OPERATION AND MAINTENANCE MANUAL

VELLATHOOVAL DIVERSION WEIR

Kerala State Electricity Board Limited

Chief Engineer (Civil-Dam Safety & DRIP)

January 2024

Front Cover Photograph: Views of Vellathooval SHEP Diversion Weir and Power House.

Operation and Maintenance Manual

Diversion Weir of Vellathooval SHEP

Approved

Chief Engineer (Civil-Dam Safety & DRIP)

Kerala State Electricity Board Ltd.

Pallom, Kottayam.

January 2024

Government of Kerala

Kerala State Electricity Board Ltd

Dam Safety Organisation

DISCLAIMER

This *Operation and Maintenance Manual for Vellathooval Diversion Weir* 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 weir and appurtenant structures.

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

For any information, please contact:

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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.

Director (Generation Civil)
Kerala State Electricity Board Limited

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.

Smt. Supriya S
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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. Dam Safety Act, 2021 also mandates that the dam owner shall ensure that a well-documented operation and maintenance manual is kept at each of the specified dams and are followed at all times. Accordingly, Kerala State Electricity Board Limited is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy dam safety management system.

Operation and Maintenance Manual of Vellathooval Small Hydro Electric Project under KSEBL is prepared as per the guidelines by CWC. The Vellathooval SHEP of KSEBL was commissioned on 2016

The Vellathooval small hydroelectric project is a run-off the river scheme in Muthirapuzha river of Periyar basin. The Project area is situated at 9° 56'26" N latitude and 77° 1' 48" E longitude. The scheme envisages the utilization of tail discharge of Sengulam Hydroelectric Project and spill from upstream reservoirs in addition to the inflow from own catchment.

This Operation and Maintenance Manual is prepared for the Vellathooval Diversion Weir under Vellathooval SHEP.

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LIST OF ACRONYMS

The following acronyms are used in this publication:

AE	Assistant Engineer
AEE	Assistant Executive Engineer
CWC	Central Water Commission
DDMA	District Disaster Management Authority
DHARMA	Dam Health and Rehabilitation Monitoring Application
DRIP	Dam Rehabilitation and Improvement Project
Dy CE	Deputy Chief Engineer
EAP	Emergency Action Plan
EE	Executive Engineer
IS	Indian Standard
KSEBL	Kerala State Electricity Board Ltd
KWA	Kerala Water Authority
NDSA	National Dam Safety Authority
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCC	Reinforced Cement Concrete
SDSO	State Dam Safety Organization

REFERENCES

1. Guidelines for preparing O&M Manual of Dams (DSO_ GUD_ DS_ 03_ v1. 0 January 2018) published by CWC.
2. CWC Guidelines for Safety Inspection of Dams (CDSO_GUD_DS_07_v2.0 January 2018)
3. Guidelines for Operation of Reservoirs (IS7323:1994)
4. Hydraulic Design of High Ogee Over flow Spillways (IS6934:1998)
5. Technical Completion Report of Vellathooval SHEP

Chapter 1 : General Information

1.1 Introduction

The Vellathooval Small Hydro Electric Project is located in Muthirapuzha River, downstream of the Sengulam Power House, in Vellathooval Panchayat of Devikulam Taluk in Idukki District of Kerala State. The Scheme is utilizing the tail discharge of Sengulam Hydro Electric project and spill from upstream reservoirs in addition to the inflow from own catchment for power generation.

The scheme consists of a small diversion Weir across the Muthirapuzha River downstream of the bridge near Sengulam Power House, a power intake provided at weir, a penstock of 3.30 m dia. with feeder pipes of 2.5 m dia. and 50.50 m length, power house of installed capacity 3.6 MW and a tail race channel of size 14 x 32 m.

Water from the reservoir is primarily utilized for power generation. The expected annual generation from the project is 12.17 million units (Mu). After generating power, the water is diverted to the river immediately downstream and fed into the Kallarkutty Reservoir of the Neriyamangalam Hydro Electric Project.

Vellathooval Small Hydro Electric Project is located in Vellathooval Grama Panchayat and Vellathooval Village of Devikulam Taluk in Idukki District, situated approximately 15 km away from Adimaly Town. The nearest railway station is Aluva, which is 100 km from the project site, and the closest airport is Cochin International Airport, approximately 150 km away.

1.2 Purpose, location and Description of the Project

Kerala is having large potential for development of Hydro power. To provide electricity at minimum cost, we have to develop hydroelectric projects for power generation to the maximum extent. But the share of hydro power addition was declining in the state due to various reasons. The development of major hydro projects could not be taken up due to issues regarding forest and environmental clearances. Harnessing hydroelectric potential without detrimental to the environment is the key strategy accepted in Kerala. From this point of view Kerala State Electricity Board Limited has been taking fast step to implement as many as small hydroelectric projects as possible. Vellathooval Small Hydro Electric Project is one among them, which had completed within a short period. The main advantages of this scheme are that no need of forest land for implementation, environment friendly and contribute rural development. The submergence of the land has been restricted to the bare minimum.

The Vellathooval Small Hydro Electric Project is located in Muthirapuzha River, downstream of the Sengulam Power House. The Project area is situated at 9° 56'26" N latitude and 77° 1'

48" E longitude. The Project is situated very near to the Sengulam and Panniyar Generating Stations.

1.3 Background Details of the Project

Kerala State Electricity Board Limited is committed to its objective of supplying best quality electricity at reasonable price without interruption to all sectors. To accomplish this, **(KSEBL)** have been taking earnest steps to improve the power system by adding capacity in generation, transmission and distribution. Increasing capacity of hydel generation without much disturbance to the forest and its biodiversity is the key strategy followed by Board to provide electricity at minimum cost. The implementation of many hydel schemes with storage were dropped or postponed due to issues regarding forest, environmental and socio economic reasons. The State Government /Board have taken stern decision to tap maximum extend of Hydro Electric Power and considered the run-off-river Schemes, which will have minimum impact on forest and environment. Vellathooval Small Hydro Electric Project is one among them, which had completed within a short period. The main advantages of this scheme are that no need of forest land for implementation, environment friendly and contribute rural development. The submergence is also minimal. The Ministry of New and Renewable Energy (MNRE) has sanctioned an amount of ` 354.00 lakhs as capital subsidy towards the implementation of the project.

1.4 Salient Features

LOCATION	
State	Kerala
District	Idukki
Taluk	Devikulam
Panchayat	Vellathooval
Latitude	9°56’26”N
Longitude	77 °1’48”E
Basin	Periyar
River	Muthirapuzha
HYDROLOGY	
Catchment Area	Tail discharge from the existing Sengulam Power House and water from free catchment area of 247 sq.km.
Original Design Flood	460 cumecs
Revised Design Flood	4176.8 cumecs
Maximum rainfall	3106.9 mm

Minimum rainfall	2451.3 mm
Average annual rainfall	2778.4 mm
COMPONENT STRUCTURES	
DIVERSION WEIR	
Type	Concrete gravity
Normal river bed level	+460.00 m
Full Reservoir Level	+472.00 m
Maximum Water Level	+474.80 m
Top of dam	+ 475.80 m
Minimum Draw Down Level	+469.50 m
Length of Dam at Top	71.40 m
SPILLWAY	
Length of spillway	50.40 m
Crest level	+ 472.00
Upstream face	Vertical
Downstream face	Ogee curve
Deepest foundation level	+ 455.00
NON OVERFLOW SECTION	
Total length	21.00 m
Length at left bank	15.00 m
Length at right bank	6.00 m
Top level	+ 475.80 m
Top width	2.50 m
Height above deepest foundation	20.80 m
Upstream profile	Vertical
Downstream profile	Vertical above + 472.50 and 0.7 H to 1 V below + 472.50 m
INTAKE STRUCTURE	
Type	Rectangular
Size of bell mouth	3.57x4.75 m
RL of C/L of pipe	+ 463.70 m
Sill level of intake	+ 462.05 m
Top level of intake	+ 467.27 m

Apron level	+ 460.95 m
TRASHRACK	
Bottom level	+ 460.375 m
Top level	+ 474.80 m
Height	14.425 m
Plan dimension	0.6 x 7.35 m
PENSTOCK	
Length of penstock	51.10 m
Diameter of pipes	3.3 m
Diameter of feeder pipe	2.5 m
Shell thickness	12 mm (ASTM-285C Steel)
Maximum Discharge	38.82 m^3 /s
POWER HOUSE	
Type	Over ground
Size	27.5 m x 22.5 m x 13.12 m above yard
Installed capacity	3.6MW (2x1.8MW)
Annual Energy	12.17 Mu
Type of turbine	Horizontal Kaplan
Crest level of Tail race pool	+ 457.00m
Generator floor level	+ 452.41m
C/L of turbine	+ 452.8m
Service bay level	+ 465.0m
TAIL RACE	
Shape	Rectangular
Size	14 x 32 m
Bed slope	1 in 4
Bed level	Varies from + 448.99 to + 457.00

Fig 1.1 Location Map of the Project

Fig 1.2 Components of the Project

1.4.1 Major components

Reservoir

A small reservoir having a pondage of 0.069 Mm^3 is formed by constructing a weir. Dead storage up to MDDL (+469.50 m) is 0.044 Mm^3 and Live storage between MDDL and FRL is 0.025 Mm^3. Full Reservoir Level (FRL) is + 472.00 m and Maximum Water Level (MWL) is +474.80m. This reservoir helps to store water for running the project in line with the generation at Sengulam PH.

Fig 1.3: Vellathooval SHEP Reservoir Google view

Diversion Weir

The diversion weir is constructed across the river in four blocks. The total length of the weir is 71.40m out of which 21.00 m length is non-overflow section (15.00 m in left bank and 6.00m in the right bank) and the middle 50.40 m length is overflow section. The top levels of non-overflow portion and crest level of overflow portion are +475.8 m & +472m respectively. Contraction joints are provided in between blocks.

The intake structure and scour outlet are accommodated in block-1. The centerline of penstock is 9.6 m towards the left-hand side of Block no.1 and at +463.70 m. A rectangular bell mouth is provided at the entrance to the penstock pipe in front of the gate groove. The length of the bell mouth is 3.3 m from the dam body and the gate is located at the end of the bell mouth. The actual sill level of the intake gate is +462. The total length of transition pipe provided in the dam body is 3.3 m. Hoisting and dogging arrangements for intake gate are provided. The MDDL is fixed as +469.50 m.

Air vent is opened to the atmosphere at the d/s face of the dam body. The openings are protected with weld mesh.

The Ogee-type overflow section has a crest at +472.00 m and is divided into four blocks. The bottom width and elevation of the overflow section, including the bucket portion, vary according to the founding level.

Fig 1.4: Photograph of Diversion Weir

Scour Sluice

Scour outlet pipe is provided in Block-1. The center of the pipe is at +460 m. At intake, the bed level of the intake pool is +460.95 m. The actual sill level of the scour gate is +459.50 m and provided with an independent hoisting arrangements from the dam body.

Penstock

The water conductor system consists of a steel penstock of 3.30 m diameter, 51.10m long completely embedded in reinforced concrete. It starts with a rectangular bell mouth. After the bell mouth is the intake gate followed by the transition from rectangular section to circular section. After the vertical bend the penstock bifurcates to two feeder pipes of 2.50m diameter. The steel plates 12mm thick ASTM 285C are used for the penstock.

Fig 1.5: Photograph of Diversion Weir

Power House

Power House is located downstream of the weir with a machine bay, service bay, switchgear room and control room. Two numbers of horizontal Kaplan turbines, generator units, and other auxiliaries are accommodated in the machine bay. To facilitate erection, repair and maintenance of units an EOT crane has been installed on steel gantry girders supported on RCC columns. The switchgear room is equipped with one auxiliary transformer, feeder breaker, 2 nos. generator incomer breakers, one no. transformer feeder and one number LTAC panel and a battery bank. The control room is equipped with one number 110 V battery charger, 2 nos. TACP, 1 no. synchronizing panel, 2 nos. generator metering panels, 1no. transformer metering panel, 2 nos. GRP and 2 nos. excitation control panels.

Fig 1.6: Power House – Vellathooval SHEP

Tail Race

Fig 1.7: Tail Race

Tail Race pool with reinforced concrete bed slab and retaining wall on both sides is provided downstream of PH. The pool measure 14 x 32 m with bed level varies from +448.99 to +457.00 and tailrace channel opens into the river Muthirappuzha.

Switchyard

Fig 1.8: Switchyard

A switch yard has been constructed on upstream side of Power House to facilitate the evacuation of power and to provide auxiliary supply. The equipment in the switch yard are 11kV isolator units, lightning arrestors, potential transformers, current transformers, circuit breaker, 1No.3.3kV/11kV, 5MVA transformer, 1No. 3.3kV/440v, 250kVA transformer and a transformer oil filtering unit. From the switch yard a 11kV XLPE UG cable has been taken to the Substation, for evacuating power.

1.4.2 Access Roads

The Vellathooval SHEP is located on the side of road to Panniyar Power House and the left bank of Muthirappuzha and hence no separate access is required for project. The project site is very near to the Vellathooval town.

1.5 Assignment of Responsibility

Kerala State Electricity Board Ltd is the owner and has the final authority and responsibility for the operation and maintenance of the Weir. 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.

Dam Owner	Kerala State Electricity Board Limited
Project Administration Officer	The Director (Generation – Civil), KSEB Ltd.
Chief Controlling Officer	Chief Engineer (Civil–Dam Safety & DRIP)
Authority of Spillway operations and Flood releases	Chief Engineer (Civil– Dam Safety &DRIP), KSEB Ltd
Operation and safety of the dam	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, KSEB Ltd.
Controlling/Operation Officer at dam site	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
Reservoir operations, inspection &maintenance	Executive Engineer, Research &Dam Safety Division IV, Pambla.
Dam Health Engineer	Executive Engineer, Research & Dam Safety Division No.IV, Pambla.
Recording reservoir data, inspection, monitoring and maintenance at site	Assistant Executive Engineer, Research & Dam Safety Sub Division, Pambla.
Handling Dam operations, inspection, monitoring and performing duties and Maintenance- Officer at dam	Assistant Engineer, Research & Dam Safety Sub Division, Pambla.
Competent Authority for the dam safety unit	Executive Engineer, Research &Dam Safety Division IV, Pambla.
Competent engineers for the dam safety unit	Assistant Executive Engineer/Assistant Engineer, Research & Dam Safety Sub Division, Pambla.
Reviewing Authority for the dam safety unit	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, KSEB Ltd.

Table 1.1: Officers and their responsibilities

1.5.1 Roles and Responsibilities of the AE and AEE during Monsoon

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

1. Collect rainfall information in the catchment, inflow status, reservoir level and to bring it to the notice of the EE/DyCE.

2. Assist the EE/DyCE/CE to coordinate with the Revenue authorities (District Administration), to alert the downstream inhabitants and to alert DDMA to evacuate from the flood zone to prevent loss of life and livestock.
3. Assist the EE/DyCE/CE to coordinate with the CWC flood monitoring authorities on the flood condition.
4. Maintain the reservoir water level gauge register and to update on hourly basis during floods and report to EE/DyCE/Chief Engineer.
5. Submit to the EE/DyCE/CE on the inflows and outflows from the reservoir and status of the reservoir at 3 hr interval during flood or at interval as decided by competent authority/ DDMA.
6. Monitor the condition of the umbrellas, toolkits, torches etc. to see that things are in place to handle any emergency situation.
7. Observe and ensure that the dam top, approach roads are well maintained.
8. Observe the performance of the Dam and its appurtenant structures/scour Gates and Hoists during flood water releases and to report to the EE/DyCE/CE in case of any untoward incidents or malfunctioning of the scour gates, excessive seepages, leakages etc. noticed.
9. Assist EE/DyCE/CE to coordinate with the Generating staff of Vellathooval SHEP Power house downstream in the operation and power generation.

1.5.2 Roles and Responsibilities of the EE and DyCE

1. Conduct Periodical (Pre and Post Monsoon to assess the health status of the Dam and appurtenant structures to attend 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 Hydro Mechanical components of the Dam project such as Gates and Hoists before and after monsoon and to issue necessary instructions to the field officers.
3. Coordinate with the field Engineers to get the information in respect of rainfall and inflow status and to bring to the notice of the CE.
4. Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers and DDMA to initiate evacuation from the flood zone to prevent any loss of life and livestock.
5. Assist the CE to coordinate with the CWC flood monitoring authorities on the flood condition.
6. Submit to the CE the status of inflows and releases from the reservoir daily or as instructed.
7. Observe the dam top, embankment, approach roads are well maintained.
8. Observe the performance of the dam and its appurtenant structures, including scour gates and hoists, during floodwater releases. Report any untoward incidents or malfunctions of the gates, excessive seepages, leakages, etc., to the Chief Engineer.

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

1. Coordinate with the CWC flood monitoring authorities on the flood condition.
2. Observe the performance of the Dam and its appurtenant structures/Scour Gates and Hoists during flood water releases and to issue necessary instructions to the DyCE/EE.
3. Coordinate with the Generation wing of KSEBL regarding the power generation requirement.

1.6 Collection & Reporting of Data

Following data are collected, recorded and documented.

- Reservoir water surface elevation.
- Reservoir inflow.
- Spillway outflow.
- River releases.
- Hydropower releases.
- Rainfall data etc.

Executive Engineer is responsible for daily collection and reporting of inflow and outflow data to the Deputy Chief Engineer in the following format.

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

Table1.2: Daily Reservoir Data

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

Table1.3: Daily Reservoir Status

On collecting the details in the above format, a daily reservoir status shall be submitted to the Chief Engineer as in the **Table 1.3**.

Records/Logbooks of the operations for the following activities shall be 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.

- Record the date and time
- Attendance statement during normal operations– both during monsoon and non-monsoon periods.
- Operations of the intake / scour outlet.
- Operating hours of mechanical equipment.
- Testing/operation of Outlet gates 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.

The data collection and reporting shall be done as follows:

Reservoir water surface elevation	This is collected daily
Spillway out flow	This is calculated during spill
River releases	The tail water is released directly downstream
Weather related data	Collected and reported daily
Water quality	Shall be tested once in 6 months
Attendance statement	Both during monsoon and non-monsoon period maintained at field office.
Operations of outlet gates	Shall be recorded
Operating hours of mechanical equipment.	Maintained at field office
Testing/operation of Outlet gates, 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, Circle and CEs office

Unusual conditions or occurrences, including acts of vandalism	Details maintained
Attendance statement at dam during emergency operations	Details shall be maintained at field office
Changes to normal operating procedure	Details shall be maintained at field office
Communication	Available at Dam site.
Safety and special instructions	Safety equipment shall be available
Names and addresses of official visitors	Record of inspections maintained at office

1.7 Public Utilities and Safety

As safety of Project Staff is of prime concern, safety instructions & protection measures at the dam are to be followed by all staff/project personnel.

Sufficient accommodation facilities are available at nearby Town Adimaly which is around 15.00 Km from Weir Site. The Vellathooval Diversion Weir is very close to the Vellathooval junction in Adimaly Rajakkad road. Panniyar Generating station and Sengulam Generating station are situated very close to the Vellathooval SHEP site.

Distances to the nearest medical assistance is available at Adimaly. Government Taluk Hospital is located at Adimaly. Police station is also located at Vellathooval itself. Private Hospitals with medical facilities are also available at Adimaly town. Minor medical assistance are available at Vellathooval itself.

