involve an unwarrantably heavy expenditure with no corresponding benefit, since during normal working there is no point in making the channel water tight.

Three drainage flumes of RC construction cross the channel. Two of these are 13.56 m clear span. The approach channel leads into the tunnel intake chamber with a suitable transition section. The tunnel intake chamber is rectangle in shape 17.07 long 4.8 m wide and 3.89 m high from the floor to the top of the wall. Floor level is RL 1447.42 m. At the entrance to the channel to the tunnel chamber a pier 50 mm thick and 3.66 m long has been constructed. There are grooves on either side of the pier, as well as on both walls of the tunnel chamber opposite.

At the entrance to the tunnel from the tunnel inlet chamber, a sluice gate of clear opening 2.59x2.44 m channel take off and the one at the tunnel portal are operated by electric motors. Emergency hand operation with safety cut off electrical circuit when hand operating gear is used has also been provided.

Fig 2.12 Tunnel Inlet

Fig 2.13 Tunnel Inlet – Operating Switches

Fig 2.14 Tunnel Inlet – Hand Operating Arrangements

2.3.5 Operation of the Reservoir

The RA Head Works reservoir was being operated as per 'Guidelines for Operation of Storage Reservoirs (IS 7323:1994). The RA head works reservoir is not a storage reservoir. It is only a diversion structure to divert water released from Madupetty reservoir to the Tunnel mouth of Pallivasal HEP and hence no rule curve was prepared for this. In flood condition, the water can be spilled with necessary precautions and after giving vide publicity viz mike announcement, TV, Radio, local channels if any etc. Also informed local authorities like concerned villages, panchayats, police station, district disaster management authority etc.

Fig 2.15 Reservoir Reading Scale

2.3.6 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 RA Head Works reservoir is only $0.223 Mm^3$ and hence, the rule curve is not prepared. Water from RA Head Works is used for generating electricity at power house located at Pallivasal and the tail race water is pumped to a short height of 9.14 m so as to reach the tunnel mouth of Sengulam HEP.

2.3.7 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 three spillway gates in RA Head Works. The sequence of operation of spillway gates is Gate No. 2, 1 & 3. Gate No.2 is to be opened first to a unit height on the basis of requirement. Then Gate No. 1 & 3 are operated to the same height as that of Gate No. 2. Further increase in openings is also performed in this manner.

Discharge through RA Head work for different gate openings		
FRL	4759 ft.	1450.54 m
Sill level of gate	4740 ft.	1444.75 m
Opening size m.	**Discharge through one gate cumecs**	
0.30	26	
0.60	51	
0.90	75	
1.20	98	
1.50	121	
1.80	143	
2.10	164	
2.40	184	
2.70	204	
3.00	222	
3.30	240	
3.60	256	
3.90	272	
4.20	286	
4.50	299	
4.80	311	
5.10	320	
5.40	328	
5.79	334	
6.00	360	
6.30	387	
6.70	425	

Table 2.1 Discharge through RA Head Works for different gate opening

2.3.8 Reservoir Capacities

The Gross storage and live storage of the reservoir 0.223 Mm^3 and the MWL/ FRL is +1450.54 m

2.3.9 Climate

RA Head Works and its allied catchment receive 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 maximum one day rainfall reported is 36 cm. The maximum design flood as per the revised hydrology studies is 1301 m^3/s.

2.3.10 Inflow forecasting/Methodology

There is no inflow forecasting system at present in RA Head Works.

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 RA Head Works for a rate of rise in reservoir level. 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.

2.3.11 Emergency Operation

The purpose of Emergency Action Plan is to identify emergency situations that could threaten RA head works and to plan for an expedited, effective response to prevent failure of the dam and warn downstream residents of impending danger. This plan defines the notification procedures to be followed in the event of a potentially hazardous situation. The procedures are intended to protect lives and prevent property damage from and excessive release of water from the spillways or an uncontrolled outflow of water from the breached portion of dam.