1.7.1 Security Arrangements

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

1.8 Organogram

The organogram of the officials under Dam Safety Wing responsible for the operation and maintenance of the weir and their contact details is shown below;

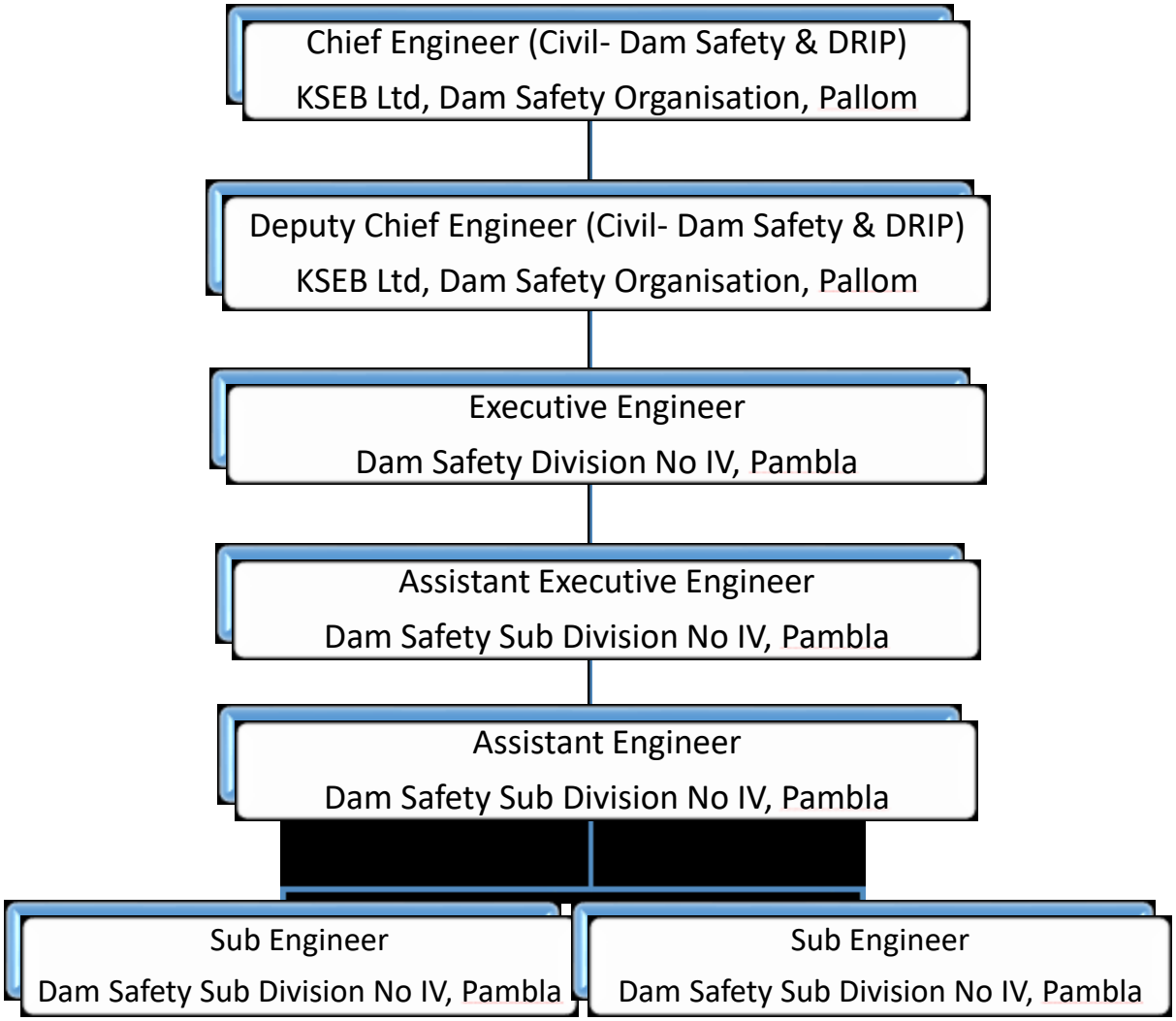


Fig.1.9: Organogram

Designation and office address	Contact number and e-mail
Chief Engineer Civil (Dam safety & DRIP), KSEB Ltd, Dam Safety Organization, Pallom, Kottayam	Ph:9496018719 e-mail:cedamsafety@gmail.com
Deputy Chief Engineer, Research& Dam Safety Organization, Pallom, Kottayam	Ph:9446008492,0481-2432290, e-mail:dirroplm2@gmail.com
Executive Engineer, Dam Safety Division No.IV, Pambla	Ph: 9446008421 e-mail: eerdspambla@gmail.com
Assistant Executive Engineer, Dam Safety Sub Division, Pambla	Ph: 9496011802 e-mail:aeedspambla@gmail.com

Assistant Engineer, Dam Safety Sub Division, Pambla	Ph: 9447981054 e-mail:aeedspambla@gmail.com

Table 1.4: Contact details of officials

1.9 Warning system

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

1.10 Releases through Spillway

Spillway of the weir is ungated. Water will flow freely through the spillway when the reservoir level reaches FRL/Spillway crest level. The spill water will flow through Muthirappuzha River and reaches the Kallarkutty reservoir just below.

Fig 1.10: Flow path of spill water

1.11 Distribution of Operation & Maintenance Manuals

The following officers/ field staff at different levels in the Division under the supervision of Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom and Administrative control of Chief Engineer, Dam Safety Organization, KSEB Ltd, Pallom are entrusted with the specific responsibility for carrying out O & M activities for **Vellathooval Diversion weir.**

1) Executive Engineer, Dam Safety Division No. IV, Pambla.

2) Asst. Executive Engineer, Dam Safety Sub Division, Pambla

3) Assistant Engineer, Dam Safety Sub Division, Pambla

4) Personnel in charge of works of the Dam.

The offices/officers to which the O & M Manual of Vellathooval Diversion weir is to be distributed are:

1. Dam Safety Division No. IV, Pambla

2. Dam Safety Sub Division, Pambla

3. Assistant Engineer, Dam Safety Sub Division, Pambla

4. Office of the Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom

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

1.12 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 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

1.13 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned officials are tabulated below in **Table1.6.**

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	weekly	Sub Engineer/Dam operators on contract
2	Record water surface elevation, reservoir in flow and spillway discharge.	Daily (as decided 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. Replace fuse light bulbs.	Weekly	Assistant Engineer
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	Fortnightly	Assistant Engineer/ AEE
7	Check security and safety devices, logbook and site register which include the above information.	monthly	Assistant Executive Engineer
8	Measuring devices, communication devices, instruments, status of vegetation growth	monthly	Assistant Executive Engineer
9	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
10	Check measuring devices/Instruments, Security and safety devices, Communication Devices, Status of Vegetation growth,–rectification, if needed.	Monthly	Executive Engineer
11	Check Sign/Warning display boards near vulnerable locations	Monthly	Executive Engineer
12	Cleaning of control panel boards.	Monthly	Assistant Engineer
13	Check outlet works, updating operating instruction, check gate air vents, clean gate controls witch boxes, check operation of gates, grease gate hanger/ dogging	Quarterly	Executive Engineer

14	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
15	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 and clear drains.	Quarterly	Executive Engineer
16	Check for adherence to instrument at action schedule, Record pertinent information in Operation of Gates,	Quarterly	Executive Engineer
17	Inspection of outlet works, hydro mechanical components,	Half yearly (Pre and Post Monsoon)	Deputy Chief Engineer along with Executive Engineer in charge of dam
18	Submission of Inspection report to State DSO, CWC and uploading into DHARMA.	Half yearly	Chief Engineer/Deputy Chief Engineer
19	Comprehensive inspections	Annually	SDSO along with Dam Owners
20	Inspect dam and gate structures, trash racks and stilling basin/energy dissipation arrangement, which normally are under water (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
21	Comprehensive inspection of performance of the dam and gate structures and reservoirs, trash racks and energy dissipation arrangement.	Ten Yearly	Dam Safety Review Panel

Table 1.5: Schedule of duties/inspections

Chapter 2 : Project Operation

2.1 General

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

The Vellathooval weir is an un gated overflow weir and the water level is to be monitored daily. No Control arrangements are provided for the releases through spillway. The diversion weir is constructed across the river in four blocks. The total length of the weir is 80.2m out of which 29.8 m length is non-overflow section (23.80 m in left bank and 6.00m in the right bank) and the middle 50.40 m length is overflow section. The top levels of non-overflow portion and overflow portion are +475.8 m & +472m respectively.

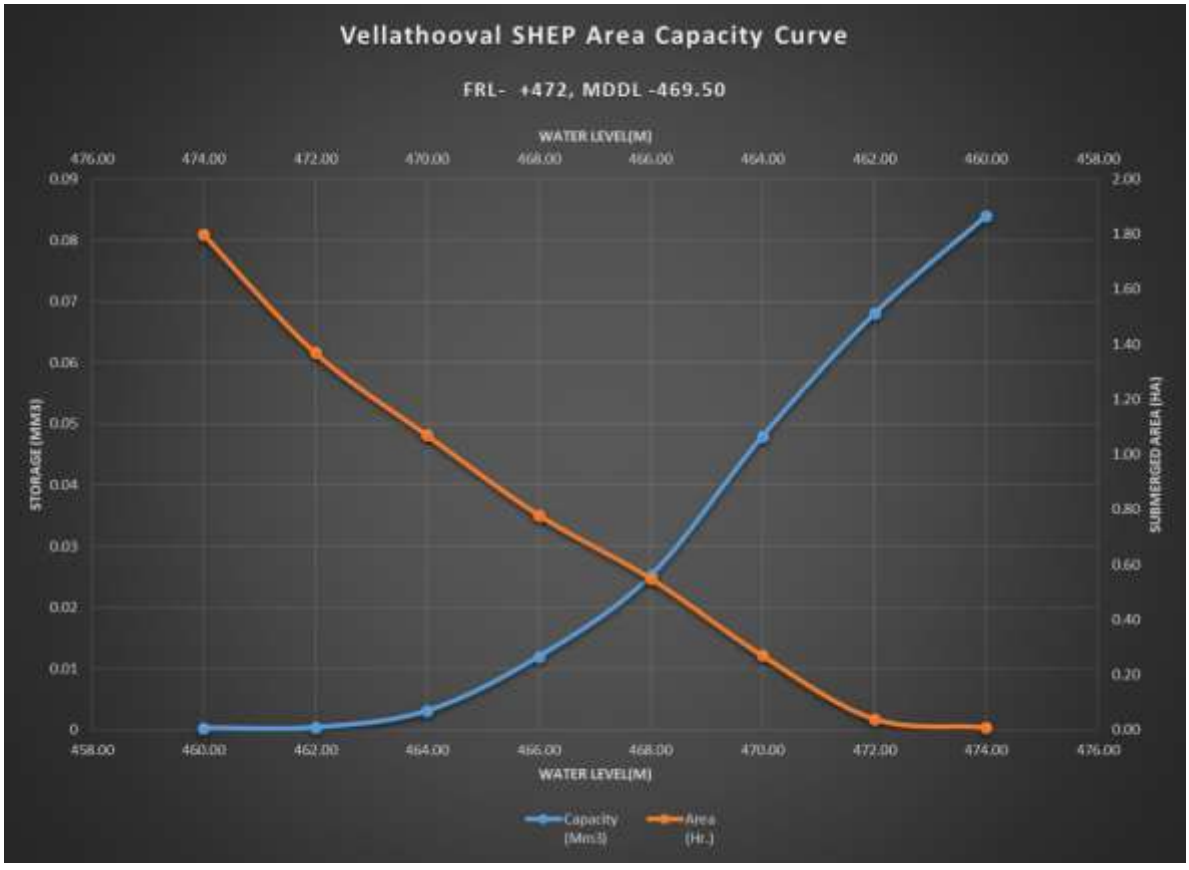


Fig. 2.1: Elevation – storage & Elevation – Area curves

2.2 Operation Plan

2.2.1 Data of Historical Flood

As per historical records, the maximum flood observed in the Western Ghats occurred in 1924. The center of the storm for the 1-day rainfall on July 17, 1924, and the 2-day rainstorm from July 16 to 17 was located at Devikulam in Kerala, where rainfall of 484 mm and 751 mm, respectively, was recorded. The second historical flood took place from August 14 to 17 in 2018, resulting in record inflow into the reservoir.

During the southwest monsoon of 2018, similar to the 1924 Devikulam storm, Kerala experienced abnormally high rainfall from June 1, 2018, to August 19, 2018, leading to severe flooding in 13 out of 14 districts in the State. The 2-day and 3-day rainfall depths from August 15 to 17, 2018, in Pamba, Periyar, and Bharathapuzha sub-basins were almost comparable to the Devikulam storm of July 16 to 18, 1924. For the entire Kerala, out of 758.6 mm of rainfall from August 1, 2018, to August 19, 2018, about 414 mm occurred in just three days from August 15 to 17, 2018, causing severe flooding in the State. In comparison, during July 16 to 18, 1924, it was 443 mm.

Notably, there is no rain gauge station at the Vellathooval Weir Site. The rainfall details of the nearby Kallarkutty Rain Gauge Station from 2015 to November 2023 are attached as Annexure III

2.2.2 Design Flood Studies

The Scheme is utilizing the tail discharge of Sengulam Hydro Electric project and water available from free catchment area of 247sq.km below Panniyar & its Augmentation Scheme for power generation. Average Annual Rainfall received is 2778.4 mm. Design Flood of 460 cumecs is revised during 2022 as 4176.8 cumecs. A copy of the revised Design Flood Review Report is attached as Annexure II.

2.3 Normal Operations

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

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

2.3.1 River Outlets

Scour outlet, one-meter dia. is provided near the intake area to let out water for use in the downstream in case of shut down of the power house. The river bed is rocky at the downstream end of the scour pipe. This eliminates the need for special arrangement for energy dissipation. For closure of the scour pipe and regulation of discharge fixed wheel vertical lift gate is provided.

To enable periodical repair of this gate, an additional gate of identical design is provided. The gates are provided with independent hoists. Since the gates are small the hoists are 3 T chain pulley blocks. The maximum discharge capacity of this scour outlet is 8.5 m^3/sec when the reservoir is at FRL (+472.00 m level). The gates are designed for unbalanced operation. The seals are provided on upstream side.

Scour outlet pipe is provided in Block-1. The Centre Line of the pipe is at +460 m. At intake, the bed level of the intake pool is +460.95 m. The actual sill level of the scour gate is +459.50 m and provided with an independent hoisting arrangement from the dam body.

Fig 2.2 Closing arrangements of the Scour Gate

2.3.2 Intake Gates

The intake structure is accommodated in block-1. The centre line of penstock is 9.00 m towards the left hand side of Block No.1 and at +464.75 m. The intake of the penstock is rectangular bell mouth type ending to the rectangular section of intake gate. The length of the bell mouth is 3.3 m. The sill level of the intake gate is +462. The total length of transition pipe provided in the dam body is 3.2 m. Hoisting and dogging arrangements for intake gate are provided. The MDDL is fixed as +469.50 m. There is a fixed wheel vertical lift gate with upstream skin plate with seal. The gate is designed for unbalanced operation. The hoist is chain pulley block. Except during initial filling of the penstock, this gate is not to be used under partial open condition.

Fig 2.3 Intake Gate

2.3.3 Draft tube Gates

These are slide type gates designed for operation under balanced condition. One common gate is provided for the two units. Hoist is a common chain pulley block on monorail. This gate is dogged in the operating platform.

Fig 2.4 Draft tube Gate

2.3.4 Trash rack at power intake

Removable sections of trash rack panels are provided in front of the penstock pipe at intake block. The trash rack panel has a size of 2.625x2.98 m each, arranged in a pattern of 5 horizontal by 6 vertical panels. Detailed drawings are attached as annexures.

2.3.5 Operating Procedure of gates

All the gates shall be properly maintained for proper functioning.

Procedure

i. The gate is designed for operation in unbalanced condition. So the gate can be opened against full water thrust from the upstream side. Closing can be done against flowing water.
ii. Periodically grease the wheels through the grease nipple in each wheel shaft.
iii. Keep the wheel treads and wheel tracks free of grease/oil.
iv. Store the gate leaf in the gate slot using the dogging beams to protect the seals against the heat of the sun.
v. Periodically inspect the seals for any damage.

Safety

i. Only experienced operators shall be allowed to operate the gates.

ii. The operators shall strictly use hand protection gloves.
iii. The gate hook can be fitted on any hooking link with the help of dogging pin.
iv. Original Dogging frame shall be used while adding or removing dogging links.
v. The chain shall not be tied to any member for lifting.
vi. The hoist and hoisting structure shall be strictly used for handling vertical loads only.
vii. The gate slots shall always be covered with cover plates unless any lifting operations are carried out.
viii. Ensure the hoists are not lifting any load beyond its safety headroom.

Annual Maintenance

All hydraulic gates shall be thoroughly inspected during the summer period preferably in the beginning of April every year. Annual shutdown is necessary for inspection of gate grooves, gate sluices, and bell mouths. Painting of metal inserts provided along the path of sluice opening such as bell mouth skin plates, gate embedded parts etc. shall be carried out during the shutdown period.

Painting, repairing work of gate, changing of rubber seal, greasing, inspection of wheels, chain blocks, travelling trolley, servicing of electric motors, electric connections etc. shall be carried out through experienced agencies.

The inside of gate sluices shall be cleared off silt, pebbles and other debris.

Routine Maintenance

The gates shall be lifted and lowered for testing purpose once in every 3 months. The greasing of wheels, chains and other visual inspection shall be carried out during this operation. Emergency gates may be used at the time of routine maintenance to prevent the loss of water from reservoir.

Lubricants

Regular application of lubricant is necessary for the smooth functioning and long lasting of the moving parts such as Chain, Sprockets, Wheels etc. of Manual as well as Electric Chain Hoists. The manufacturer of Electric Hoists, M/s Hercules Hoists Ltd recommended the following grade lubricants. OIL: HP Parthan: 320 Grade. & Grease: HP MP3

2.3.6 Operation of scour gates during flooding

The gates are designed for operation in unbalanced condition. So they can be opened against full water thrust from the upstream side. Closing can be done against water

i. There are two gates. One is normally kept closed while the other one is in dogged condition.
ii. Periodically grease the wheels through the grease nipple in each wheel shaft.
iii. Keep the wheel treads and wheel tracks free of grease/oil.
iv. Periodically inspect the seals for any damage.

2.3.7 Operation of Draft Tube Gates

i. Separate gates are provided for the two units.
ii. The draft tube gates are designed for operation under balanced condition so that water pressure on either side of the gate shall be equal.
iii. This condition can be achieved by opening the valve in the draft tube filling pipe (the pipe from the upstream side of the Butterfly valve to the draft tube).
iv. The water from the penstock will fill the draft tube, and the water levels on either side of the gate will become and remain equal. Now, the gates can be opened.
v. The gates are kept in the gate slot suspended from the dogging beam.
vi. The gates shall be visually inspected periodically and all precautions shall be taken against tearing of the seals or corrosion of the gate leaf and necessary repairs if any shall be carried out

2.3.8 Rule Curve

Rule curves with dynamic flood cushion for moderating the floods of lower return periods are provided for reservoirs having a storage of more than 200 MCM only. Hence No Rule curve is adopted for Vellathooval pondage.

2.4 Emergency Action Plan

Emergency Action Pan (EAP) is prepared and published in the web site.

2.5 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details shall be kept at the field office and DSO. Also documents as per the dam safety guidelines and DSA 2021 shall be kept at the dam site office. Following records of reservoir operations shall be maintained:

1. Data of Rain gauges in the catchment area.
2. Reservoir levels on daily basis during non-monsoon and at short interval as decided during monsoon.
3. Depth of out flow over the spillway during monsoon.
4. Spillway outflows.
5. Power house releases.
6. 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 Deputy Chief Engineer in the presence of Executive Engineer and field officers shall carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC. The Deputy Chief Engineer shall submit the inspection report to the Chief Engineer for onward transmission to CWC. The Executive Engineer at site shall conduct quarterly inspections and inform any remedial measures to be taken to higher ups. The inspection reports are to be uploaded in DHARMA. Also, SDSO conducts pre monsoon & Post monsoon inspections. The dam comes under the specified dam category as per Dam Safety Act 2021.

3.1 Types of inspections

Safety inspections are to be carried out for Vellathooval Diversion Weir as this is a specified dam as per DSA 2021. These include, but not limited, to the following:

1. Comprehensive dam safety evaluation shall be done as per DSA 2021
2. Scheduled inspections (Pre & Post monsoon inspections & other scheduled inspections)
3. Special (Unscheduled) inspections
4. Informal inspections.

The frequency of each type of inspection depends on the condition of the weir and State DSO regulations, etc. A comprehensive health checklist for recording the status of each item being inspected and the overall condition of the structures along with any consequential risks on the health of the weir and appurtenant structures 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 safety evaluation of weir and appurtenant structures. The panel will undertake evaluation of the dam and appurtenant structures 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 limited to;

- General assessment of hydrologic and hydraulic conditions, review of 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, appurtenant works etc.
- 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 consists of five major parts:

- 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 including.
- Inspection of the weir and its appurtenant works.
- To review the results and reports of additional field investigations & laboratory testing.
- Review of design studies, review of design flood, checking of the adequacy of Spillway capacity, freeboard requirements, dam stability and any special study.
- Preparation of a detailed report of the inspection.

3.3 Scheduled Inspections

Scheduled inspections by dam owner include pre and post monsoon inspections which include;

- 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 and also to be forwarded to NDSA & SDSO.

3.3.1 Pre and Post-Monsoon Inspection

The form and checklist provided as Annexure B to the Guidelines for Safety Inspection of Dams published by Central Water Commission, shall be followed for conducting scheduled inspections including Pre and Post Monsoon Inspections.

3.3.2 Special (Unscheduled) Inspections

Special inspections may need to be performed to resolve specific concerns or conditions at the site on a non-scheduled 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 SDSO after an initial assessment based on informal inspection carried out by project personnel reveal dam safety related concerns like cracking in the weir, damages, erosion/scour, undermining /piping/ sinkholes/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. Review of available relevant files or data,

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.

3.4 Informal Inspections

An informal inspection, is a continuing effort by on-site personnel (dam owners 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 Vellathooval Diversion Weir 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 stretch. 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 hydro mechanical components prepared based on manual of operating parts is included in Chapter 2 - Project operation and section 4.4.2.2 Routine Maintenance. This shows tasks to be performed and how frequently to be inspected/observed and repaired.

4.2 Maintenance Priorities

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

4.2.1 Immediate Maintenance

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

- The dam is about to be overtopped or being over topped during high flood.
- The dam showing signs of piping or internal erosion along faults, weak zone etc. indicated by increasingly cloudy seepage or other symptoms.
- A dam showing signs of failure due to aging/cracking, sliding, overturning etc.
- The spillway being blocked.
- Evidence of excessive seepage as seen in the gallery/on downstream face of the dam.

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

4.2.2 Preventive Maintenance

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

4.2.2.1 Condition Based Maintenance

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

- Remove all vegetation and bushes by roots from the dam surfaces, restoring any eroded areas.
- Repair of defective gates, valves, and other hydro-mechanical equipment.

- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/ foundations in concrete / masonry dams.
- Repair any damages on spillway glacis, piers, energy dissipaters, training walls, downstream area etc.
- Repairs on u/s face of dams in case the lift joints are damaged resulting in increased seepage.
- Controlling any heavy seepage in the foundation
- Repairs of any cracks/ cavities/ joints in concrete structures.
- Desiltation of the reservoir

However, many of these works will require the services of experienced engineers/ experts.