Dam owner's responsibilities before and during an Emergency event, Dam Engineers Preparedness& Responsibilities, Responsibilities for Notification, Responsibilities for Evacuation, Responsibilities for Termination and Follow-Up, Communication Networks, Emergency Detection, Evaluation and Classification, Preparedness, Remedial Actions, Emergency Operations Centre, Inundation Areas, Local Evacuation Plan, Implementation, Vicinity Map Inundation cum Evacuation

Maps etc. are provided in the detailed EAP document of RA head works. Summary of Alert Conditions during Emergency are given in **Annexure V**.

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.

2.4 Power Generation

The Power House for Pallivasal Hydro Electric Project is located at Pallivasal in Pallivasal village, Pallivasal Panchayath in Devikulam Taluk in Idukki District around 25 Km from Adimaly. The Power Station was commissioned during 1947 with total Six Generating units having a total capacity of 44640 KVA. Renovation and modernization was done by M/s SNC Lavlin. After power generation, the tail race water is pumped a short distance to fed the Sengulam balancing reservoir.

2.4.1 Trash-rack structure

The main intake and approach channel is situated upstream of the weir on the right bank almost at right angles to the weir. There are three sluice gates each giving a free opening of 3.04x2.13m with a trash rack in front of each gate.

2.4.2 Intake structure

The main intake and approach channel is situated upstream of the weir on the right bank almost at right angles to the weir. There are three sluice gates each giving a free opening of 3.04x2.13m with a trash rack in front of each gate. The gates are operated both electrically and manually on the time of commissioning.

Fig 2.16 Intake Bridge and Hoisting Arrangements

At the entrance to the tunnel from the tunnel inlet chamber, a sluice gate of clear opening 2.59x2.44 m channel take off and the one at the tunnel portal are operated by electric motors. Emergency hand operation with safety cut off electrical circuit when hand operating gear is used has also been provided.

2.4.3 Initial Filling of Reservoir

The initial filling of the reservoir was carried out during 1944.

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.
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 RA Head Works 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. 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, CWC2018 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 RA Head Works 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 RA Head Works. 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 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 RA Head Works 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, past 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.

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 pages B3-B45.

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, and
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 RA Head Works 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.

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 RA Head Works is attached as **Annexure III**. 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 Weir is about to be overtopped or being overtopped during high flood.
- The Weir showing signs of piping or internal erosion along faults, weak zone etc. indicated by increasingly cloudy seepage or other symptoms.
- The Weir showing signs of failure due to aging/cracking, sliding, overturning etc.
- The spillway being blocked or with some inoperable gates.
- Evidence of excessive seepage.

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.
- 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 eg. Servicing of spillway gates, hoisting arrangements, and gates/hoist of outlet works/sluices & stand by generator.
- Maintaining proper lighting at dam top etc.
- 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
- 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 addressed 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 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 that the dam is behaving as designed.
- 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 – Vertical lift gates

Vertical lift gates are provided at the spillway, intake to access channel, Intake of tunnel and scour vent of RA Head Works for controlling the flow. The aspects to be inspected and maintained periodically for ensuring proper operation of these gates are as under;

i) 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.

ii) 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.

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

iv) 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.

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

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

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

viii) Roller assembly should be adjusted by the eccentricity arrangement to ensure all rollers rest

uniformly on the track plates particularly in the closed position of the gate.

ix) 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 without delay.

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

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

xii) All nuts and bolts shall be tightened.

4.3.5 Trash Racks

Trash racks at intakes that have become clogged with debris or trash reduce 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 ensure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

4.3.6 Maintenance of Electrically operated fixed hoists

General Instructions:

a) Operation of fixed hoist without lifting the gate is not possible and need not therefore be attempted. It will be possible to operate the unit and observe operation of load carrying hoist component when gate is being lifted or lowered.

b) 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.

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. Chains shall be checked for wear and tear and shall be replaced if any damage is noticed.

xvii. All chains shall be greased

xviii. Check the overload relays for proper functioning.

xix. 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.

xx. 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.

xxi. Adjust the tension of chain if unequal.

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

requirement.

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

4.3.7 Maintenance of Electrical components of Fixed 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

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.

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

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.

4.3.8 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.

4.3.9 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.

4.3.10 General Cleaning

For proper operation of spillways, 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 top road is 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 RA Head Works, round the clock patrol is to be carried out during monsoon period. At the same time the manpower requirements during monsoon period are to be enhanced. 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 RA Head Works 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)

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

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

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

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

vii) **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.

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	MOTOR VEHICLE EXPENSES			
5	MAINTENANCE OF OFFICE & COLONY COMPLEX			
	SUB-TOTAL - A			
B. WORKS				

1	**CIVIL**			
1.1	CONCRETE / MASONRY DAM			
1.2	EARTHEN DAM			
1.3	INTAKE / OUTLETS IN EARTHEN DAMS			
1.4	SLUICES IN CONCRETE / MASONRY DAMS			
1.5	APPROACH / INSPECTION ROADS WITHIN DAM AREA			
2	**HYDRO-MECHANICAL**			
2.1	SPILLWAY GATES & HOISTS			
2.2	SPILLWAY STOP-LOG & GANTRY CRANE			
2.3	OUTLETS IN EARTHEN DAMS - SERVICE / EMERGENCY GATES & HOISTS			
2.4	SLUICES IN CONCRETE / MASONRY DAMS – SERVICE / EMERGENCY GATES & HOISTS			
3	**ELECTRICAL**			
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/CCTV			
4	**INSTRUMENTATION**			
5	**MISCELLANEOUS WORKS**			
6	**SALARY OF WORK- CHARGED STAFF INCLUDING ALL BENEFITS**			
7	**MATERIALS TO BE STORED BEFORE MONSOON**			
	SUB-TOTAL - B			
8	**CONTINGENCY (10%) ON SUB-TOTAL OF A & B**			
9	**TOOLS & PLANTS**			
	SUB-TOTAL- C			
10	**TOTAL ANNUAL COST**			

Table 4.1 O&M Budget Costs (Annual)

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

5.1 Instrument Types and Usage

Since RA Head Works is only a gated diversion structure, the weir is not instrumented at all.

5.2 Parameters monitored

5.2.1 Water Level

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

5.2.2 Seepage Flow

Not measured.

5.2.3 Seepage assessment

Not done.

5.2.4 Seismic Activity

The project area falls in zone no III of the seismic zone map of India. 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: 5.0 and

Event 2: Date: 1/07/20011, Epicenter: Erattupetta, Magnitude: 4 . 8

There is no Seismic observatory o r accelerographs installed at RA Head Works.

5.2.5 Weather Conditions

The rainfall data are measured with rain gauges.

5.3 Frequency of Monitoring

Water levels are monitored daily.

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.

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.

5.5.2 Monitoring Results

Analysis and observation of the water level, leakages, 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.

Chapter 6

Previous Rehabilitation Efforts

6.1 Issues with the dam

The Head Works is functioning well and no major rehabilitation works proposed.

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.

Annexure VII

Glossary

Abutment - that part of a valley side against which a dam is constructed. Right and left abutments are those on respective sides of the observer looking downstream.

Air Vent Pipe - a pipe designed to provide air to the outlet conduit to reduce turbulence during release of water and safeguard against damages due to cavitation.

Appurtenant Structures - ancillary features of a dam, such as the outlet, spillway, energy dissipation arrangement powerhouse, tunnels, etc.

Arch Dam - a concrete or masonry dam that is curved to transmit the major part of the water pressure to the abutments.

Auxiliary Spillway (Emergency Spillway) - a secondary spillway designed to operate only during exceptionally large floods.

Base Width (Base Thickness) - the maximum width or thickness of a dam measured horizontally between upstream and down-stream faces and normal (perpendicular) to the axis of the dam but excluding projections for outlets, etc.

Berm - a horizontal step or bench in the sloping profile of an embankment dam.

Buttress dam - a dam consisting of a watertight upstream face supported at intervals on the downstream side by a series of but-tresses.