4.2.2.2 Routine Maintenance

Several tasks should be performed on a continuous basis. These include but 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 (muddy) 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 etc. Servicing of gates (Intake and Emergency gates), hoisting arrangements of gates, valves of outlet works/sluices
- Maintaining proper lighting at dam top.
- Maintenance access roads.
- Operation of electrical and mechanical equipment and systems
- To keep the gate slots, clear of silt/debris.
- Maintenance/testing of monitoring equipment and safety alarms.
- Testing of security equipment.
- Testing of communication equipment.
- Any other maintenance considered necessary.

4.3. Procedure for Routine Maintenance

4.3.1 Maintenance to the vertical lift gates

Vertical lift gates are provided at the intake of the weir for controlling the flow to penstock and scour outlet. The aspects to be inspected and maintained periodically for ensuring proper

operation of these gates are as under;

1. 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.
2. The gate leaf should be thoroughly cleaned and repainted at 5year interval or 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.
3. 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 found leaking excessively should be adjusted, repaired or replaced as considered necessary.
4. 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.
5. Hoisting connection of the gate leaf should be lubricated where necessary and defects if any should be rectified.
6. All nuts, bolts, check nuts and cotter pins of the lifting devices should be checked periodically.
7. All components should be greased and lubricated. Recommended and approved oils and grease only should be used.
8. 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.
9. 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.
10. The guide-assemblies, wheel-assemblies and sealing-assemblies shall be cleared off grit, sand or any other foreign material.
11. The wheel pin shall be coated with corrosion resistant compound.
12. All nuts and bolts shall be tightened.
13. 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 re painted, 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. 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.

4.3.2 Maintenance to 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 frequently to ensure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

4.3.3 Trash Rack Cleaning

Since the river carries heavy trash loads a rake-cleaning machine may be installed. Access to the downstream side of the trash rack is provided through a manhole in the operating platform. There are 5 trash rack panels between two columns. The total number of panels are 25 Nos. The gap between trash rack bars are 50mm. The accumulation of floating trash, bottles, vegetation, bamboo stumps, decayed vegetables, domestic wastes, dead animals etc. will be prevented by the trash rack structure installed in weir to enter. Regular trash rack cleaning is necessary in monsoon days for the proper functioning of turbines.

4.3.4 Maintenance of access roads

Access road surfaces must be maintained to allow safe passage of automobiles and any required equipment for servicing the dam in all 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 a long road for proper drainage. This will prolong the life of the road. Road surfacing should be repaired or replaced as per requirement.

4.3.5 General cleaning

For proper operation of spillways, inlet and outlet structures, energy dissipation arrangements, 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 in to the reservoir.

4.3.6 Maintenance of Electrical Systems

Electricity is typically used at a dam for lighting and to operate the gates, hoists, recording equipment, and other miscellaneous equipment. It is important that the Electrical system be well maintained, including a thorough check of fuses and a test of the system to ensure that all parts are properly functioning. The system should be free from moisture and dirt, and wiring should be checked for corrosion and mineral deposits. All necessary repairs should be carried out immediately and records of the works kept. Maintain generators used for auxiliary emergency power - change the oil, check the batteries and antifreeze and make sure fuel is

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

4.4 Materials and establishment requirements during monsoon

Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked inadequate quantities for emergency situations that may arise. The requirements of annual and monsoon establishment for the operation and maintenance of a dam is to be decided by the Dam Owners on a case to case basis. Details of man power/ 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 should essentially include the following items:

i) **Establishment Cost of Regular Staff** - Salaries and other eligible allowances,

ii) **Establishment Cost of Work charged Staff** - salaries and other eligible allowances,

iii) **Office Expenses** – Telephone/Mobile/any other Telecommunication facility, 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 etc.

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, 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 access roads & basic facilities, provision for flood contingency works during monsoon, unforeseen events/ items etc.

4.6 Maintenance Records

Maintenance records are of utmost importance. A record register 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 time taken to complete the work with dates,
- Equipment and materials used, and
- Before and after photographs.
- Due date for next maintenance.

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

Chapter 5 : Instrumentation and Monitoring

A dam's instrumentation furnishes data for deciding if the structure is functioning as intended and provides continuous monitoring to warn of any unsafe developments. Monitoring physical phenomena that can lead to a dam failure may draw information from a wide spectrum of instruments and procedures ranging from simple to complex.

5.1 Instrument Types and Usage

A wide variety of instruments and procedures are used to monitor dam behavior. The minimum number of set of instrumentation for monitoring the performance of dams as per 07 regulations under Section 54 (2) of Dam Safety Act, 2021 includes:

- movements (horizontal, vertical, rotational and lateral);
- pore pressure and uplift pressures;
- water level;
- seepage/leakage flow;
- Temperature
- Crack and joint movement
- seismic activity;
- Stress-strain

However, since each dam is unique, the additional instruments, if required shall be installed considering site conditions and using engineering judgement.

5.1.1 Water Level

Vellathooval Diversion weir is a small weir with free overflow spillway. Galleries are not provided. Reservoir water level is monitored daily.

5.1.2 Seismic Activity

The project area falls in zone No. III of the seismic zone map of India. The weir is designed for seismic stability for Zone III as per BIS 6512 Historical significant earthquake events in the near vicinity areas are noted below which occurred before the construction of the weir.
Event 1: Date: November 1998, Epicenter: Nedumkandam, Magnitude : 4.5 and

Event 2 : Date: 12/12/2000, Epicenter: Erattupetta, Magnitude: 5

Nearest Seismic observatory is at Meencut.

5.2 Dam Performance Evaluation

Performance evaluation is to be conducted for safe normal operation before and after monsoon.

5.3 Methods of Behavior Prediction

5.1.3 Visual Observations

Observations by onsite inspection of officials (dam owners/operators and maintenance personnel) may be the most important and effective means of monitoring the performance of a dam. An officer should examine visually by walking along the dam alignment to see if any leakages, any distress, wet spots on the surface of weir, seepage from foundation etc. is there.

5.1.4 Monitoring Results

Analysis and observation of the water level, leakages, and other parameters can ascertain the behavior of the dam. 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 Works

6.1 Works carried out

The dam was commissioned in October 2017. During the 2018 flood, the dam overtopped, and water rushed into the Panniyar Power house, causing heavy damage. The access road was also damaged to a large extent. Tailrace walls were collapsed. Board accorded sanction to attend rehabilitation measures vide B.O(FTD) No. 137/2019(DGC/AEE II/ Panniyar& Vellathooval road) dated 16.02.2019.

The following works were carried out,

- Construction of flood wall up to El. + 479 .00 m along the access road and over the non overflow portion
- Dismantling of the walk way bridge over the spillway and support piers.
- Reconstruction of tail race side walls.
- Clearing the intake area from accumulated sand/ silt etc.
- Clearing some portions of downstream river.

Chapter 7 : Updating the Manual

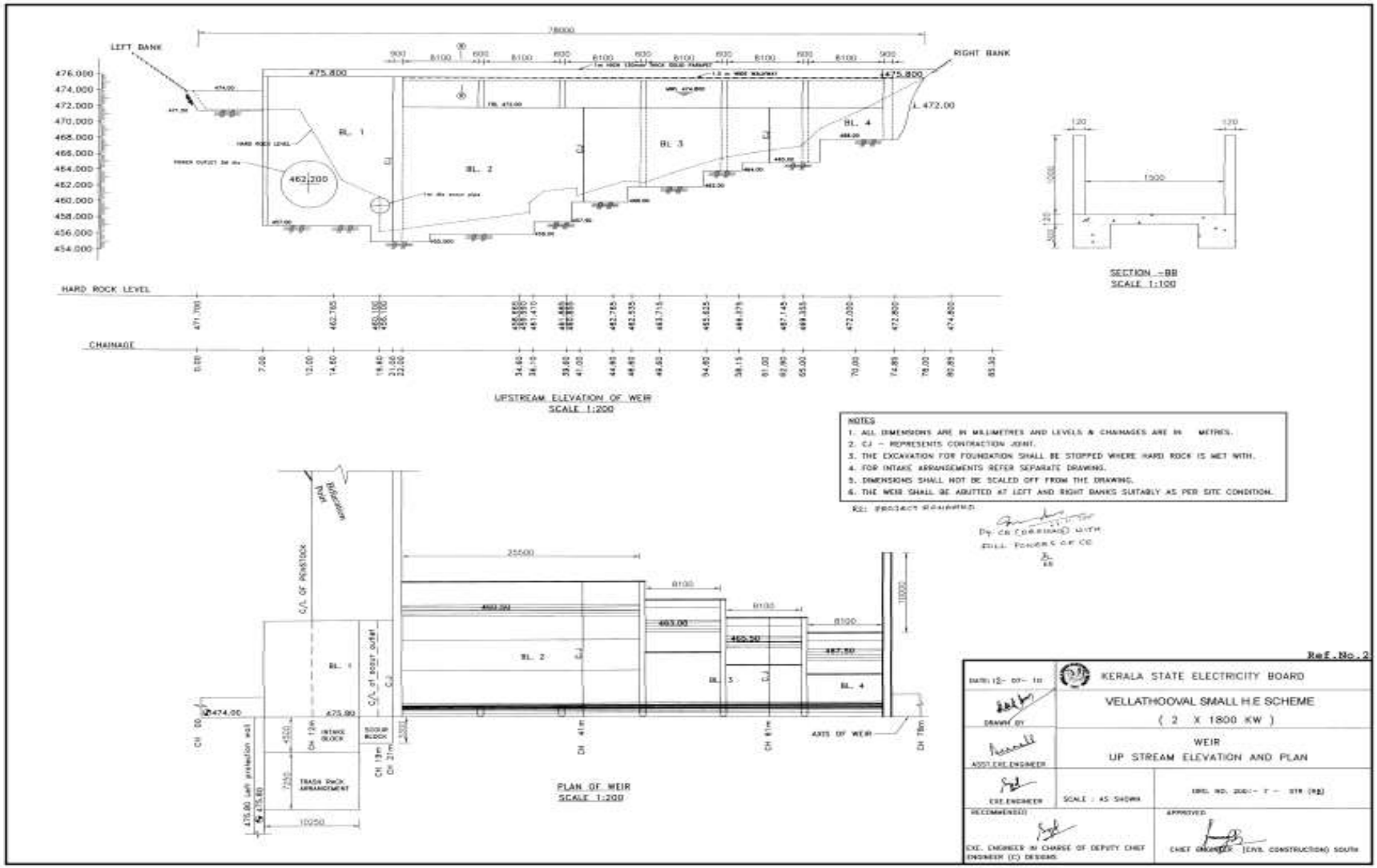
Whenever features of the dam and appurtenant structures change, the O & M Manual must be edited and portions rewritten to reflect these changes. This task is often ignored. Updating information in the O&M Manual should be done whenever major changes like construction of an additional spillway, construction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

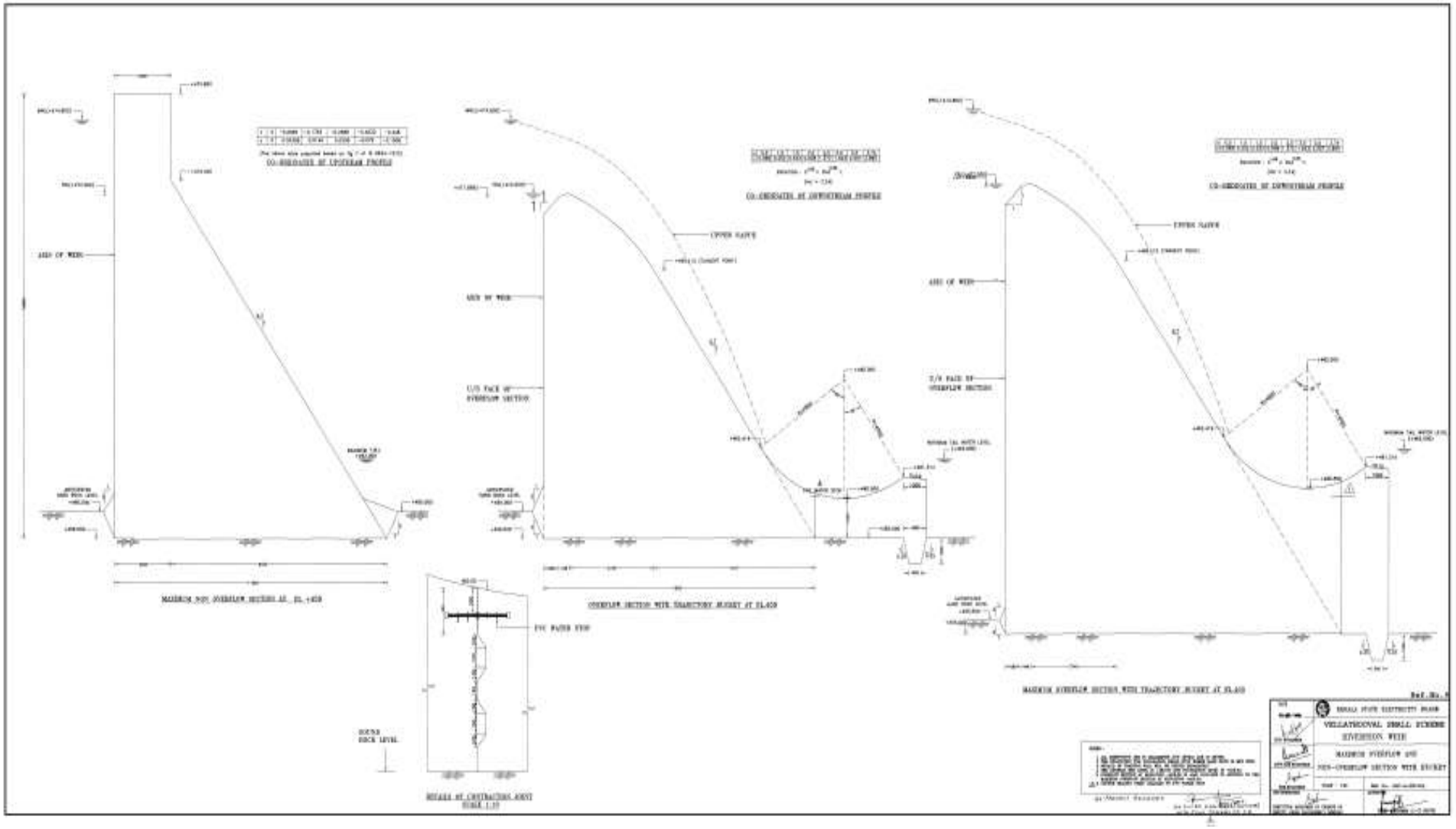
It is recommended that the O&M Manuals maybe reviewed/ updated after every 10 years or whenever there is any change in the information given in the Manual needs updation by the respective Dam Owners.

Annexures

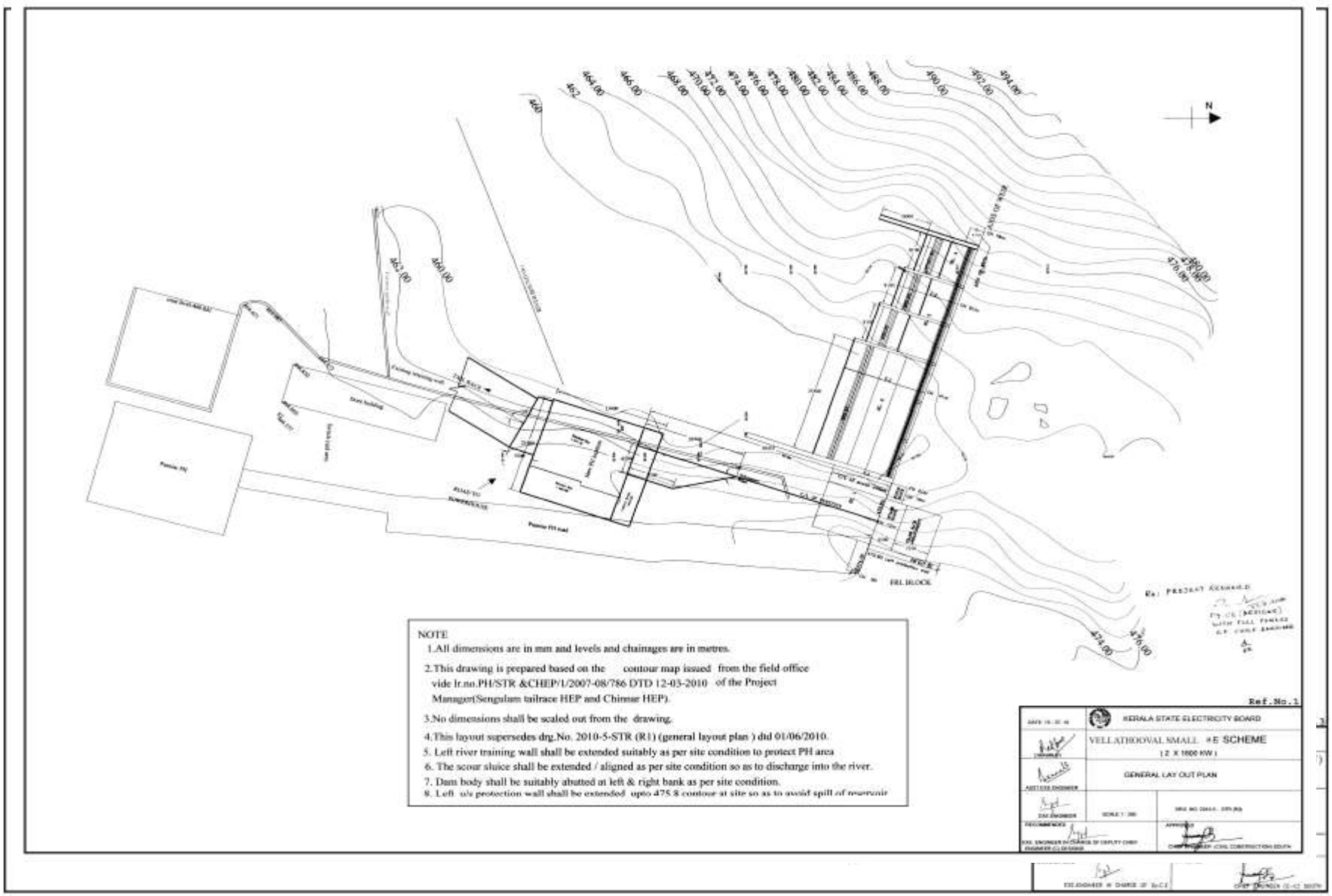
ANNEXURE I - Drawings



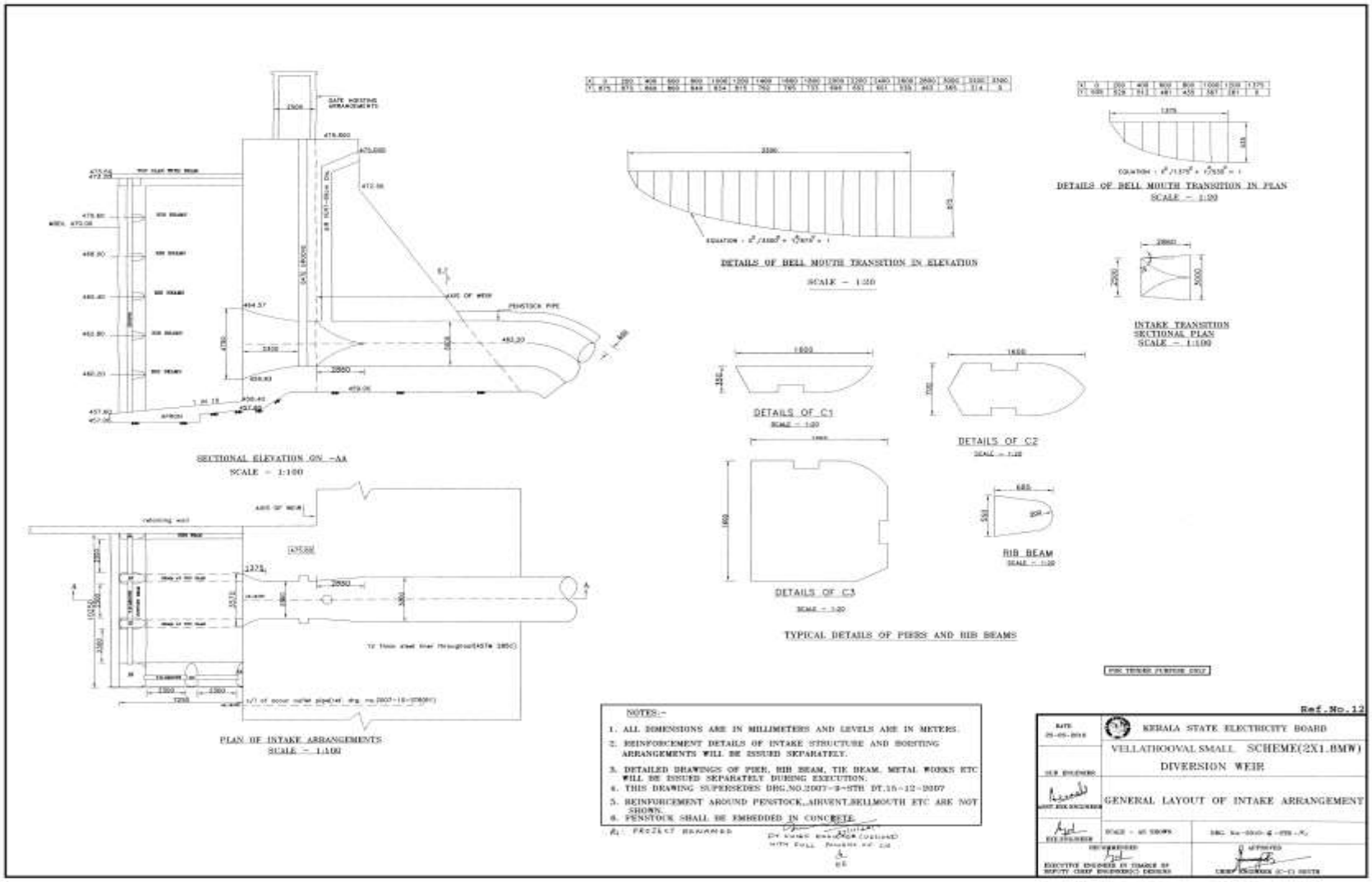
Drg. 1: Plan - Vellathooval Diversion Weir