Cofferdam - a temporary structure enclosing all or part of a construction area so that construction can proceed in a dry area.

Concrete Lift - in concrete works the vertical distance between successive horizontal construction joints.

Conduit Outlet Works - a closed conduit for conveying discharge through or under a dam for different project purposes.

Consolidation Grouting (Blanket Grouting)- the injection of grout to consolidate a layer of the foundation, resulting in greater im permeability, strength, or both.

Construction Joint - the interface between two successive placing or pours of concrete where a bond, not permanent separation, is intended.

Core Wall - a wall built of impervious material, usually concrete or asphaltic concrete, in the body of an embankment dam to prevent leakage.

Crest gate (spillway gate) - a gate on the crest of a spillway to control overflow or reservoir water level.

Crest Length - the length of the dam at its crest (dam top) top of a dam, including the length of the spillway, powerhouse, navigation lock, fish pass, etc., where these structures form part of the length of a dam. If detached from a dam, these structures should not be included.

Crest of dam - Used to indicate the "top of dam". To avoid confusion to indicate the crest of spillway and top of dam may be used.

Culvert - a drain or waterway built under a road, railway, or embankment, usually consisting of a pipe or covered conduits.

Cut off - an impervious construction or material which reduces seepage through the foundation material.

Cut off trench - an excavation later to be filled with impervious material to form a cut off.

Cut off wall - a wall of impervious material (e.g., concrete, asphaltic concrete, steel-sheet piling) built into the foundation to reduce seepage under the dam.

Dam - any artificial barrier including appurtenant works constructed across rivers or tributaries thereof with a view to impound or divert water; includes barrage, weir and similar water impounding structures but does not include water conveyance structures such as canal, aqueduct and navigation channel and flow regulation structures such as flood embankments, dikes, and guide bunds.

Dam failure - failures in the structures or operation of a dam which may lead to the uncontrolled release of impounded water resulting in downstream flooding affecting the life and property of the people.

Dam incident - all problems occurring to a dam that has not degraded into „dam failure" and including the following: a) Structural damage to the dam and appurtenant works; b) Unusual readings of instruments in the dam; c) Unusual seepage or leakage through the dam body; d) Change in the seepage or leakage regime; e) Boiling or artesian conditions noticed below an earth dam; f) Stoppage or reduction in seepage or leakage from the foundation or body of
The dam into any of the galleries, for dams with such galleries; g) Malfunctioning or inappropriate operation of gates;
h) Occurrence of any flood, the peak of which exceeds the available flood discharge capacity or 70% of the approved design flood; i) Occurrence of a flood, which resulted in encroachment on the available free-board, or the adopted design freeboard; j) Erosion in the near vicinity, up to five hundred meters, downstream of the spillway, waste weir, etc.; and k) Any other event that prudence suggests would have a significant unfavourable impact on dam safety.
Dam inspection - on-site visual examination of all components of dam and its appurtenances by one or more persons trained in this respect and includes investigation of the non-overflow portion, spillways, abutments, stilling basin, piers, bridge, down-stream toe, drainage galleries, operation of mechanical systems (including gates and its components, drive units, cranes), interior of outlet conduits, instrumentation records, and record-keeping arrangements.
Dam owner - the Central Government or a State Government or public sector undertaking or local authority or company and any or all of such persons or organizations, who own, control, operate or maintain a specified dam.

Dam safety - the practice of ensuring the integrity and viability of dams such that they do not present unacceptable risks to the public, property, and the environment. It requires the collective application of engineering principles and experience, and a philosophy of risk management that recognizes that a dam is a structure whose safe function is not explicitly determined by its original design and construction. It also includes all actions taken to identify or predict deficiencies and consequences related to failure, and to document, publicize, and reduce, eliminate, or remediate to the extent reasonably possible, any unacceptable risks.

Dead storage - the storage that lies below the invert of the lowest outlet and that, therefore, cannot be withdrawn from the reservoir.

Decommission - Taking a dam out of service in an environmentally sound and safe manner or converting it to another purpose.