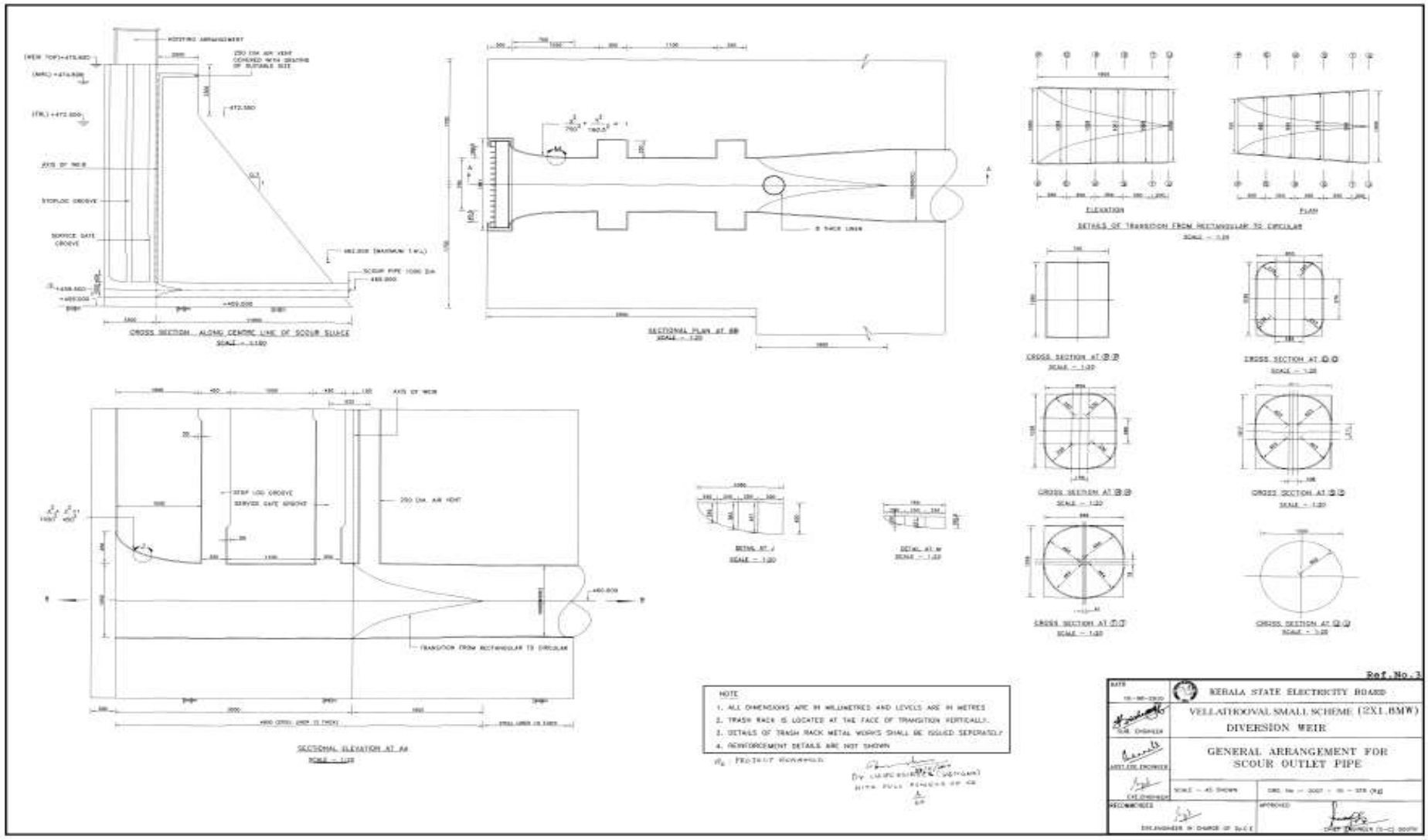
Drg. 2: Cross Sections - Vellathooval Diversion Weir



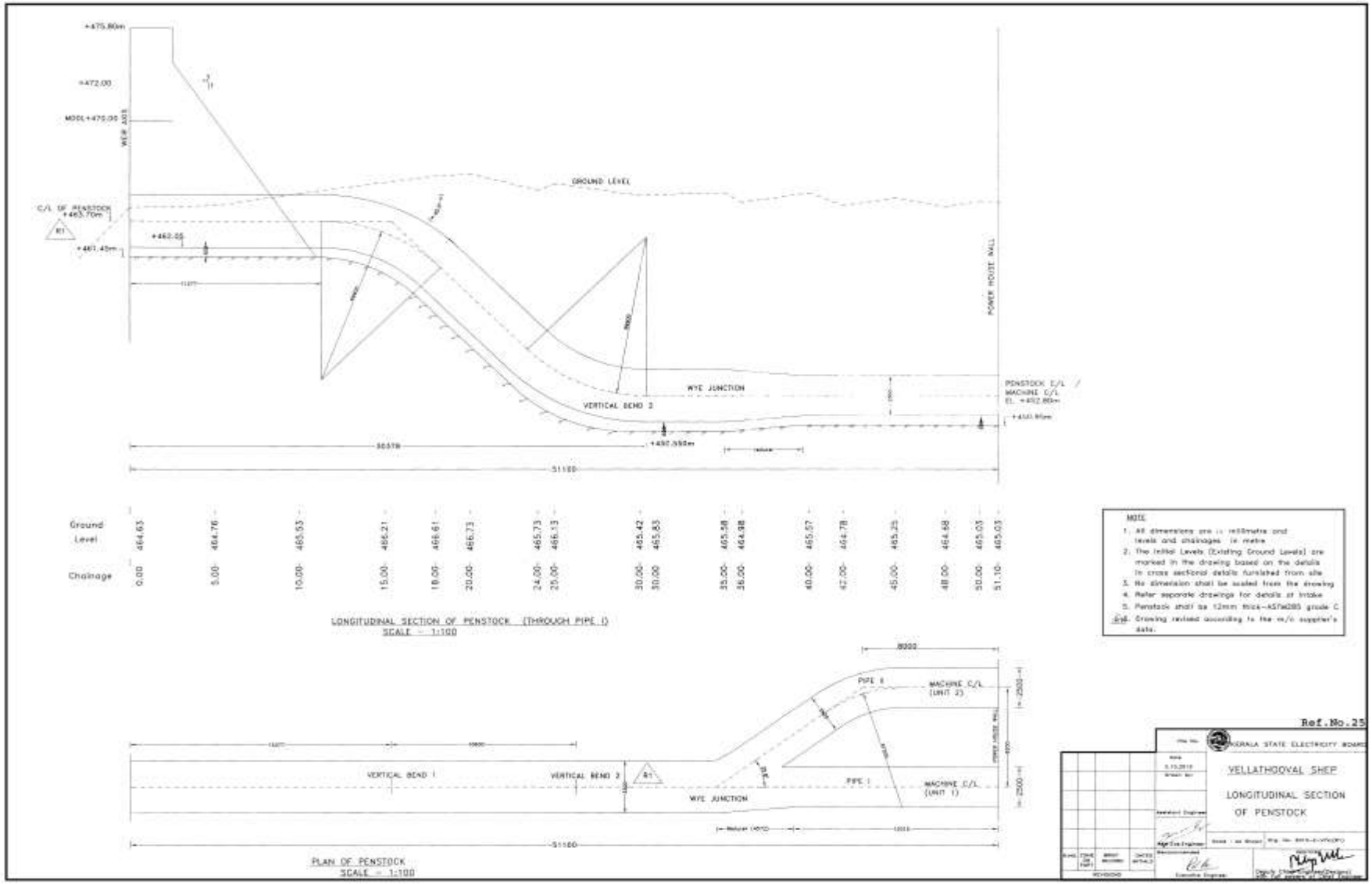
Drg. 3: General Arrangements of Weir and Power House - Vellathooval SHEP



Drg. 4: General Arrangements of Intake Gate

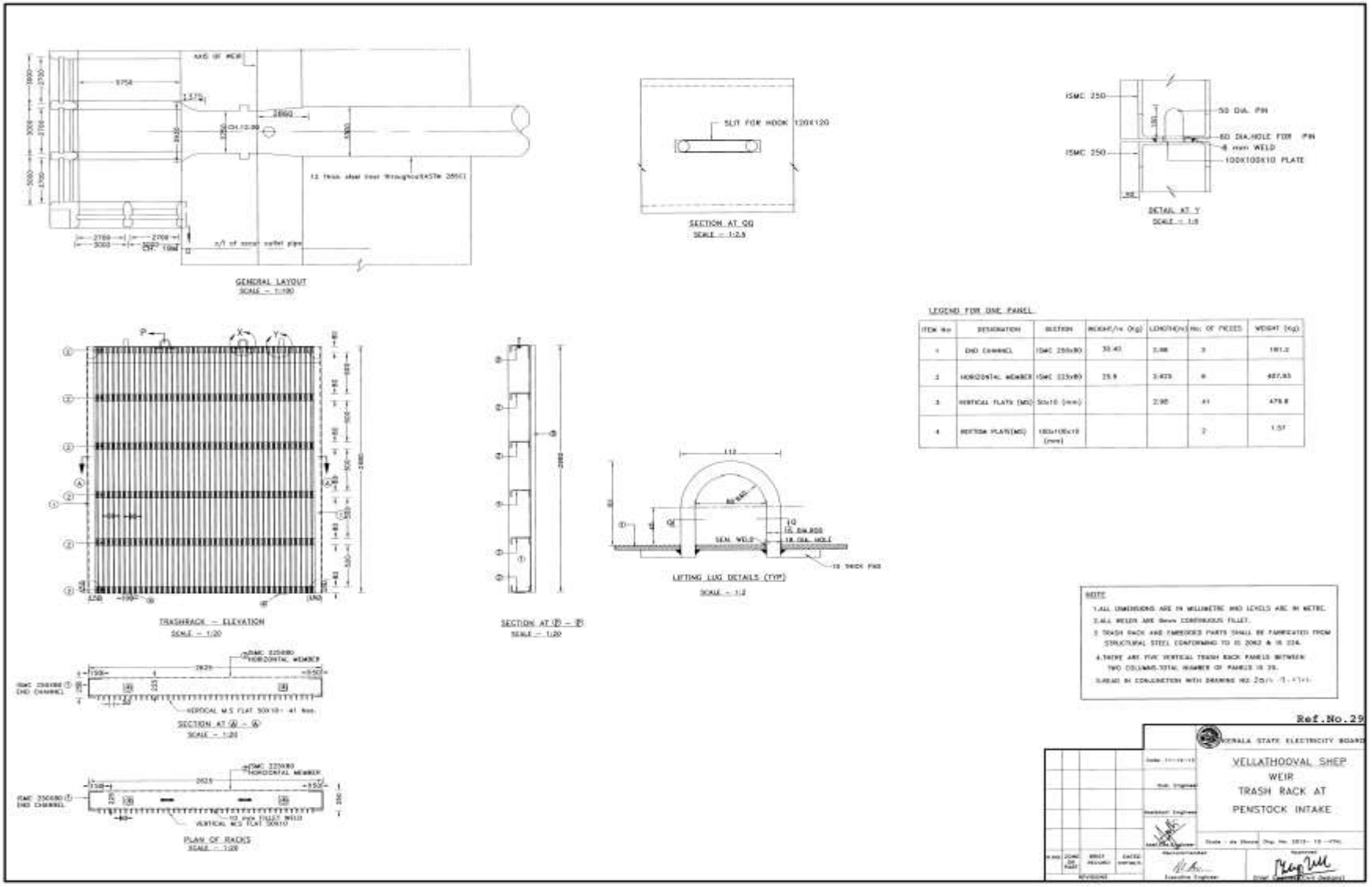


Drg. 5: General Arrangements of Scour Outlet

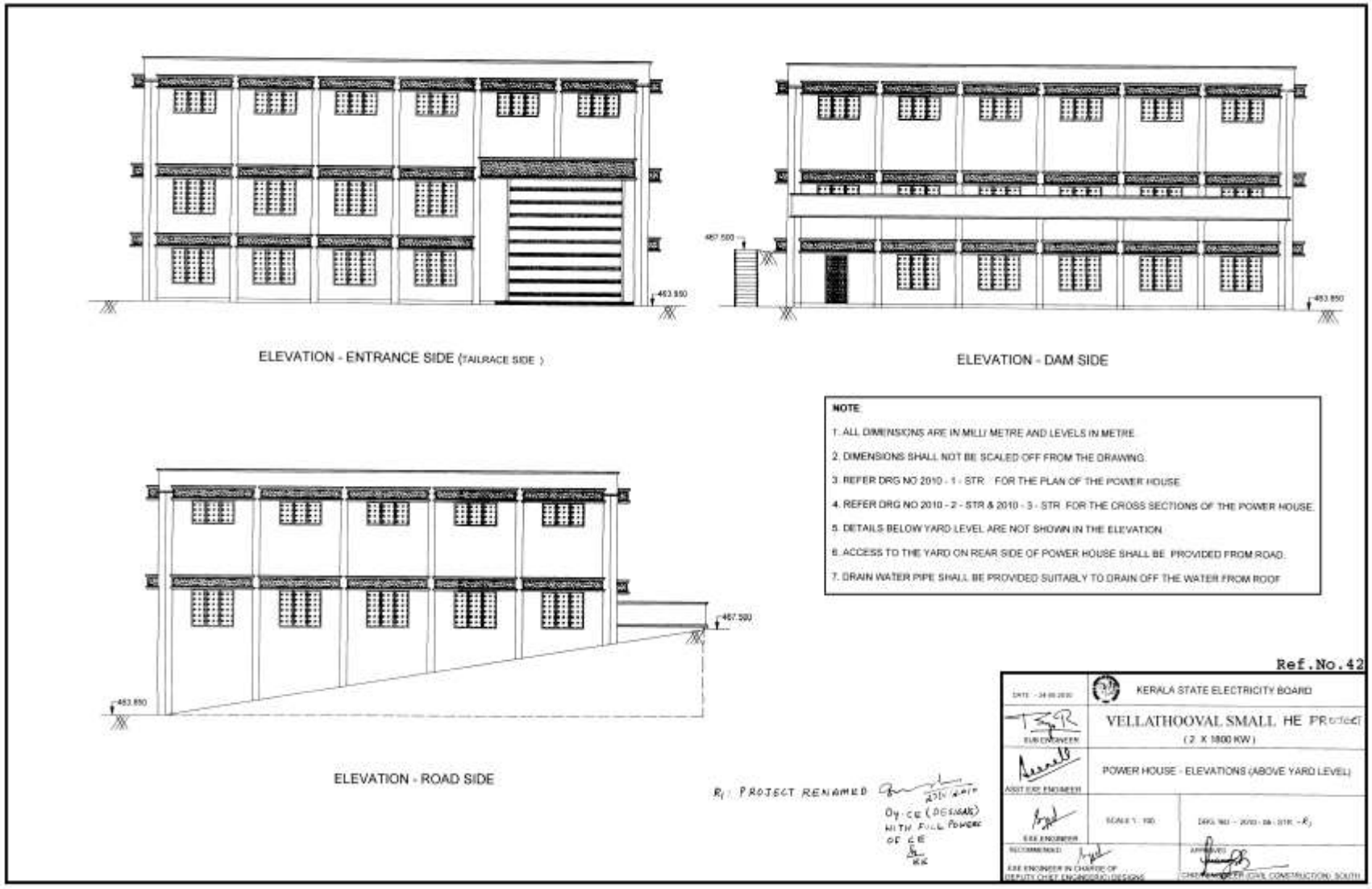


Drg.

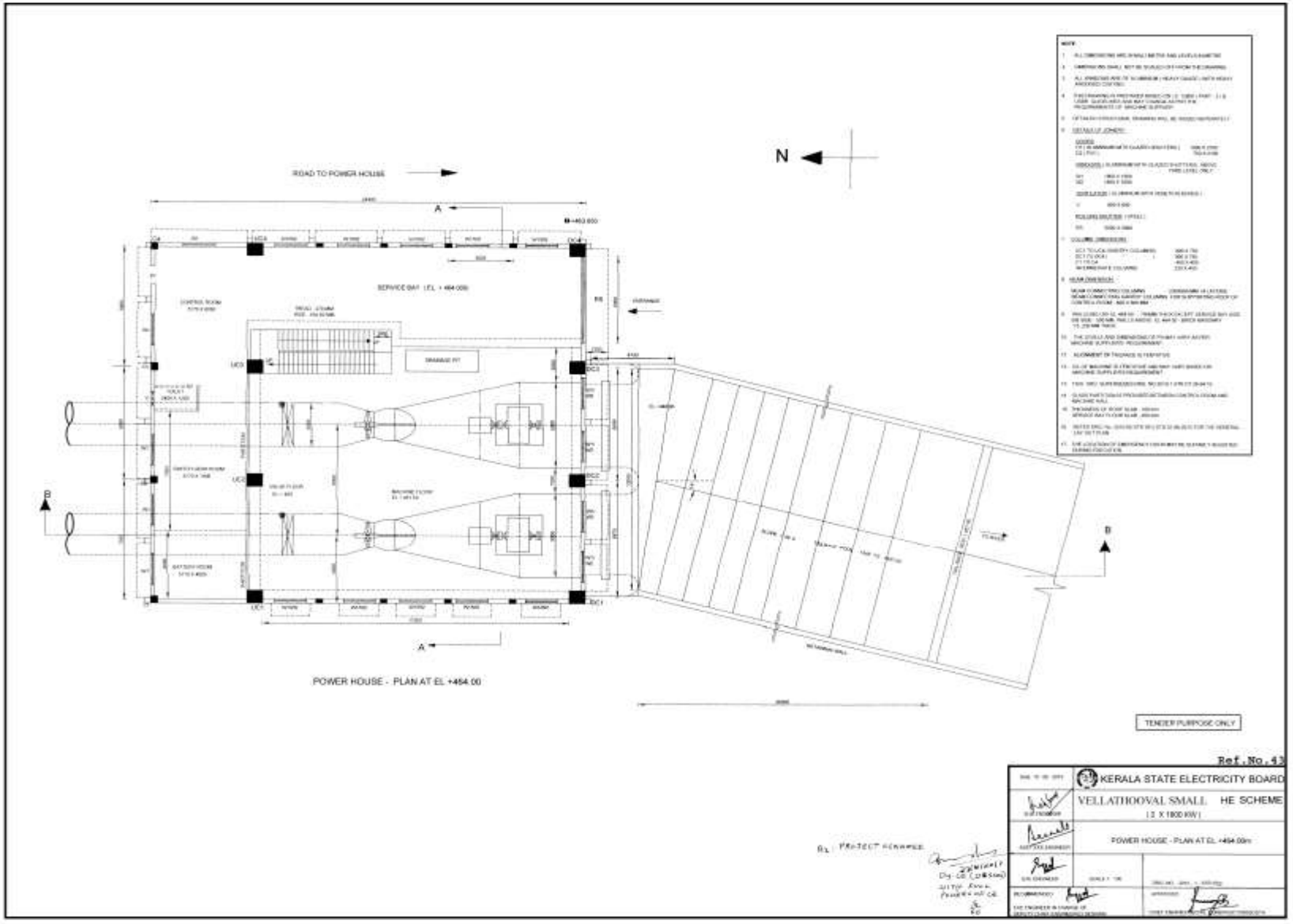
6 : General Arrangements of Penstocks



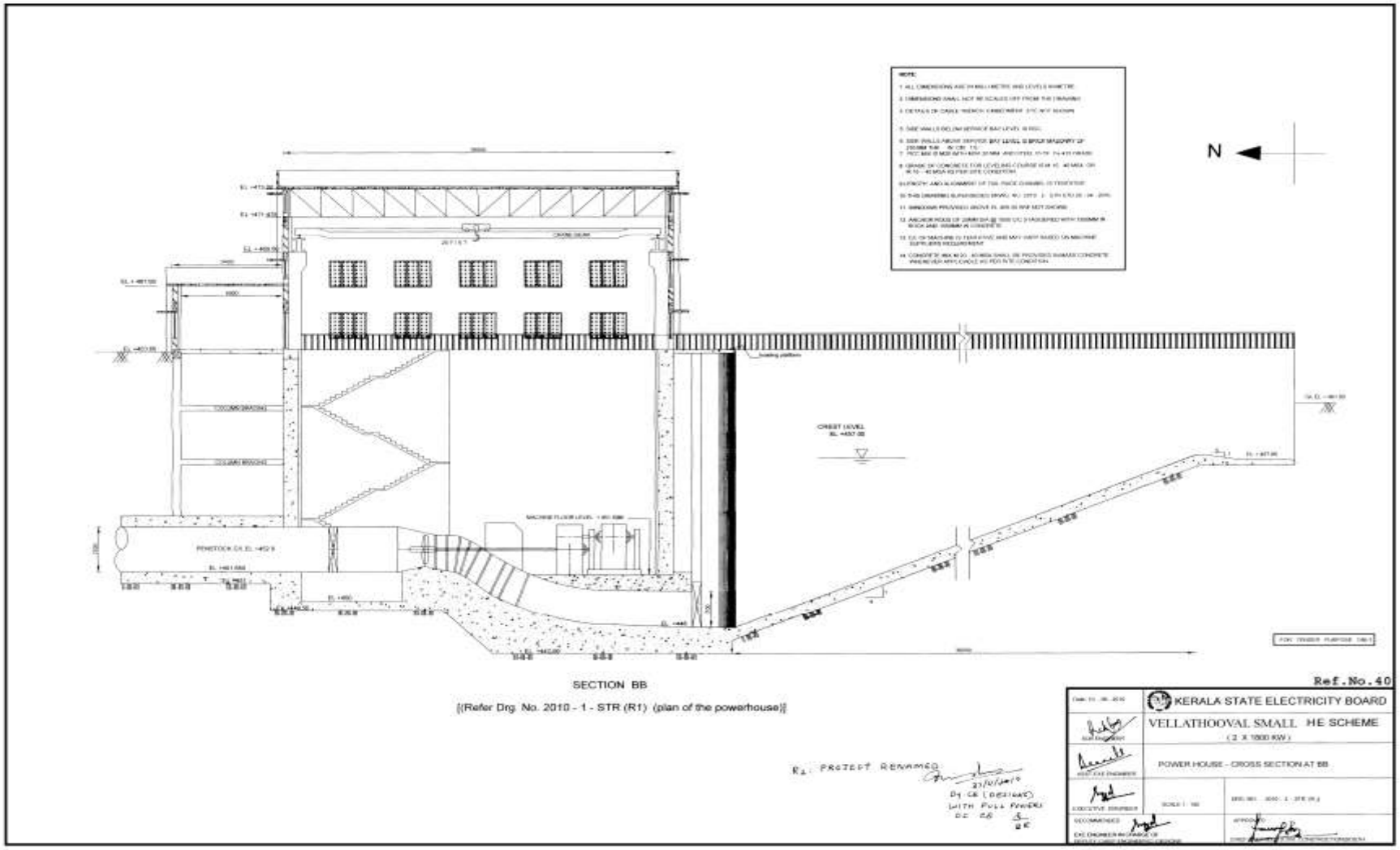
Drg. 7: General Arrangements of Trask rack