Design flood - see spillway design flood.

Design life - the intended period that the dam will function successfully with only routine maintenance; determined during design phase.

Distress condition - the occurrence or potential development of such conditions in the dam or appurtenance or its reservoir or reservoir rim, which if left unattended to, may impede the safe operation of dam for its intended benefits or may pose unacceptable risks to the life and property of people downstream.

Diversion channel, canal, or tunnel - a waterway used to divert water from its natural course. These terms are generally applied to temporary structures such as those de-signed to bypass water around a dam site during construction. "Channel" is normally used

instead of "canal" when the waterway is short. Occasionally these terms are applied to permanent structures.

Documentation - all permanent records concerning investigation, design, construction, operation, performance, maintenance and safety of dams and includes design memorandum, construction drawings, geological reports, reports of specialized studies simulating structural and hydraulic response of the dam, changes made in design and drawings, quality control records, emergency action plan, operation and maintenance manual, instrumentation readings, inspection and testing reports, operational reports, and dam safety review reports.

Drainage area - an area that drains naturally to a point on a river.

Drainage layer or blanket - a layer of permeable material in a dam to relieve pore pressure or to facilitate drainage of fill.

Drawdown - the lowering of water surface level due to release of water from a reservoir.

Earth dam (Earth fill dam) - An embankment dam in which more than 50 percent of the total volume is formed of compacted fine-grained material obtained from a borrow area.

Earthen dam or earth filled dam - see embankment dam.

Embankment dam (Fill dam) - any dam constructed of excavated natural materials.
Emergency Action Plan (EAP) - a plan of action to be taken to reduce the potential for damage to property and loss of life in the area affected by failure of a dam or other potentially hazardous practice.

Emergency gate - a standby or reserve gate which is lowers only for repairing / servicing of the service gate.

Emergency spillway - see spillway.

Face - the external surface of a structure, e.g., the surface of a wall of a dam.

Failure - the uncontrolled release of water from a dam.

Filter (filter zone) - A band or zone of granular material that is incorporated into a dam and is graded (either naturally or by selection) to allow seepage to flow across or down the filter without causing the migration of material from zones adjacent to it.

Fixed wheel gate (fixed-roller gate, fixed axle gate) - a gate having wheels or rollers mounted on the end posts of the gate. The wheels move against rails fixed in side grooves or gate guides.
Flap gate - a gate hinged along one edge, usually either the top or bottom edge. Examples of bottom-hinged flap gates are tilting gates and belly gates, so called due to their shape in cross-section.

Flashboards - a length of timber, concrete, or steel placed on the crest of a spillway to raise the retention water level but that may be quickly removed in the event of a flood, either by a tripping device or by deliberately designed failure of the flashboard or its supports.

Flood gate - a gate to control flood release from a reservoir.

Flood routing - the determination of the attenuating effect of storage on a flood passing through a valley, channel, or reservoir.

Flood surcharge - the volume or space in a reservoir between the controlled retention water level (Full Reservoir Level) and the maximum water level. Flood surcharge cannot be retained in the reservoir but will flow over the spillway until the controlled retention water level is reached.

Flood wall - a concrete wall constructed adjacent to a stream to prevent flooding of property on the landward side of the wall, normally constructed in lieu of or to supplement a levee where the land required for levee construction is expensive or not avail-able.

Flood plain - an area adjoining a body of water or natural stream that has been, or may be, covered by flood water.

Flood plain management - a management program to reduce the consequences of flooding, either by natural runoff or by dam failure, to existing and future properties in a floodplain.

Foundation of dam - the natural material on which the dam structure is placed.

Freeboard - the vertical distance between a stated reservoir level and the top of a dam. Normal freeboard is the vertical distance between Full Reservoir Level (FRL) and the top of the dam. Minimum freeboard is the vertical distance between the Maximum Water Level (MWL) and the top of the dam.

Full Reservoir Level (FRL)/Normal water level - for a reservoir with un-gated spillway it is the spillway crest level. For a reservoir, whose outflow is controlled wholly or partly by movable gates, siphons or other means, it is the maximum level to which water can be stored under normal operating conditions, exclusive of any provision for flood surcharge.

Gallery - (a) a passageway within the body of a dam or abutment, hence the terms grouting gallery, inspection gallery and drainage gallery (b) a long and rather narrow hall, hence the following terms for a power plant viz. valve gallery, transformer gallery and bus bar gallery.

Gate - a device in which a leaf or member is moved across the waterway from an external position to control or stop the flow.

Gravity dam - a dam constructed of concrete, masonry, or both that relies on its weight for stability.

Grout cap - a pad or wall constructed to facilitate pressure grouting of the grout curtain beneath it.

Grout curtain (grout cut off) - a barrier produced by injecting grout into a vertical zone, usually narrow horizontally, in the foundation to reduce seepage under a dam.

Hazard Classification - a system that categorizes dams according to the degree of adverse incremental consequences of a failure or improper operation of the dam. CWC classifies dam hazards as "low", "significant", or "high".

Height above lowest foundation - the maximum height from the lowest point of the general foundation to the top of the dam.

Homogeneous earth fill dam - an embankment dam constructed of similar earth material throughout, except internal drains or drainage blankets; distinguished from a zoned earth fill dam.

Hydraulic fill dam - an embankment dam constructed of materials, often dredged, that are conveyed and placed by suspension in flowing water.

Hydraulic height - the height to which water rises behind a dam and the difference between the lowest point in the original streambed at the axis of the dam and the maximum controllable water surface.

Hydrograph - a graphic representation of discharge, stage, or other hydraulic property with respect to time for a point on a stream. (At times the term is applied to the phenomenon the graphic representation describes; hence a flood hydrograph is the passage of a flood discharge past the observation point.)

Inclinometer - an instrument, usually consisting of a metal or plastic tube inserted in a drill hole and a sensitized monitor either lowered into the tube or fixed within it. The monitor measures at different points the tube's inclination to the vertical. By integration, the lateral position at various levels of the tube may be found relative to a point, usually the top or bottom of the tube, assumed to be fixed. The system may be used to measure settlement.

Intake - any structure in a reservoir, dam, or river through which water can be drawn into an aqueduct.

Internal Erosion - see piping.

Inundation map - a map delineating the area that would be inundated in case of a failure.

Leakage - Uncontrolled loss of water by flow through a hole or crack.

Lining - a coating of asphaltic concrete, reinforced or unreinforced concrete, shotcrete, rubber or plastic on a canal, tunnel etc. to provide water tightness, prevent erosion, reduce friction, or support the periphery of structure. May also refer to lining, such as steel or concrete, of outlet pipe or conduit.

Low-level outlet (bottom outlet) - an opening at a low level from a reservoir generally used for emptying or for scouring sediment and sometimes for irrigation releases.

Maintenance - the recurring activities necessary to retain or restore a dam in a safe and functioning condition, including the management of vegetation, the repair or replacement of failed components, the prevention or treatment of deterioration, and the repair of damages caused by flooding or vandalism.

Masonry dam - a dam constructed mainly of stone, brick or concrete blocks that may or may not be joined with mortar. A dam having only a masonry facing should not be referred to as a masonry dam.

Maximum cross-section of dam - a cross section of a dam at the point of its maxi-mum height.
Maximum water level - the maximum water level, including flood surcharge, the dam is designed to withstand.

Membrane (Diaphragm) - a sheet or thin zone or facing made of a flexible material, sometimes referred to as a diaphragm wall or diaphragm.

Minimum operating level - the lowest level to which the reservoir is drawn down under normal operating conditions.

Morning glory spillway - see spillway.
One-Hundred Year (100-Year) Exceedance Interval - the flood magnitude expected to be equalled or exceeded on the average of once in 100 years. It may also be expressed as an exceedance frequency, i.e. a percent chance of being exceeded in any given year.

Operation - the administration, management, and performance of maintenance activities necessary to keep a dam safe and functioning as planned.