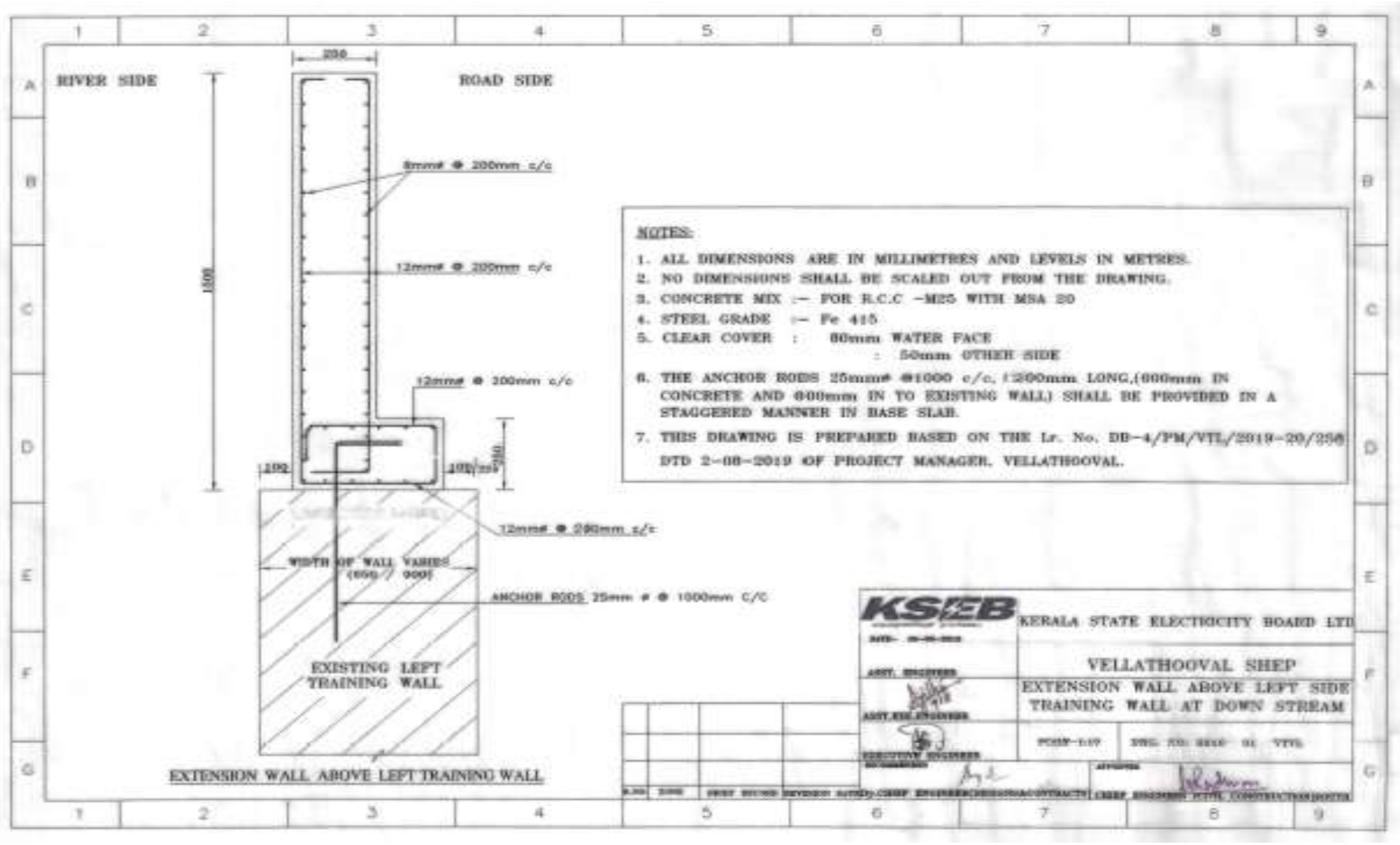
Drg. 8 : Power House Elevation and Sections


ROAD TO POWER HOUSE
N
SERVICE BAY (EL + 464.00)
POWER HOUSE - PLAN AT EL +464.00
TENDER PURPOSE ONLY
Ref.No.43
KERALA STATE ELECTRICITY BOARD
VELLATHOOVAL SMALL HE SCHEME
(2 X 1800 KW)
POWER HOUSE - PLAN AT EL +464.00m

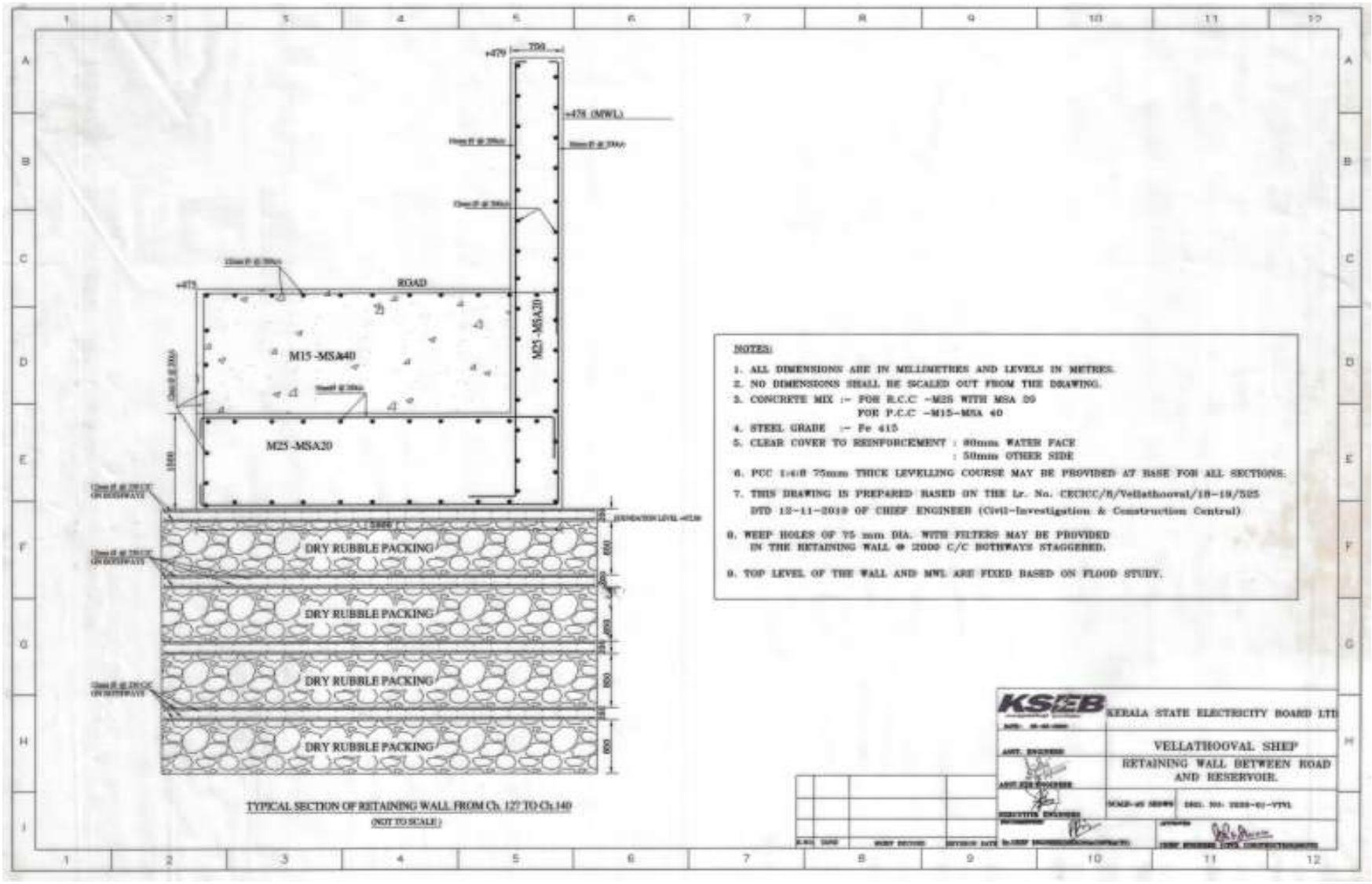
Drg. 9 : Power House Plan



Drg. 10: Power House Section



Drg.11: Rehabilitation Works



TYPICAL SECTION OF RETAINING WALL FROM Ch. 127 TO Ch.140
(NOT TO SCALE)

Drg. 12: Rehabilitation Works

ANNEXURE II - Design Flood Review

REPORT ON DESIGN FLOOD REVIEW

VELLATHOOVAL DIVERSION WEIR

1/KSEBL/DFR/VELLATHOOVAL/2023

KERALA STATE ELECTRICITY BOARD LIMITED

Chief Engineer (Civil – Dam Safety & DRIP) March 2023

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Report on Design Flood Review of Vellathooval Diversion Weir

1. Background

Vellathooval diversion weir is constructed as part of Vellathooval Small Hydro Electric Project (2X1.8 MW). The project is located in Idukki District. Geographic coordinates of location of the weir is 9° 58' 28" N, 77° 01' 40" E. The weir is constructed across Muthirapuzha in the near upstream of Kallarkutty reservoir. Series of dams are there in the upstream catchment of this weir across main river as well as in its tributaries. The major dam projects in the upstream are Maduppetty and Ponmudi. The streams in upstream catchment are extensively controlled and the flow in the river is regulated to a large scale by the upstream projects. There is a diversion project under construction in the stream Kallar, a tributary of Muthirapuzha, flowing on the Northern side and joins with main stream downstream of Vellathooval weir. The diversion from Kallar will be routed through Sengulam reservoir for improving the power generation from Sengulam. Tail water from Sengulam Power station releases to Muthirapuzha in the upstream of the weir. But the controlled releases from the Power station is insignificant compared to the flow in the main river during active monsoon. Hence contribution of the diversion is not included in the present study.

The pondage of the weir is 0.07 Mm3. The weir divert water to the power station of Vellathooval Small Hydro Electric Project (SHEP). Vellathooval SHEP is purely a diversion project. The maximum height of the weir is 16.8 m and the hydraulic head is about 13.5 m. Hence the weir falls under the intermediate category for estimating the design flood. Project lay out is shown in Figure 1.1.

Figure 1.1 : Project Layout

1

The length of the weir is 72 m. Length of overflow section is 50.40 m. The cross section of overflow section is shown as Figure 1.2 and Plan of the structure is shown as Figure 1.3.

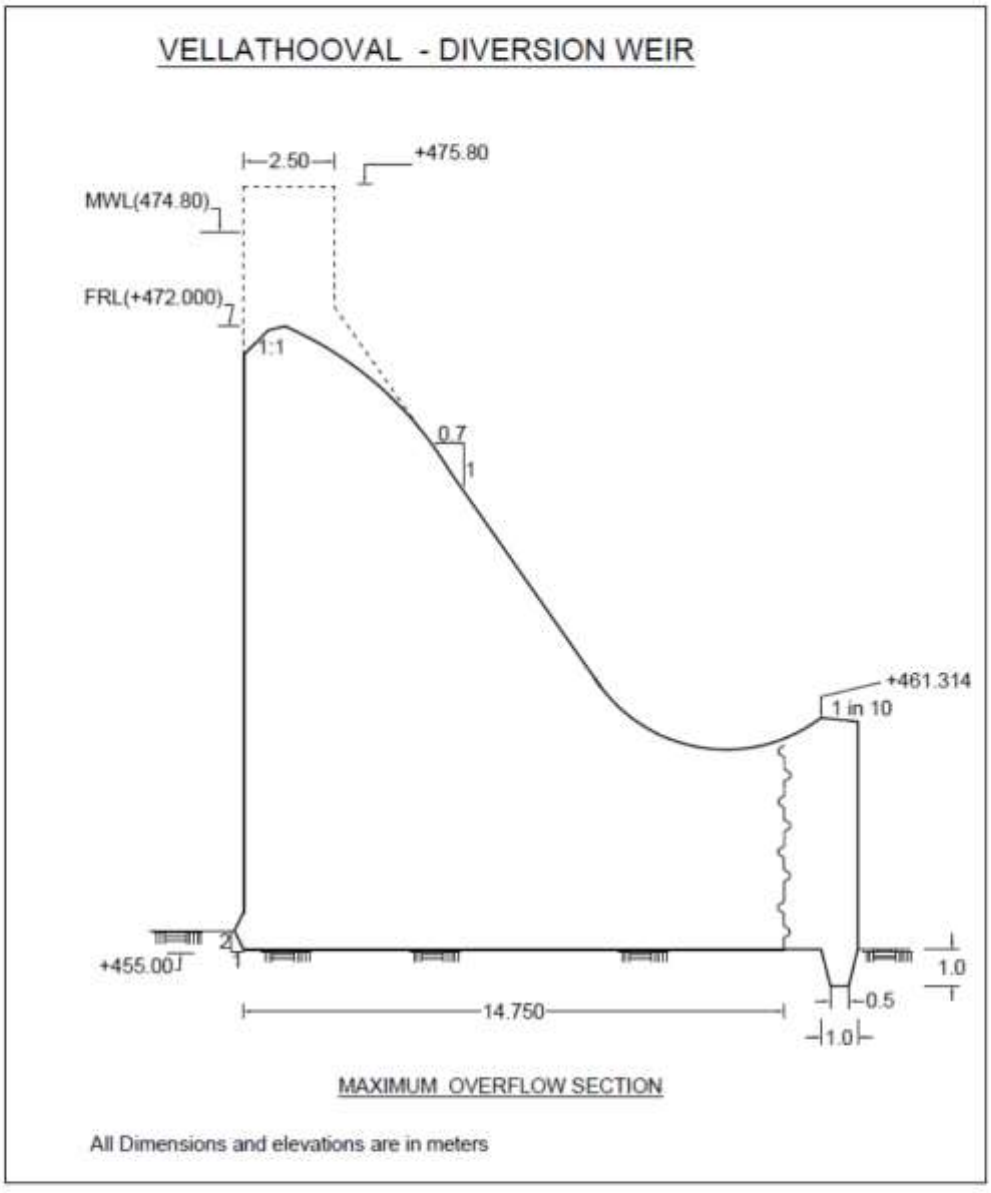

Figure 1.2 : Cross Section – Overflow Section

2

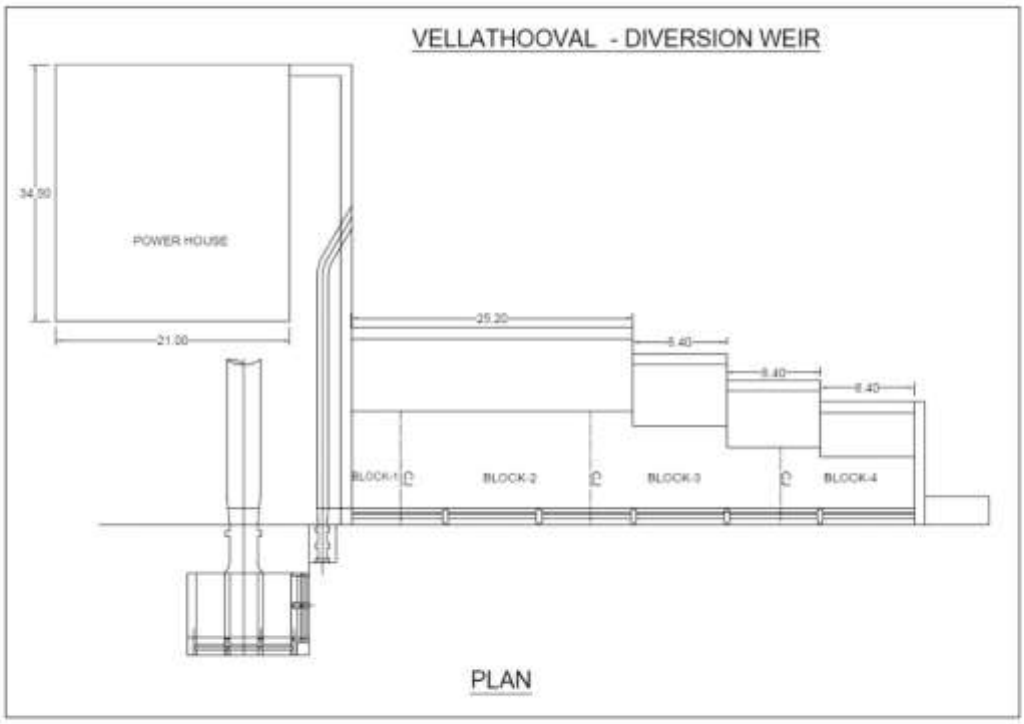

Figure 1.3: Plan – Vellathooval Diversion weir

3

Design flood of the project is estimated with updated information and following the procedures laid down in Flood Estimation Report & PMP Atlas 2015 published by the Central Water Commission. DFR studies are now made as part of conducting the dam break analysis of specified dams, to comply with the relevant provisions of Dam Safety Act 2021, so as to determine the extent of inundation and to estimate the flood hazard parameters and preparing Emergency Action Plan.

2. Project catchment

The catchment area of the project is 628 Km2. Out of this 101 km2 is intercepted by Maduppetty project and 280 km2 is intercepted by Ponmudi. As there no control to regulate spill at Anayirankal, a dam at the upstream of Ponmudi, this project is not considered independently. Ponmudi catchment include the catchment of Anayirankal dam also and is considered as one unit. Free catchment of the weir is 247 Km2. Catchment area map of the project is shown in Figure 2.1.

Figure 2.1: Catchment Area Map

3. Categorisation

Hydraulic head of the weir is more than 12 m and hence the design storm for the project is SPS and design flood is SPF.

4. Design storm

1924 Devikulam storm is considered to estimate SPS. Eye of this storm is located within the catchment. Still the storm is transposed to get the highest value of spatial average of the precipitation over the basin. The project catchment is delineated using Arc Hydro Tools and sub catchments are delineated with outlets at Maduppetty & Ponmudi Dam points. Uncontrolled catchment at Vellathooval weir is also separated. The shape file of the storm is used for transposition. Transposition is done using GIS tools. Spatial average of the

transposed storm is determined from the raster generated from storm isohyets by performing Zonal statistics. One-day rainfall over free catchment is estimated as 39.5 cm and the same for Maduppetty and Ponmudi sub catchments are 33.2 cm and 38 cm respectively.

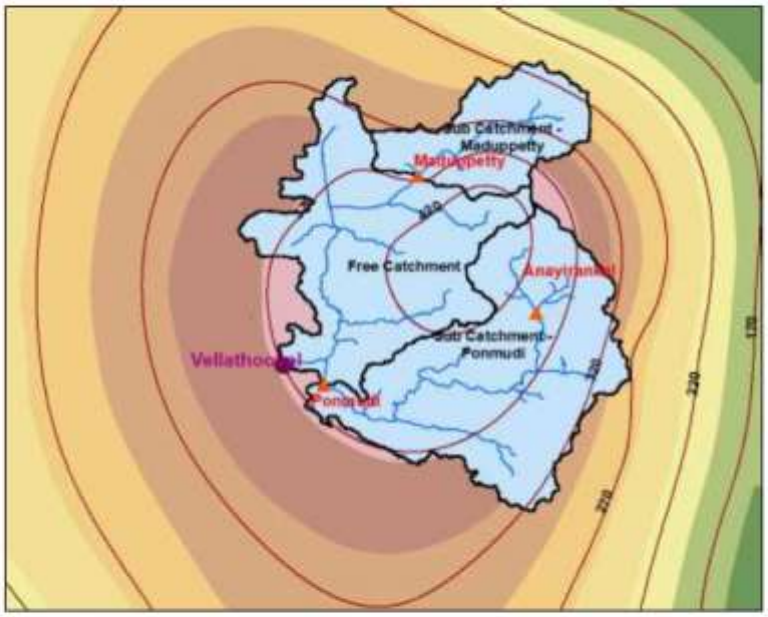

Figure 4.1 : Isohyetal Map of 1924 Devikulam Storm - Transposed

The hydrological analysis is carried out considering the project catchment as three units viz. Free catchment, Maduppetty and Ponmudi sub catchments.

5. Estimation of Design flood.

The design flood hydrograph of this Project is derived after modelling the basin in HEC-HMS. For free catchment, the unit hydrograph is derived from catchment parameters. For Maduppetty and Ponmudi sub catchments unit hydrograph provided by the Central Water Commission in the Design Flood Report of the respective projects are directly taken. The flood routing studies of Maduppetty and Ponmudi reservoirs are carried out in HEC-RAS. Channel routing is done in HEC HMS. The details of model are explained under section 6.

5.1. Free Catchment

5.1.1 Derivation of Unit Hydrograph

Sl No.	Parameter	Value	
1	Catchment area (A)	247	km2
2	Longest river length from outlet (L)	37.020	km
3	Equivalent stream slope along longest stream (Seq.)	41.771	m/km

Table 5.1: Catchment Parameters

Parameter	Unit	Value
tp	hr	1.619 (say 1.5 hrs.)
qp	cumec/sq. km	0.967

5

W50	hr	1.997
W75	hr	1.055
WR50	hr	0.601
WR75	hr	0.359
TB	hr	9.939 (say 10 hrs.)
Qp	cumec	238.8
Tm	hr	2

Table 5.2: Unit hydrograph parameters as per FER-5(a) & 5 (b)

Time (hr.)	Ordinates of UH (cumec)
0	0.00
1	76.00
2	238.00
3	170.00
4	97.00
5	52.00
6	28.00
7	15.00
8	8.00
9	3.00
10	0.00

Table 5.3: Unit Hydrograph ordinates

Figure 5.1 : Unit Hydrograph of Vellathooval Free Catchment

6

5.1.2 Determination of rainfall excess and critical sequencing

Average rainfall over the free catchment is 39.5 cm. 12 hr bell distribution of rainfall is shown in Table 5.4. Hourly distribution of rain fall is shown in Table 5.5. Loss considered is 0.19 cm/hr. The rain fall excess is shown in the Table 5.6. Rainfall series after Critical sequencing is shown in Table 5.7. and Figure 5.2.

Standard Project Storm	39.50 cm
24 hr. rainfall (with 15% clock hour correction restricted to maximum 50 mm)	44.50 cm
Depth of 12 hr. bell (0.71 x 44.5)	31.60 cm

Table 5.4: 12 Hr Bell Distribution – Free Catchment

Time	Hourly Distribution (cm)
1	6.22
2	4.14
3	3.35
4	2.75
5	2.02
6	1.99
7	2.12
8	2.78
9	1.77
10	1.61
11	1.26
12	1.58

Table 5.5: Hourly Distribution – Free Catchment

Time	Hourly Rainfall excess (cm)
1	6.03
2	3.95
3	3.16
4	2.56
5	1.83
6	1.80
7	1.93
8	2.59
9	1.58
10	1.42
11	1.07
12	1.39

Table 5.6: Hourly Rainfall excess – Free Catchment

7

Time	Hourly rainfall after critical sequencing (cm)
1	1.07
2	1.39
3	1.58
4	1.80
5	1.83
6	1.93
7	2.56
8	3.16
9	3.95
10	6.03
11	2.59
12	1.42

Table 5.7: Hourly Rainfall after critical sequencing – Free Catchment

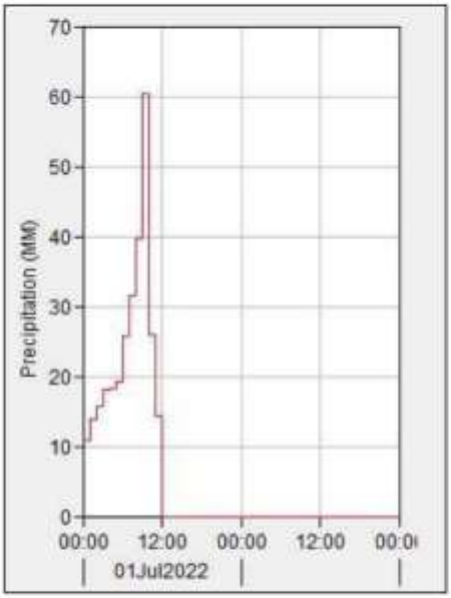

Figure 5.2: Hourly Rainfall after critical sequencing – Free Catchment

8

5.1.3 Inflow Hydrograph

The Inflow peak from free catchment is estimated from model as 2882.5 m3/s. The results are shown below in tabular and graphical format.

Time	Inflow from Free Catchment (m3/s)
00:00	0.0
01:00	118.4
02:00	397.3
03:00	669.8
04:00	890.0
05:00	1063.6
06:00	1180.8
07:00	1313.8
08:00	1559.3
09:00	1896.1
10:00	2418.7
11:00	2882.5
12:00	2455.6
13:00	1753.9
14:00	1027.8
15:00	570.7
16:00	315.0
17:00	175.8
18:00	97.2
19:00	56.2
20:00	41.3
21:00	37.0
22:00	37.0
23:00	37.0
24:00	37.0
25:00	37.0
26:00	37.0
27:00	37.0
28:00	37.0

Table 5.8: Inflow – Free Catchment

9

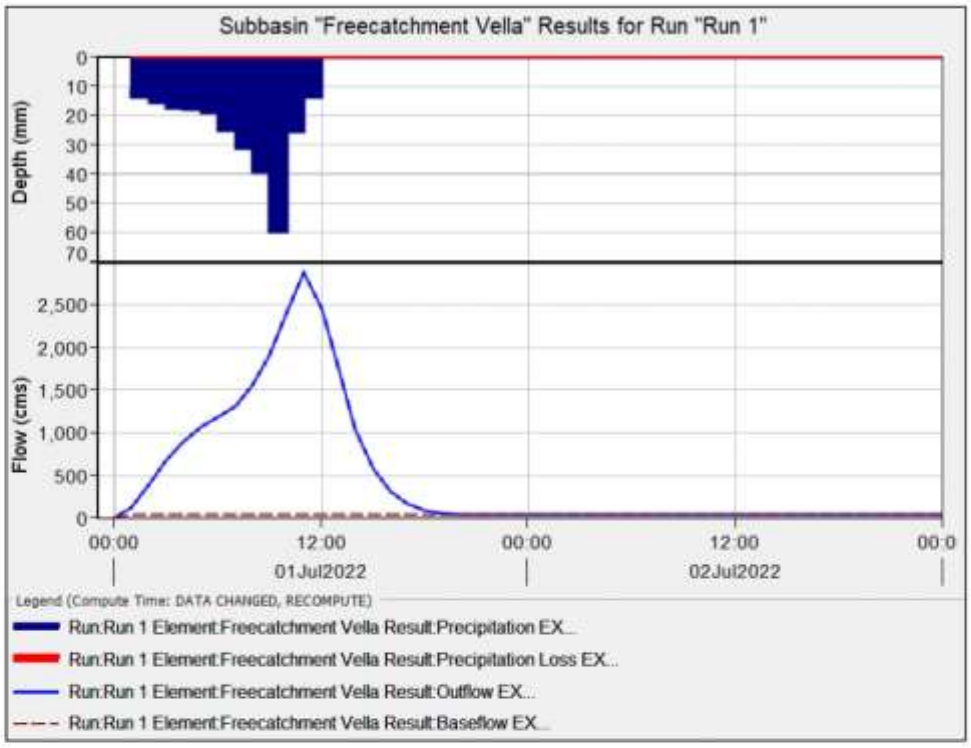

Figure 5.3: Inflow Hydrograph – Free Catchment

5.2. Maduppetty Sub Catchment

5.2.1 Derivation of Unit Hydrograph

The unit hydrograph of Maduppetty dam point is taken from the DFR of Maduppetty project prepared by the Central Water commission (CWC).

Time (hr.)	Ordinates of UH (cumec)
0	0
1	10
2	27
3	79
4	55
5	35
6	26
7	19
8	13
9	9
10	6
11	3
12	0

Table 5.9: Unit Hydrograph ordinates (from CWC DFR 2020)

10

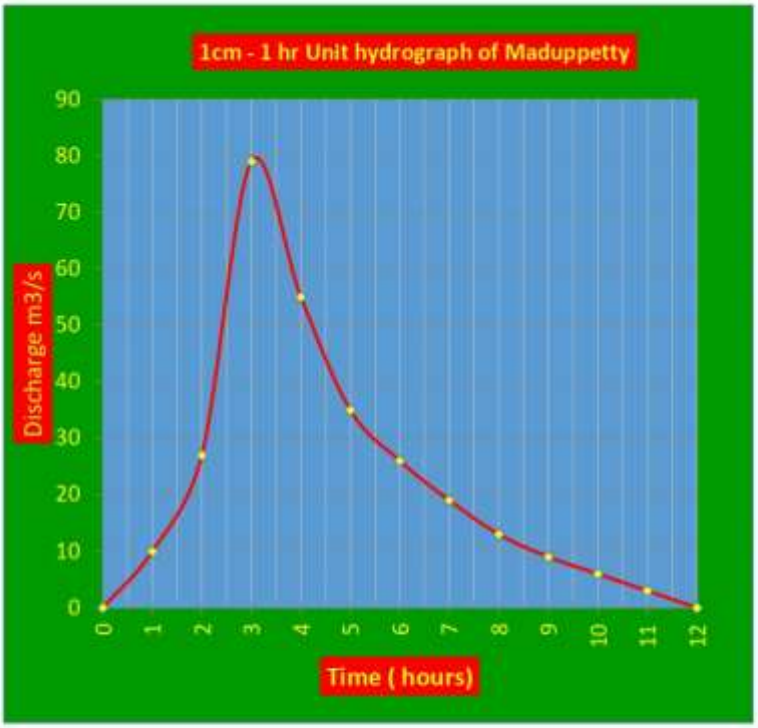

Figure 5.4 : Unit Hydrograph of Maduppetty Sub Catchment

5.2.2 Determination of rainfall excess and critical sequencing

Average rainfall over the free catchment is 33.2 cm. 12 hr bell distribution of rainfall is shown in Table 5.10. Hourly distribution of rain fall is shown in Table 5.11. Loss considered is 0.19 cm/hr. The rain fall excess is shown in the Table 5.12. Rainfall series after Critical sequencing is shown in Table 5.13.

Standard Project Storm	33.20 cm
24 hr. rainfall (with 15% clock hour correction restricted to maximum 50 mm)	38.18 cm
Depth of 12 hr. bell (0.71 x 38.18)	27.11 cm

Table 5.10: 12 Hr Bell Distribution – Maduppetty Sub Catchment

Time	Hourly Distribution (cm)
1	5.34
2	3.55
3	2.87
4	2.36
5	1.73
6	1.71
7	1.82
8	2.39
9	1.52
10	1.38
11	1.08
12	1.36

Table 5.11: Hourly Distribution – Maduppetty Sub Catchment

Time	Hourly Rainfall excess (cm)
1	5.15
2	3.36
3	2.68
4	2.17
5	1.54
6	1.52
7	1.63
8	2.20
9	1.33
10	1.19
11	0.89
12	1.17

Table 5.12: Hourly Rainfall excess – Maduppetty Sub Catchment

Time	Hourly rainfall after critical sequencing (cm)
1	0.89
2	1.17
3	1.19
4	1.33
5	1.54
6	1.63
7	2.17
8	2.68
9	3.36
10	5.15
11	2.20
12	1.52

Table 5.13: Hourly Rainfall after critical sequencing – Maduppetty Sub Catchment

12

5.2.3 Inflow Design Flood

The peak Inflow from Maduppetty Sub catchment is estimated as 905.22 m3/s. The inflow hydrograph is routed through the reservoir impinging it at crest level of spillway using HEC RAS. Peak after reservoir routing is 483.97 m3/s. The results are shown below in tabular and graphical format.

Time	Inflow Hydrograph - Maduppetty Sub Catchment (m3/s)	Hydrograph after reservoir routing (m3/s)
00:00	15.15	0
01:00	24.09	0.32
02:00	50.95	1.12
03:00	129.19	4.03
04:00	201.88	10.39
05:00	256.06	26.61
06:00	307.67	46.56
07:00	364.86	73.58
08:00	425.23	107.24
09:00	516.41	149.45
10:00	642.33	202.97
11:00	774.48	271.46
12:00	905.22	357.82
13:00	788.04	433.97
14:00	630.52	476.05
15:00	442.03	483.97
16:00	308.94	468.93
17:00	216.14	435.83
18:00	147.10	394.43
19:00	95.63	352.53
20:00	57.43	312.45
21:00	30.84	270.89
22:00	19.70	237.18
23:00	15.15	207.29
24:00	15.15	182.62
25:00	15.15	161.04

Table 5.14: Design Flood Hydrograph – Maduppetty Sub Catchment

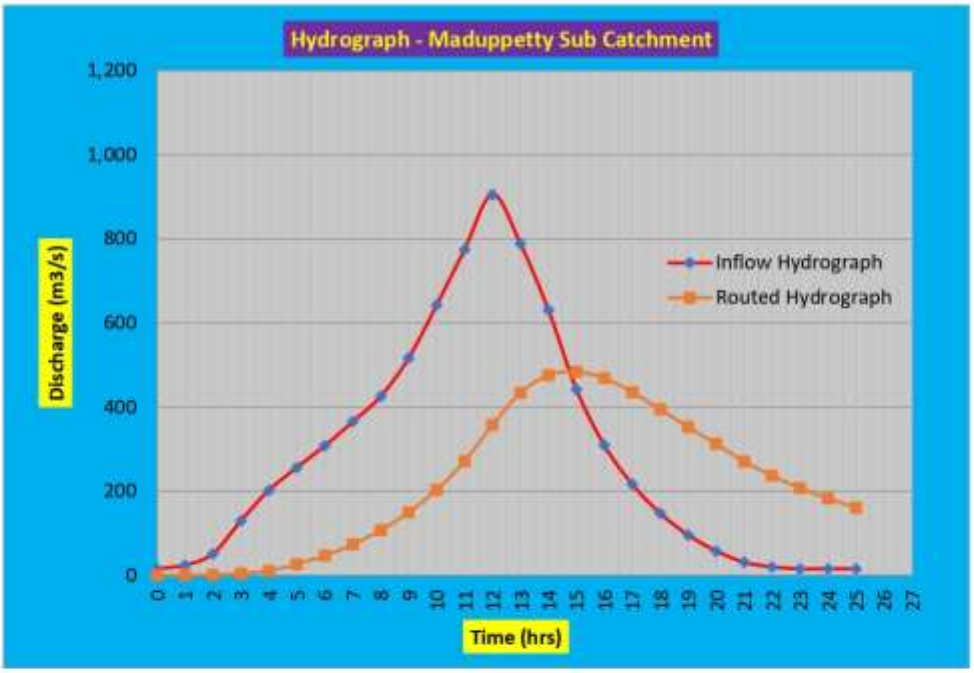

Figure 5.5: Hydrograph (Inflow and Outflow)– Maduppetty Sub Catchment

5.3. Ponmudi Sub Catchment

5.3.1 Derivation of Unit Hydrograph

The unit hydrograph of Ponmudi dam point is taken from the DFR of Ponmudi project prepared by the Central Water commission (CWC).

Time (hr.)	Ordinates of UH (cumec)
0	-
1	29
2	84
3	183
4	138
5	96
6	68
7	52
8	41
9	32
10	24
11	17
12	10
13	4
14	-

Table 5.15: Unit Hydrograph ordinates (from CWC DFR 2020)

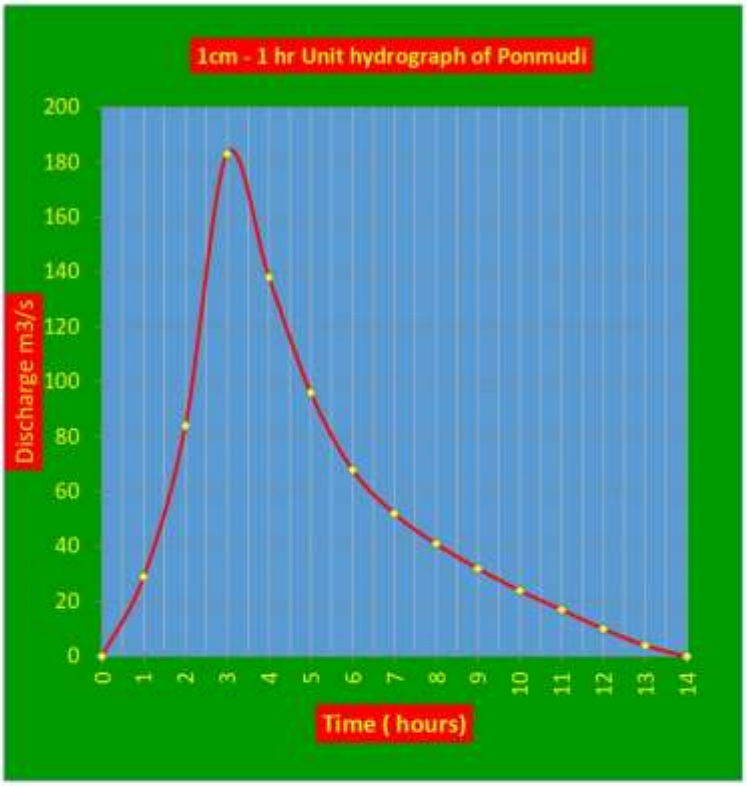

Figure 5.6 : Unit Hydrograph of Ponmudi Sub Catchment

5.3.2 Determination of rainfall excess and critical sequencing

Average rainfall over the free catchment is 38 cm. 12 hr bell distribution of rainfall is shown in Table 5.16. Hourly distribution of rain fall is shown in Table 5.17. Loss considered is 0.19 cm/hr. The rain fall excess is shown in the Table 5.18. Rainfall series after Critical sequencing is shown in Table 5.19.

Standard Project Storm	38 cm
24 hr. rainfall (with 15% clock hour correction restricted to maximum 50 mm)	43 cm
Depth of 1st 12 hr. bell (0.71 x 43)	30.53 cm
Depth of 2nd 12 hr. bell (0.29 x 43)	12.47 cm

Table 5.16: 12 Hr Bell Distribution – Ponmudi Sub Catchment

15

Time	Hourly Distribution 1st Bell (cm)	Hourly Distribution 2nd Bell (cm)
1	6.75	2.76
2	3.91	1.60
3	3.27	1.33
4	2.71	1.11
5	2.06	0.84
6	1.59	0.65
7	2.41	0.98
8	2.06	0.84
9	1.63	0.67
10	1.46	0.60
11	0.90	0.37
12	1.76	0.72

Table 5.17: Hourly Distribution – Ponmudi Sub Catchment

Time	Hourly Rainfall excess 1st Bell (cm)	Hourly Rainfall excess 2nd Bell (cm)
1	6.56	2.57
2	3.72	1.41
3	3.08	1.14
4	2.52	0.92
5	1.87	0.65
6	1.40	0.46
7	2.22	0.79
8	1.87	0.65
9	1.44	0.48
10	1.27	0.41
11	0.71	0.18
12	1.57	0.53

Table 5.18: Hourly Rainfall excess – Ponmudi Sub Catchment

Time	Hourly rainfall after critical sequencing B1-B2 (cm)
1	0.71
2	1.27
3	1.40
4	1.57
5	1.87
6	1.87
7	2.22
8	3.08
9	3.72
10	6.56
11	2.52
12	1.44

16

13	0.18
14	0.41
15	0.46
16	0.53
17	0.65
18	0.65
19	0.79
20	1.14
21	1.41
22	2.57
23	0.92
24	0.48

Table 5.19: Hourly Rainfall after critical sequencing – Ponmudi Sub Catchment

5.2.3 Inflow Design Flood

The peak Inflow from Ponmudi Sub catchment is estimated as 2743.23 m3/s. The inflow hydrograph is routed through the reservoir impinging at crest level using HEC RAS. Peak after reservoir routing is 2475.18 m3/s. The results are shown below in tabular and graphical format.