Outlet - an opening through which water can be freely discharged from a reservoir.

Outlet gate - a gate controlling the outflow of water from a reservoir.

Overflow dam - a dam designed to be overtopped.

Parapet Wall - a solid wall built along the top of a dam for ornament, for the safety of vehicles and pedestrians, or to prevent overtopping.

Peak Flow - the maximum instantaneous discharge that occurs during a flood. It coincides with the peak of a flood hydrograph.

Pervious Zone - a part of the cross-section of an embankment dam comprising material of high permeability.

Phreatic Surface - the top most flow line in an embankment dam.

Piezometer - an instrument for measuring pore water pressure within soil, rock, or concrete.

Piping - the progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles.

Pore Pressure - the interstitial pressure of water within a mass of soil, rock, or concrete.

Pressure Cell - an instrument for measuring pressure within a mass of soil, rock, or concrete or at an interface between one and the other.

Pressure Relief Pipes - Pipes used to relieve uplift or pore water pressure in a dam's foundation or structure.

Primary Spillway (Principal Spillway) - the principal or first-used spillway during flood flows.

Probable Maximum Flood (PMF) - a flood that would result from the most severe combination of critical meteorologic and hydrologic conditions possible in the region.

Probable Maximum Precipitation (PMP) - the maximum amount and duration of precipitation that can be expected to occur on a drainage basin.

Program — any authorized activity used to implement and carry out goals, actions, and objectives contained within the authorizing legislation.

Program Life - the period in a contract, conservation plan, or plan during which the conservation practice or conservation sys-tem shall be maintained and used for the intended purpose; determined by program requirements.

Pumped storage reservoir - a reservoir filled entirely or mainly with water pumped from outside its natural drainage area.

Radial gate - a gate with a curved upstream plate and radial arms hinged to piers or other supporting structures.

Regulating dam - a dam impounding a reservoir from which water is released to regulate

Rehabilitation - the completion of all work necessary to extend the service life of the practice or component and meet applicable safety and performance standards.

Relief well - vertical wells or boreholes, constructed downstream of an embankment dam to relieve the pressure from confined pervious layers in foundation overlaid by an impervious layer to arrest boiling.

Repair - actions to restore deteriorated, damaged, or failed dam or its component to an acceptable by meeting functional condition.

Replacement - the removal of a structure or component and installation of a similar, functional structure or component.

Reservoir area - the surface area of a reservoir when filled to controlled retention level.

Reservoir routing - the computation by which the interrelated effects of the inflow hydrograph, reservoir storage, and discharge from the reservoir are evaluated.

Reservoir surface - the surface of a reservoir at any level.

Riprap - a layer of large stones, broken rock, or precast blocks placed randomly on the upstream slope of an embankment dam, on a reservoir shore, or on the sides of a channel as a protection against wave action. Large riprap is sometimes referred to as armouring.

Risk assessment - as applied to dam safety, the process of identifying the likelihood and consequences of dam failure to provide the basis for informed decisions on a course of action.

Rock fill dam - an embankment dam in which more than 50 percent of the total volume comprises compacted or dumped pervious natural or crushed rock.

Rock fill Dam - see embankment dam.

Roll Crete or Roller-Compacted Concrete - A no-slump concrete that can be hauled in dump trucks, spread with a bull-dozer or grader, and compacted with a vibratory roller.

Rolled fill dam—an embankment dam of earth or rock in which the material is placed in layers and compacted using rollers or rolling equipment.

Seepage - the interstitial movement of water that may take place through a dam, its foundation, or its abutments.

Service Life - the actual period after construction of a dam, during which the practice functions adequately and safely with only routine maintenance; determined by onsite review.

Service/Regulating gate (regulating valve) - a gate or valve that operates under full pressure

and flow to throttle and vary the rate of discharge.

Shaft Spillway (Morning Glory Spill-way - water spills and then is conducted through, under, or around a dam by means of a conduit or tunnel. If the upper part of the shaft is splayed out and terminates in a circular horizontal weir, it is termed a "bell mouth" or "morning glory" spillway.