Time	Inflow Hydrograph - Ponmudi Sub Catchment (m3/s)	Hydrograph after Reservoir routing (m3/s)
00:00	42.00	0
01:00	62.70	1.9
02:00	138.85	8.23
03:00	320.10	39.75
04:00	536.56	108.7
05:00	728.77	233.82
06:00	905.31	386.34
07:00	1,081.63	560.27
08:00	1,260.64	750.79
09:00	1,507.66	956.08
10:00	1,918.59	1213.94
11:00	2,362.02	1459.53
12:00	2,743.23	2119.17
13:00	2,431.09	2475.18
14:00	1,965.61	2186.86
15:00	1,498.56	1795.88
16:00	1,207.62	1549.54
17:00	1,018.11	1449.42
18:00	887.11	1324.26
19:00	793.83	1182.39
20:00	729.85	1035.6
21:00	717.39	932.3
22:00	800.52	879.08
23:00	928.26	875.87

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24:00	1,064.10	913.76
25:00	931.52	940.2
26:00	741.99	904.38
27:00	549.95	819.63
28:00	416.85	713.4
29:00	322.58	609.78
30:00	250.38	514.44
31:00	191.09	428.16
32:00	141.59	353.2
33:00	100.35	291.96
34:00	69.55	240.99
35:00	50.44	194.2
36:00	43.91	162.42
37:00	42.00	134.34
38:00	42.00	113.85

Table 5.20: Hydrograph – Ponmudi Sub Catchment

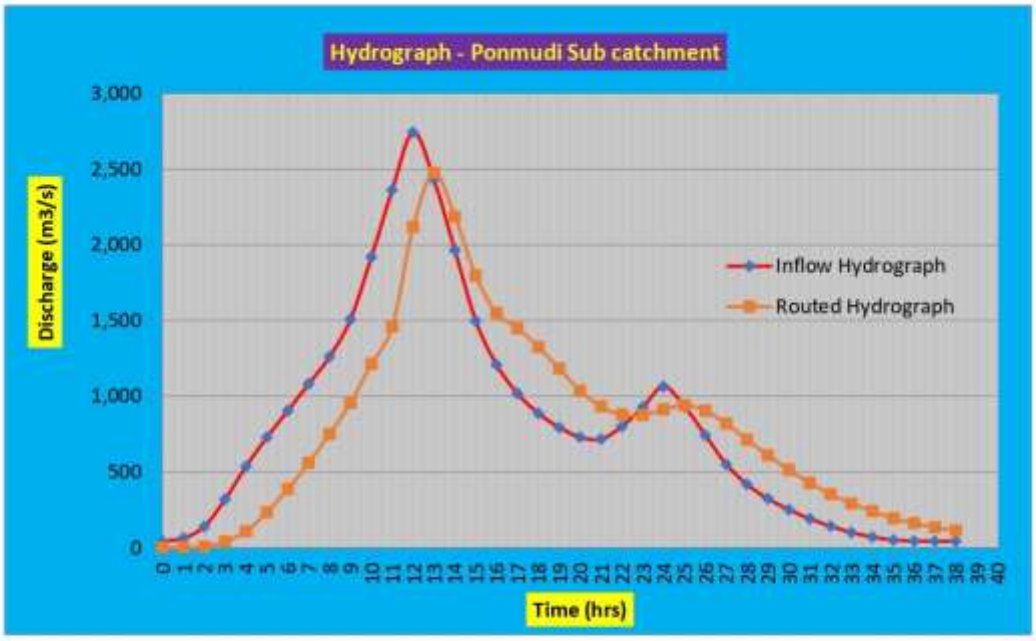

Figure 5.7: Hydrograph (Inflow & Outflow) – Ponmudi Sub Catchment

6. Hydrologic Model.

The system is modelled in HEC HMS. Total catchment is divided into three sub units viz. Free catchment, Maduppetty and Ponmudi sub catchments.

Figure 6.1: HMS Model of Vellathooval Project

For free catchment, UHG is derived as per FER and design flood hydrograph is derived with SPS over the catchment. The UHG derived and SPS are input for model.

The outflow from the controlled sub catchments is modelled as source. There are two sources one at dam point Maduppetty and the other at dam point Ponmudi.

For Maduppetty sub catchment UHG is as per the DFR (CWC). Design flood hydrograph is estimated with SPS. The inflow design flood is routed through reservoir in HEC-RAS. The outflow hydrograph is the input for source Maduppetty in HEC-HMS. The outflow hydrograph is routed through the channel downstream using Muskingum model in HMS.

For Ponmudi sub catchment UHG is as per the FR(CWC). Design flood is routed through the reservoir in HEC-RAS. The outflow hydrograph is the input for source Ponmudi in HEC-HMS. The outflow hydrograph is routed through the channel downstream using Muskingum model in HEC-HMS.

The free catchment is modelled as sub catchment. The Vellathooval pond is modelled as sink. Reach elements are included between sources and sink.

The combined hydrograph is generated in HEC-HMS considering the outflows and inflows from free catchment.

7. Results & Discussion

The design flood of Vellathooval weir is estimated as 4176.8 m3/s. The results are shown below in tabular and graphical format. The flood estimation is carried by categorising the project as per BIS 11223. The parameters for transform, loss, baseflow and routing models are considered as per the FER published by CWC. Flood routing of inflow design flood through the reservoirs are carried by considering the impingement level as crest level, the lowest level which can be assumed practically for getting maximum possible flood moderation.

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The results of the study can be refined further by deriving site specific unit hydrographs at all the outlet points from concurrent short interval rainfall – runoff data and considering those UHG as input in the model or adopting the transform models available in HMS. When the models available in HMS is used, the parameters of those models are to be estimated and calibrated with measured data at respective locations. Similarly, the parameters of Muskingum model are also to be estimated from the site-specific measurements. Temporal distribution of the rain fall may be determined form recording type rain gauge data after selecting representative storms.

Time	Inflow from Free Catchment (m3/s)	Inflow -Reach routed Maduppetty – Vellathooval (m3/s)	Inflow from Reach routed Ponmudi – Vellathooval (m3/s)	Total Inflow (m3/s)
00:00	0.0	0.0	0.0	0.0
01:00	118.4	0.0	0.4	118.8
02:00	397.3	0.0	2.9	400.2
03:00	669.8	0.1	13.5	683.4
04:00	890.0	0.3	48.3	938.6
05:00	1063.6	1.0	121.6	1186.3
06:00	1180.8	3.1	241.9	1425.8
07:00	1313.8	7.9	392.2	1713.9
08:00	1559.3	17.1	564.8	2141.2
09:00	1896.1	32.1	754.6	2682.8
10:00	2418.7	53.0	967.4	3439.1
11:00	2882.5	80.5	1213.7	4176.8
12:00	2455.6	115.8	1542.3	4113.7
13:00	1753.9	160.4	2075.0	3989.3
14:00	1027.8	216.2	2337.5	3581.5
15:00	570.7	282.5	2138.8	2992.0
16:00	315.0	351.6	1815.2	2481.8
17:00	175.8	410.2	1582.6	2168.6
18:00	97.2	447.3	1451.0	1995.5
19:00	56.2	459.7	1321.2	1837.1
20:00	41.3	450.4	1180.8	1672.5
21:00	37.0	425.2	1044.0	1506.2
22:00	37.0	390.7	944.0	1371.7
23:00	37.0	352.1	891.4	1280.6
00:00	37.0	312.9	886.6	1236.5
01:00	37.0	275.4	913.6	1226.1
02:00	37.0	241.3	927.7	1206.1
03:00	37.0	208.7	892.1	1137.9
04:00	37.0	168.9	812.9	1018.8
05:00	37.0	113.2	712.6	862.8
06:00	37.0	56.3	611.3	704.6
07:00	37.0	22.9	516.6	576.5
08:00	37.0	8.2	430.8	476.1
09:00	37.0	2.7	356.5	396.2
10:00	37.0	0.8	294.7	332.5

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11:00	37.0	0.2	242.4	279.7
12:00	37.0	0.1	197.5	234.6
13:00	37.0	0.0	163.8	200.9
14:00	37.0	0.0	136.1	173.2
15:00	37.0	0.0	95.5	132.6
16:00	37.0	0.0	19.1	56.2
17:00	37.0	0.0	3.8	40.9
18:00	37.0	0.0	0.8	37.8
19:00	37.0	0.0	0.2	37.2
20:00	37.0	0.0	0.0	37.1
21:00	37.0	0.0	0.0	37.1
22:00	37.0	0.0	0.0	37.1
23:00	37.0	0.0	0.0	37.1
00:00	37.0	0.0	0.0	37.1

Table 7.1 – Design flood of Vellathooval Project

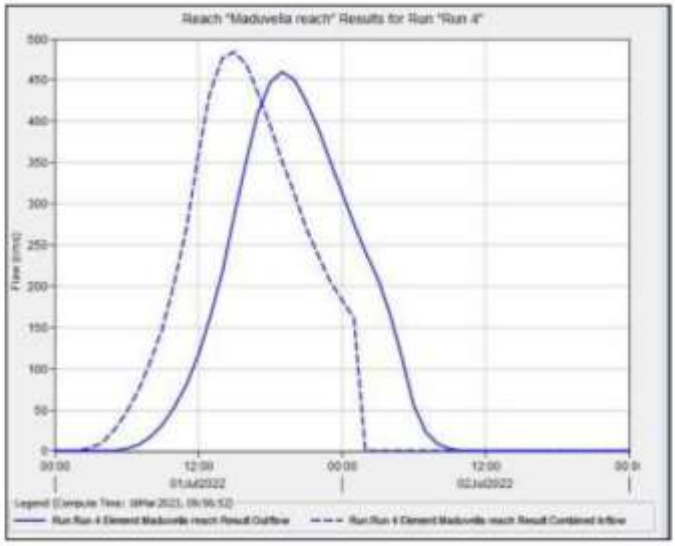

Figure 7.1: Reach Routed Hydrograph – Maduppetty - Vellathooval

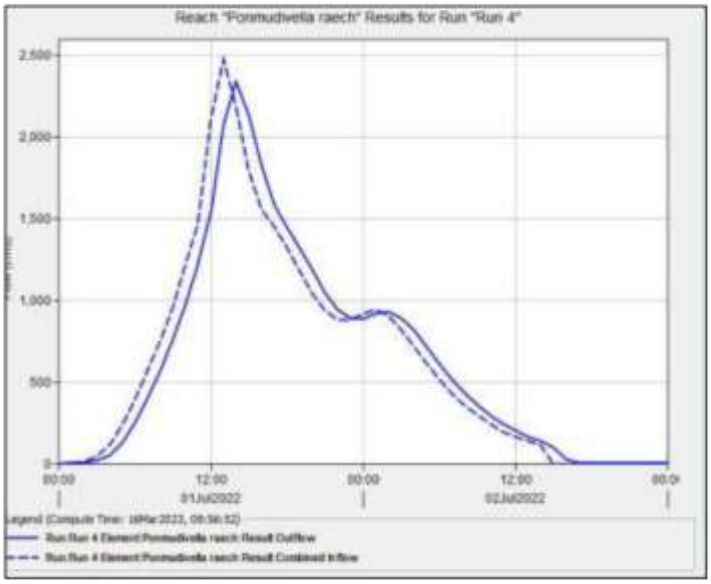

Figure 7.2: Reach Routed Hydrograph – Ponmudi - Vellathooval

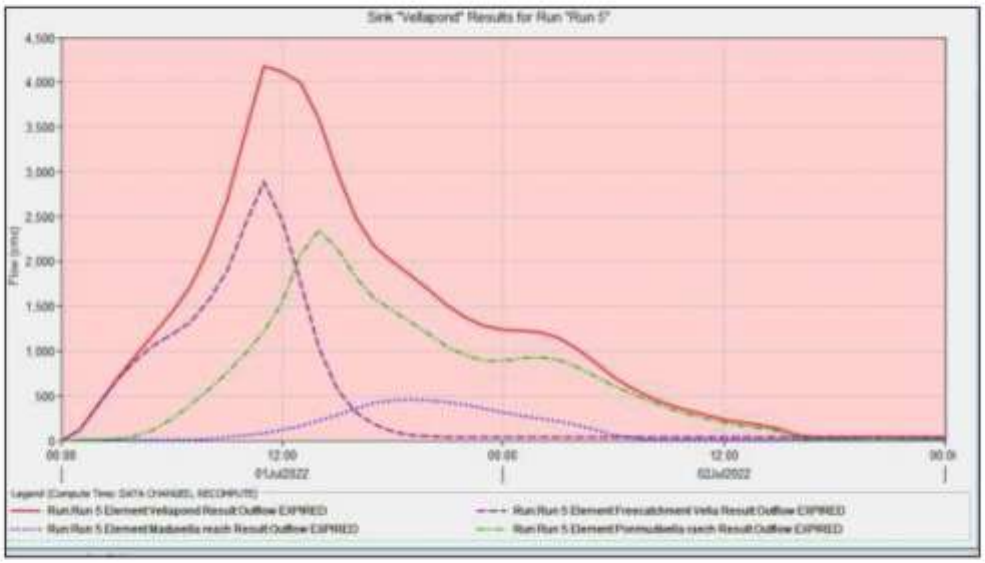

Figure 7.3: Design Flood Hydrograph – Vellathooval Project

ANNEXURE III – Rainfall Data

Rainfall Data (in mm) for the year 2015 Basin - Periyar, Rain Gauge Station - Kallarkutty												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	9.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	10.0
2	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	2.0	17.0
3	0.0	0.0	0.0	22.0	5.0	0.0	11.0	13.0	0.0	3.0	4.0	5.0
4	0.0	0.0	16.0	0.0	0.0	0.0	0.0	11.0	0.0	7.0	30.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	15.0	31.0	28.5	7.0	0.0	2.0
6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	33.0	12.0	7.0	0.0
7	0.0	0.0	8.0	0.0	0.0	4.0	7.0	13.0	22.0	0.0	14.0	0.0
8	0.0	0.0	0.0	0.0	16.0	12.0	28.0	5.0	10.0	7.0	9.0	4.0
9	0.0	0.0	0.0	4.0	0.0	0.0	26.0	0.0	14.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	19.0	0.0	19.0	51.0	2.5	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	3.0	6.0	7.0	40.0	13.0	4.0	0.0	0.0
12	0.0	0.0	0.0	20.0	28.0	0.0	11.0	66.0	0.0	0.0	2.0	0.0
13	0.0	10.0	0.0	51.0	13.0	25.0	0.0	6.0	0.0	0.0	0.0	8.0
14	0.0	0.0	0.0	17.0	2.0	0.0	16.0	0.0	0.0	0.0	2.0	0.0
15	0.0	0.0	0.0	0.0	0.0	57.0	16.0	25.0	7.0	0.0	1.0	0.0
16	0.0	0.0	1.0	24.0	12.0	5.0	28.0	9.0	23.0	20.0	8.0	0.0
17	0.0	0.0	0.0	0.0	6.0	39.0	54.0	0.0	9.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	63.0	36.0	22.5	0.0	20.0	1.0	11.0	0.0
19	0.0	0.0	0.0	5.0	17.0	57.0	23.5	0.0	20.0	1.0	12.0	0.0
20	0.0	0.0	0.0	3.0	0.0	41.0	33.0	0.0	0.0	1.0	0.0	0.0
21	0.0	0.0	0.0	59.0	0.0	130.0	67.0	16.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	82.0	15.0	10.0	0.0	0.0	1.0	0.0
23	0.0	0.0	0.0	0.0	0.0	34.0	72.0	12.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	3.0	0.0	25.0	0.0	7.0	11.0	5.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	61.0	0.0	0.0	27.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	81.0	16.0	0.0	3.0	3.0	0.0	0.0
27	0.0	14.0	0.0	0.0	0.0	34.0	0.0	0.0	8.0	0.0	10.0	0.0
28	0.0	10.0	0.0	7.0	0.0	14.0	0.0	0.0	8.0	0.0	5.0	0.0
29	13.0		0.0	0.0	0.0	9.0	0.0	0.0	14.0	0.0	6.0	0.0
30	0.0		0.0	0.0	0.0	0.0	0.0	0.0	23.0	0.0	3.0	0.0
31	0.0		0.0		0.0		0.0	0.0		5.0		0.0
TOTAL	**13.0**	**34.0**	**36.0**	**218.0**	**194.0**	**752.0**	**487.0**	**315.0**	**296.0**	**89.0**	**140.0**	**46.0**

Rainfall Data (in mm) for the year 2016 **Basin - Periyar, Rain Gauge Station - Kallarkutty**												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	0.0	9.0	0.0	7.0	6.0	0.0	1.0	7.0
2	0.0	0.0	0.0	0.0	0.0	7.0	4.0	0.0	8.0	0.0	2.0	0.0
3	0.0	0.0	0.0	0.0	0.0	2.0	12.0	6.0	1.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	27.0	12.0	25.0	0.0	0.0	1.0	0.0
5	0.0	0.0	0.0	0.0	0.0	4.0	14.0	6.0	0.0	0.0	0.0	15.0
6	0.0	0.0	0.0	0.0	0.0	9.0	10.0	2.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	11.0	13.0	16.0	1.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	2.0	14.0	70.0	23.0	0.0	0.0	0.0	0.0
9	0.0	1.0	0.0	0.0	0.0	27.0	37.0	6.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	18.0	13.0	46.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	4.0	0.0	21.0	77.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	13.0	0.0	10.0	5.0	17.0	21.0	0.0	0.0	0.0	0.0
13	8.0	0.0	0.0	0.0	0.0	7.0	4.0	16.0	0.0	73.0	0.0	2.0
14	0.0	0.0	0.0	0.0	13.0	12.0	6.0	2.0	3.0	2.0	0.0	0.0
15	0.0	0.0	0.0	4.0	1.0	4.5	29.0	29.0	11.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	12.0	5.0	20.0	4.0	0.0	0.0	0.0
17	0.0	0.0	0.0	6.0	18.0	73.0	37.0	64.0	0.0	0.0	0.0	0.0
18	1.0	0.0	0.0	0.0	19.0	57.5	34.0	29.0	27.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	5.0	2.5	0.0	4.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	1.0	2.5	0.0	0.0	2.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	6.0	12.0	0.0	12.0	8.0	0.0	0.0
22	0.0	0.0	6.0	0.0	2.0	53.0	26.0	4.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	17.0	29.0	20.0	9.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	15.0	4.0	19.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	16.0	0.0	4.0	2.0	13.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	31.0	3.0	15.0	5.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	13.0	29.0	53.0	33.0	0.0	0.0	0.0	0.0
28	0.0	1.0	0.0	0.0	0.0	124.0	16.0	18.0	2.0	5.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	94.0	0.0	7.0	24.0	0.0	0.0	0.0
30	0.0		7.0	0.0	1.0	5.0	13.0	12.0	0.0	2.0	0.0	0.0
31	0.0		0.0		0.0		24.0	7.0		1.0		0.0
TOTAL	**9.0**	**2.0**	**26.0**	**14.0**	**145.0**	**685.0**	**629.0**	**379.0**	**127.0**	**91.0**	**4.0**	**24.0**

Rainfall Data (in mm) for the year 2017 **Basin - Periyar, Rain Gauge Station - Kallarkutty**												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	11.0	13.0	19.0	17.0	26.0	26.0	0.0	0.0
2	0.0	0.0	0.0	0.0	26.0	15.0	6.0	25.0	4.0	4.0	7.0	10.0
3	0.0	0.0	2.0	0.0	0.0	2.0	13.0	26.0	0.0	0.0	10.0	0.0
4	0.0	0.0	76.0	0.0	0.0	47.0	0.0	57.0	8.0	8.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	6.0	7.0	90.0	22.0	22.0	2.0	0.0
6	0.0	0.0	0.0	14.0	0.0	8.0	8.0	8.0	7.0	7.0	30.0	0.0
7	0.0	0.0	0.0	0.0	9.0	27.0	21.0	33.0	25.0	25.0	11.0	0.0
8	0.0	0.0	8.0	0.0	6.0	0.0	4.0	10.0	40.0	40.0	4.0	0.0
9	0.0	0.0	6.0	0.0	0.0	0.0	3.0	9.0	0.0	0.0	0.0	0.0
10	0.0	0.0	11.0	0.0	4.0	44.0	5.0	0.0	31.0	31.0	0.0	0.0
11	0.0	0.0	0.0	10.0	2.0	15.0	1.0	14.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	17.0	97.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	21.0	0.0	0.0	10.0	18.0	0.0	23.0	23.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	2.0	12.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	3.0	10.0	46.0	2.0	2.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	43.0	43.0	0.0	0.0
17	0.0	0.0	11.0	0.0	0.0	0.0	21.0	15.0	121.0	121.0	0.0	0.0
18	0.0	0.0	0.0	0.0	3.0	0.0	19.0	72.0	35.0	35.0	0.0	0.0
19	0.0	0.0	15.0	0.0	0.0	9.0	67.0	63.0	12.0	12.0	0.0	0.0
20	0.0	0.0	26.0	1.0	14.0	1.0	16.0	33.0	0.0	0.0	3.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	7.0	84.0	7.0	7.0	0.0	0.0
22	0.0	0.0	0.0	0.0	1.0	25.0	0.0	3.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	34.0	0.0	23.0	38.0	38.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	43.0	1.0	8.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	73.0	0.0	0.0	6.0	6.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	104.0	6.0	32.0	0.0	0.0	0.0	0.0
27	5.0	0.0	0.0	0.0	2.0	79.0	37.0	62.0	32.0	32.0	2.0	0.0
28	2.0	0.0	0.0	0.0	2.0	5.0	8.0	72.0	34.0	34.0	0.0	0.0
29	0.0		0.0	0.0	10.0	18.0	0.0	31.0	28.0	28.0	0.0	0.0
30	0.0		0.0	0.0	19.0	7.0	27.0	7.0	0.0	0.0	20.0	0.0
31	0.0		0.0		0.00		59.0	0.0		0.00		0.0
TOTAL	**7.0**	**0.0**	**176.0**	**42.0**	**206.0**	**597.0**	**395.0**	**850.0**	**544.0**	**544.0**	**89.0**	**10.0**