Side Channel Spillway - a spillway whose crest is roughly parallel to the channel immediately downstream of the spillway.

Sill - (a) A submerged structure across a river to control the water level upstream. (b) The crest of a spillway. (c) A horizontal gate seating, made of wood, stone, concrete or metal at the invert of any opening or gap in a structure, hence the expressions gate sill and stop log sill.

Siphon Spillway - a spillway with one or more siphons built at crest level. This type of spillway is sometimes used for providing automatic surface-level regulation within narrow limits or when considerable discharge capacity is necessary within a short period.

Slide gate (sluice gate) - a gate that can be opened or closed by sliding it in supporting guides.

Slope - (a) the side of a hill or mountain. (b) The inclined face of a cutting or canal or embankment. (c) Inclination from the horizontal. In the United States, it is measured as the ratio of the number of units of horizontal distance to the number of corresponding units of vertical distance. The term is used in English for any inclination and is expressed as a percentage when the slope is gentle, in which case the term gradient is also used.

Slope Protection - the protection of a slope against wave action or erosion.

Sluiceway - see low-level outlet.

Spillway - a structure over or through which flood flows are discharged. If the flow is controlled by gates, it is a controlled spillway; if the elevation of the spillway crest is the only control, it is an uncontrolled spillway.

Spillway Channel (Spillway Tunnel) - a channel or tunnel conveying water from the spillway to the river downstream.

Stilling Basin - a basin constructed to dissipate the energy of fast-flowing water, e.g., from a spillway or bottom outlet, and to protect the riverbed from erosion.

Stop logs - large logs or timber or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit providing a cheaper or easily handled temporary closure than a bulkhead gate.

Storage - the retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of over-flow areas, as in the progression of a flood crest through a natural stream channel.

Tail water Level - the level of water in the tailrace at the nearest free surface to the turbine or in the discharge channel immediately downstream of the dam.
Tailrace - the tunnel, channel or conduit that conveys the discharge from the turbine to the river, hence the terms tailrace tunnel and tailrace canal.

Toe of Dam - the junction of the downstream face of a dam with the ground surface, referred to as the downstream toe. For an embankment dam the junction of upstream face with ground surface is called the up-stream toe.

Top of Dam - the elevation of the upper-most surface of a dam, usually a road or walkway, excluding any parapet wall, railings, etc.

Top Thickness (Top Width) - the thickness or width of a dam at the level of the top of the dam. In general, "thickness" is used for gravity and arch dams, "width" for other dams.
Transition Zone (Semi-pervious Zone) - a part of the cross section of a zoned embankment dam comprising material of intermediate size between that of an impervious zone and that of a permeable zone.

Trash rack - a screen located at an intake to prevent the ingress of debris.

Tunnel - a long underground excavation usually having a uniform cross section. Types of tunnel include: headrace tunnel, pressure tunnel, collecting tunnel, diversion tunnel, power tunnel, tailrace tunnel, navigation tunnel, access tunnel, scour tunnel, draw-off tunnel, and spillway tunnel.

Under seepage - the interstitial movement of water through a foundation.

Uplift - the upward pressure in the pores of a material (interstitial pressure) or on the base of a structure.

Upstream Blanket - an impervious layer placed on the reservoir floor upstream of a dam. In case of an embankment dam, the blanket may be connected to the impermeable element in a dam.

Upstream Blanket - see blanket.

Valve - a device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway to control or stop the flow.
Water stop - a strip of metal, rubber or other material used to prevent leakage through joints between adjacent sections of concrete.

Weir - (a) a low dam or wall built across a stream to raise the upstream water level, called fixed-crest weir when uncontrolled. (b) A structure built across a stream or channel for measuring flow, sometimes called a measuring weir or gauging weir. Types of weir include broad-crested weir, sharp-crested weir, drowned weir, and submerged weir.

Zoned embankment dam - an embankment dam composed of zones of materials selected for different degrees of porosity, permeability and density.

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