Rainfall Data (in mm) for the year 2018 Basin - Periyar, Rain Gauge Station - Kallarkutty												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	0.0	0.0	5.0	1.0	0.0	6.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	1.0	44.0	3.0	0.0	7.0	0.0	0.0
3	0.0	0.0	0.0	0.0	29.0	2.0	0.0	0.0	0.0	21.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	22.0	0.0	0.0
5	0.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	10.0	23.0	5.0	24.0	0.0	4.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	48.0	18.0	90.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	15.0	0.0	63.0	86.0	306.0	0.0	10.0	0.0	0.0
9	0.0	0.0	0.0	0.0	20.0	132.0	90.0	111.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	16.0	0.0	105.0	50.0	75.0	0.0	5.0	0.0	0.0
11	0.0	0.0	0.0	0.0	22.0	141.0	52.0	4.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	8.0	2.0	48.0	60.0	70.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	5.0	0.0	70.0	60.0	80.0	0.0	14.0	0.0	0.0
14	0.0	0.0	0.0	1.0	0.0	5.0	61.0	219.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	2.0	5.0	133.0	257.0	0.0	3.0	0.0	0.0
16	0.0	0.0	4.0	14.0	12.0	59.0	74.0	158.0	4.0	48.0	132.0	0.0
17	0.0	0.0	0.0	0.0	1.0	1.0	76.0	103.0	5.0	0.0	0.0	0.0
18	0.0	0.0	48.0	2.0	0.0	27.0	35.0	50.0	0.0	14.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	35.0	69.0	34.0	31.0	12.0	15.0	0.0
20	0.0	0.0	0.0	0.0	0.0	24.0	27.0	25.0	0.0	38.0	0.0	0.0
21	0.0	0.0	0.0	15.0	0.0	18.0	18.0	3.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	5.0	29.0	2.0	0.0	6.0	16.0	0.0
23	0.0	0.0	0.0	0.0	0.0	5.0	84.0	0.0	21.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	10.0	10.0	172.0	0.0	5.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	6.0	15.0	57.0	0.0	1.0	0.0	0.0	0.0
26	0.0	0.0	0.0	23.0	0.0	17.0	14.0	0.0	44.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	1.0	31.0	0.0	27.0	18.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	98.0	6.0	120.0	9.0	44.0	0.0	0.0	0.0
29	0.0		0.0	0.0	28.0	17.0	17.0	0.0	6.0	0.0	0.0	0.0
30	0.0		0.0	0.0	4.0	11.0	59.0	0.0	4.0	0.0	0.0	0.0
31	0.0		0.0		0.0		35.0	13.0		0.0		0.0
TOTAL	**0.0**	**0.0**	**52.0**	**99.0**	**261.0**	**940.0**	**1550.0**	**1664.0**	**183.0**	**210.0**	**163.0**	**0.0**

Rainfall Data (in mm) for the year 2019 Basin - Periyar, Rain Gauge Station - Kallarkutty												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	30.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	4.0	57.0	5.0	45.0	8.0	8.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	13.0	9.0	70.0	0.0	5.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	23.0	44.0	107.0	0.0	6.0	0.0
5	0.0	0.0	0.0	0.0	0.0	8.0	10.5	14.0	83.0	13.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	14.0	90.0	28.0	0.0	2.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	11.0	70.0	7.0	0.0	17.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	2.0	277.0	9.0	1.0	33.0	0.0
9	0.0	0.0	0.0	0.0	0.0	19.0	22.5	46.0	16.0	0.0	33.0	0.0
10	0.0	0.0	0.0	0.0	0.0	14.0	2.0	45.0	0.0	6.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	17.0	0.0	16.0	18.0	18.0	6.0	0.0
12	0.0	0.0	0.0	0.0	0.0	13.0	0.0	8.0	0.0	17.0	0.0	0.0
13	0.0	0.0	0.0	0.0	2.0	17.0	6.0	86.0	4.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	26.0	0.0	13.0	1.0	27.0	11.0	0.0
15	0.0	0.0	0.0	0.0	4.0	17.0	0.0	2.0	1.0	3.0	6.0	0.0
16	0.0	0.0	0.0	0.0	4.0	0.0	2.0	10.0	38.0	26.0	0.0	0.0
17	0.0	0.0	0.0	0.0	30.0	0.0	9.0	0.0	0.0	0.0	2.0	0.0
18	0.0	0.0	0.0	0.0	0.0	4.0	180.0	42.0	3.0	7.0	0.0	0.0
19	0.0	0.0	0.0	12.0	0.0	8.0	75.0	26.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	38.0	0.0	11.0	55.0	3.0	0.0	17.0	7.0	0.0
21	0.0	0.0	0.0	0.0	0.0	19.0	41.0	24.0	7.0	31.0	0.0	0.0
22	0.0	0.0	0.0	32.0	0.0	6.0	19.0	47.0	14.0	87.0	0.0	0.0
23	0.0	0.0	0.0	1.0	0.0	24.0	24.0	13.0	13.0	39.0	0.0	0.0
24	0.0	0.0	0.0	8.0	0.0	8.0	2.0	9.0	0.0	8.0	0.0	0.0
25	0.0	0.0	0.0	0	0.0	7.0	48.0	23.0	8.0	7.0	0.0	0.0
26	0.0	0.0	0.0	0	0.0	0.0	0.0	38.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	16.0	0.0	0.0	5.0	4.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
29	0.0		0.0	0.0	0.0	7.0	0.0	20.0	27.0	0.0	0.0	0.0
30	0.0		0.0	0.0	0.0	0.0	0.0	16.0	0.0	29.0	0.0	0.0
31	0.0		0.0		9.0		0.0	15.0		13.0		0.0
TOTAL	**0.0**	**0.0**	**0.0**	**91.0**	**65.0**	**229.0**	**626.0**	**1036.0**	**533.0**	**357.0**	**136.0**	**0.0**

Rainfall Data (in mm) for the year 2020 **Basin - Periyar, Rain Gauge Station - Kallarkutty**												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.0	5.0	26.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	2.0	0.0	28.0	4.0	0.0	2.0	0.0
3	0.0	0.0	0.0	0.0	0.0	4.0	26.0	55.0	12.0	0.0	26.0	4.0
4	0.0	0.0	0.0	0.0	0.0	8.0	103.0	145.0	6.0	0.0	0.0	6.0
5	0.0	0.0	0.0	5.5	2.0	2.0	16.0	102.0	2.0	0.0	44.0	0.0
6	0.0	0.0	0.0	0.0	0.0	18.0	50.0	24.0	27.0	0.0	7.0	14.0
7	0.0	0.0	0.0	0.0	4.0	6.0	21.0	188.0	33.0	3.0	0.0	14.0
8	0.0	0.0	0.0	0.0	0.0	3.0	30.0	133.0	5.0	9.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	1.0	57.0	0.0	23.0	29.0	0.0
10	0.0	0.0	0.0	0.0	13.0	0.0	4.0	64.0	69.0	0.0	0.0	0.0
11	0.0	0.0	0.0	2.0	17.0	12.0	0.0	14.0	23.0	18.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	34.0	27.0	21.0	20.0	26.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	20.0	79.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	19.0	0.0	0.0	24.0	20.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	6.0	57.0	0.0	0.0
16	0.0	0.0	0.0	9.0	0.0	2.0	36.0	0.0	23.0	17.0	2.0	0.0
17	0.0	0.0	0.0	0.0	6.0	17.0	26.0	2.0	11.0	1.0	1.0	0.0
18	0.0	0.0	0.0	0.0	11.0	19.0	19.0	0.0	25.0	0.0	20.0	0.0
19	0.0	0.0	0.0	3.0	0.0	0.0	11.0	4.0	30.0	35.0	0.0	0.0
20	0.0	0.0	0.0	4.0	3.0	12.0	39.0	0.0	115.0	0.0	0.0	0.0
21	0.0	0.0	0.0	17.0	0.0	0.0	56.0	0.0	46.0	0.0	5.0	0.0
22	0.0	0.0	0.0	0.0	0.0	18.0	36.0	0.0	72.0	7.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	8.0	7.0	0.0	12.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	10.0	12.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	2.0	9.0	12.0	14.0	0.0	2.0	0.0	22.0	0.0
27	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0
28	0.0	0.0	0.0	12.0	12.0	16.0	0.0	0.0	2.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	10.0	7.0	0.0	1.0	24.0	0.0	0.0
30	0.0		0.0	0.0	0.0	46.0	52.0	0.0	0.0	2.0	0.0	0.0
31	0.0		0.0		5.0		20.0	5.0		0.0		0.0
TOTAL	**0.0**	**0.0**	**0.0**	**61.5**	**82.0**	**287.0**	**635.0**	**906.0**	**595.0**	**347.0**	**166.0**	**38.0**

Rainfall Data (in mm) for the year 2021 **Basin - Periyar, Rain Gauge Station - Kallarkutty**												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	0.0	7.0	0.0	5.0	0.0	18.0	11.0	0.0
2	0.0	0.0	0.0	0.0	40.0	0.0	0.0	0.0	8.0	0.0	20.0	0.0
3	0.0	0.0	0.0	0.0	17.0	14.0	4.0	12.0	4.0	18.0	23.0	4.0
4	0.0	0.0	0.0	0.0	2.0	1.0	18.0	2.0	0.0	6.0	17.0	0.0
5	0.0	0.0	0.0	0.0	0.0	62.0	4.0	0.0	20.0	19.0	16.0	0.0
6	0.0	0.0	0.0	0.0	0.0	42.0	0.0	44.0	23.0	0.0	6.0	0.0
7	48.0	0.0	0.0	0.0	0.0	0.0	0.0	54.0	74.0	2.0	44.0	23.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	11.0	3.0	9.0	0.0
9	0.0	0.0	0.0	0.0	2.0	6.0	5.0	17.0	5.0	36.0	4.0	0.0
10	0.0	0.0	0.0	0.0	10.0	0.0	59.0	26.0	0.0	18.0	2.0	0.0
11	11.0	0.0	6.0	0.0	0.0	7.0	68.0	0.0	0.0	9.0	0.0	0.0
12	22.0	0.0	0.0	11.0	0.0	18.0	10.0	24.0	48.0	66.0	41.0	0.0
13	0.0	0.0	0.0	2.0	0.0	33.0	33.0	0.0	27.0	12.0	1.0	0.0
14	0.0	0.0	0.0	0.0	24.0	83.0	64.0	19.0	9.0	6.0	15.0	0.0
15	0.0	0.0	0.0	17.0	49.0	35.0	75.0	30.0	5.0	12.0	14.0	0.0
16	0.0	0.0	0.0	47.0	110.0	83.0	62.0	0.0	18.0	0.0	1.0	0.0
17	0.0	0.0	0.0	0.0	24.0	81.0	36.0	2.0	9.0	110.0	2.0	0.0
18	0.0	0.0	0.0	0.0	8.0	34.0	39.0	8.0	0.0	53.0	78.0	0.0
19	0.0	0.0	0.0	0.0	0.0	2.0	5.0	48.0	0.0	24.0	0.0	0.0
20	0.0	0.0	0.0	19.0	2.0	3.0	18.0	0.0	3.0	24.0	20.0	0.0
21	0.0	0.0	0.0	0.0	34.0	6.0	15.0	0.0	0.0	37.0	0.0	0.0
22	0.0	0.0	0.0	0.0	1.0	23.0	29.0	0.0	0.0	17.0	0.0	0.0
23	0.0	0.0	0.0	0.0	9.0	48.0	44.0	19.0	0.0	15.0	52.0	0.0
24	0.0	0.0	0.0	0.0	13.0	55.0	93.0	0.0	39.0	7.0	44.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	48.0	0.0	28.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	137.0	0.0	22.0	2.0	0.0	19.0	43.0	0.0
27	0.0	0.0	0.0	18.0	31.0	8.0	10.0	40.0	46.0	0.0	0.0	0.0
28	0.0	0.0	0.0	51.0	5.0	11.0	28.0	26.0	33.0	33.0	29.0	0.0
29	0.0		3.0	0.0	45.0	0.0	28.0	41.0	15.0	0.0	0.0	0.0
30	0.0		4.0	0.0	0.0	0.0	0.0	37.0	0.0	0.0	8.0	0.0
31	0.0		0.0		0.0		3.0	17.0		0.0		0.0
TOTAL	**81.0**	**0.0**	**13.0**	**165.0**	**563.0**	**662.0**	**820.0**	**498.0**	**425.0**	**564.0**	**500.0**	**27.0**

Rainfall Data (in mm) for the year 2022 **Basin - Periyar, Rain Gauge Station - Kallarkutty**												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	0.0	60.0	3.0	19.0	44.0	1.0	13.0	0.0
2	0.0	0.0	0.0	0.0	0.0	18.0	16.0	57.0	4.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	101.0	76.0	4.0	32.0	24.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	39.0	69.0	0.0	10.0	0.0	0.0
5	0.0	0.0	0.0	0.0	6.0	0.0	31.0	115.0	0.0	0.0	0.0	9.0
6	0.0	0.0	0.0	0.0	0.0	0.0	41.0	41.0	56.0	6.0	12.0	0.0
7	0.0	0.0	0.0	0.0	0.0	5.0	44.0	40.0	19.0	1.0	29.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	48.0	110.0	41.0	0.0	3.0	0.0
9	0.0	0.0	0.0	19.0	0.0	5.0	58.0	118.0	38.0	4.0	6.0	1.0
10	0.0	0.0	0.0	10.0	44.0	0.0	25.0	30.0	70.0	0.0	9.0	2.0
11	0.0	0.0	0.0	0.0	74.0	5.0	120.0	8.0	37.0	0.0	0.0	41.0
12	0.0	0.0	0.0	19.0	4.0	5.0	58.0	5.0	33.0	0.0	11.0	64.0
13	0.0	0.0	0.0	6.0	22.0	3.0	15.0	0.0	12.0	8.0	1.0	2.0
14	0.0	0.0	0.0	0.0	10.0	12.0	100.0	0.0	0.0	0.0	0.0	3.0
15	0.0	0.0	0.0	5.0	15.0	3.0	85.0	0.0	0.0	0.0	5.0	0.0
16	0.0	0.0	0.0	0.0	3.0	6.0	37.0	0.0	0.0	25.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	5.0	28.0	0.0	0.0	32.0	0.0	0.0
18	0.0	0.0	0.0	15.0	3.0	14.0	14.0	0.0	0.0	55.0	0.0	0.0
19	0.0	0.0	0.0	0.0	24.0	2.0	6.0	0.0	10.0	3.0	0.0	0.0
20	0.0	0.0	0.0	0.0	11.0	0.0	0.0	1.0	0.0	20.0	0.0	0.0
21	0.0	0.0	0.0	0.0	95.0	46.0	13.0	0.0	0.0	25.0	0.0	0.0
22	0.0	0.0	0.0	0.0	39.0	31.0	0.0	12.0	0.0	17.0	0.0	0.0
23	0.0	0.0	0.0	1.0	8.0	12.0	3.0	54.0	0.0	5.0	0.0	0.0
24	0.0	0.0	0.0	0.0	2.0	24.0	50.0	50.0	0.0	9.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	19.0	0.0	15.0	0.0	13.0	0.0	0.0
26	0.0	0.0	0.0	0.0	26.0	0.0	0.0	38.0	0.0	0.0	0.0	10.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.0	0.0	0.0	0.5	0.0
28	0.0	0.0	0.0	0.0	23.0	2.0	38.0	65.0	0.0	0.0	12.0	0.0
29	0.0		0.0	0.0	0.0	13.0	15.0	40.0	2.0	0.0	7.0	0.0
30	0.0		0.0	0.0	0.0	5.0	0.0	25.0	0.0	0.0	7.0	0.0
31	0.0		14.0		0.0		5.0	32.0		2.0		0.0
TOTAL	**0.0**	**0.0**	**14.0**	**75.0**	**409.0**	**295.0**	**993.0**	**1074.0**	**370.0**	**268.0**	**139.5**	**132.0**

Rainfall Data (in mm) for the year 2023 Basin - Periyar, Rain Gauge Station - Kallarkutty												
Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Date	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	8.0	69.0	0.0	
2	0.0	0.0	0.0	21.0	53.0	0.0	4.0	0.0	25.0	31.0	9.0	
3	0.0	0.0	0.0	8.0	5.0	0.0	82.0	0.0	1.0	14.0	24.0	
4	0.0	0.0	0.0	2.0	1.0	11.0	54.0	0.0	37.0	1.0	7.0	
5	0.0	0.0	0.0	3.0	0.0	0.0	101.0	0.0	14.0	0.0	42.0	
6	0.0	0.0	0.0	0.0	0.0	0.0	82.0	0.0	11.0	0.0	44.0	
7	0.0	0.0	0.0	5.0	0.0	104.0	92.0	0.0	39.0	0.0	6.0	
8	0.0	0.0	0.0	5.0	0.0	6.0	67.0	0.0	85.0	0.0	0.0	
9	0.0	0.0	0.0	0.0	0.0	4.0	39.0	34.0	20.0	0.0	39.0	
10	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	61.0	0.0	0.0	
11	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	40.0	0.0	1.0	
12	0.0	0.0	0.0	0.0	23.0	0.0	1.0	4.0	13.0	5.0	0.0	
13	0.0	0.0	0.0	0.0	0.0	63.0	0.0	5.0	0.0	0.0	0.0	
14	0.0	0.0	0.0	0.0	0.0	3.0	1.0	0.0	27.0	12.0	0.0	
15	0.0	0.0	0.0	0.0	0.0	17.0	9.0	0.0	41.0	13.0	0.0	
16	0.0	0.0	12.0	0.0	0.0	22.0	0.0	0.0	11.0	10.0	0.0	
17	0.0	0.0	26.0	0.0	0.0	0.0	5.0	0.0	5.0	10.0	14.0	
18	0.0	0.0	6.0	0.0	0.0	22.0	17.0	0.0	13.0	3.0	0.0	
19	0.0	0.0	37.0	0.0	0.0	10.0	37.0	20.0	34.0	2.0	0.0	
20	0.0	0.0	0.0	0.0	19.0	0.0	51.0	8.0	2.0	3.0	0.0	
21	0.0	0.0	0.0	0.0	2.0	0.0	13.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	7.0	32.0	0.0	1.0	0.0	0.0	0.0	12.0	
23	0.0	0.0	0.0	3.0	0.0	12.0	49.0	0.0	0.0	12.0	61.0	
24	2.8	0.0	0.0	0.0	0.0	0.0	57.0	0.0	7.0	44.0	6.0	
25	26.0	0.0	1.0	1.0	0.0	0.0	58.0	0.0	0.0	17.0	0.0	
26	0.0	0.0	2.0	61.0	0.0	7.0	44.0	0.0	0.0	1.0	0.0	
27	0.0	0.0	0.0	31.0	0.0	1.0	12.0	0.0	3.0	0.0	0.0	
28	0.0	0.0	0.0	21.0	0.0	20.0	4.0	0.0	28.0	0.0	0.0	
29	0.0		10.0	0.0	0.0	7.0	1.0	0.0	41.0	0.0	0.0	
30	0.0		0.0	3.0	0.0	4.0	0.0	0.0	11.0	3.0	0.0	
31	0.0		0.0		0.0		0.0	29.0		0.0		
TOTAL	**28.8**	**0.0**	**94.0**	**171.0**	**135.0**	**324.0**	**898.0**	**100.0**	**577.0**	**250.0**	**265.0**	

ANNEXURE IV – GEOLOGICAL INVESTIGATION REPORT

Subsoil investigations were carried out to determine the character and depth of overburden, bed rock etc. and to determine the feasibility of foundations and specification for designs. One borehole at Power House site and seven numbers boreholes at weir site were taken at different locations using a mechanical type drilling rig. In most of the bore holes there existed rocky strata below top soils. Rock cores were taken from the rocky strata with NX diamond rock coring bits. The rock cores were identified and typical samples tested in unconfined compression to determine their compressive strength.

The rock quality designation (RQD) of the rock cores and the rock recovery ratios found out from the rock coring data. The rock cores were arranged in order and preserved. The preliminary geological investigation was done by the geologist from GSI Chennai and the rock core were got logged. Geotechnical report is enclosed

A Construction stage geotechnical investigation of progressive excavation for various components of the project was carried out by the Geologists from Geological Survey of India, Trivandrum unit. The investigation included foundation mapping of Weir (Block), mapping of side face of Power House, and Penstock excavation and geotechnical assessment of other partially excavated areas of various component of the project.

ANNEXURE V – GLOSSARY

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.

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.

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 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.

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 unfavorable 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 aphilosophy 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, - 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.

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.

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.

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 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.

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.

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.

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.)
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.
Low-level outlet (bottom outlet) - an opening
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.

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.

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

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.

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

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.

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.

, damaged, or failed dam or its component to an acceptable by meeting functional condition.

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.

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.

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.

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.

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.

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.

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.