# Operation and Maintenance Manual for Kuttiyadi Augmentation Scheme State of Kerala

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

सत्यमेव जयते

# Operation and Maintenance Manual for Kuttiyadi Augmentation Scheme

**Prepared by the Dam Safety Organisation**
**Kerala State Electricity Board Ltd**

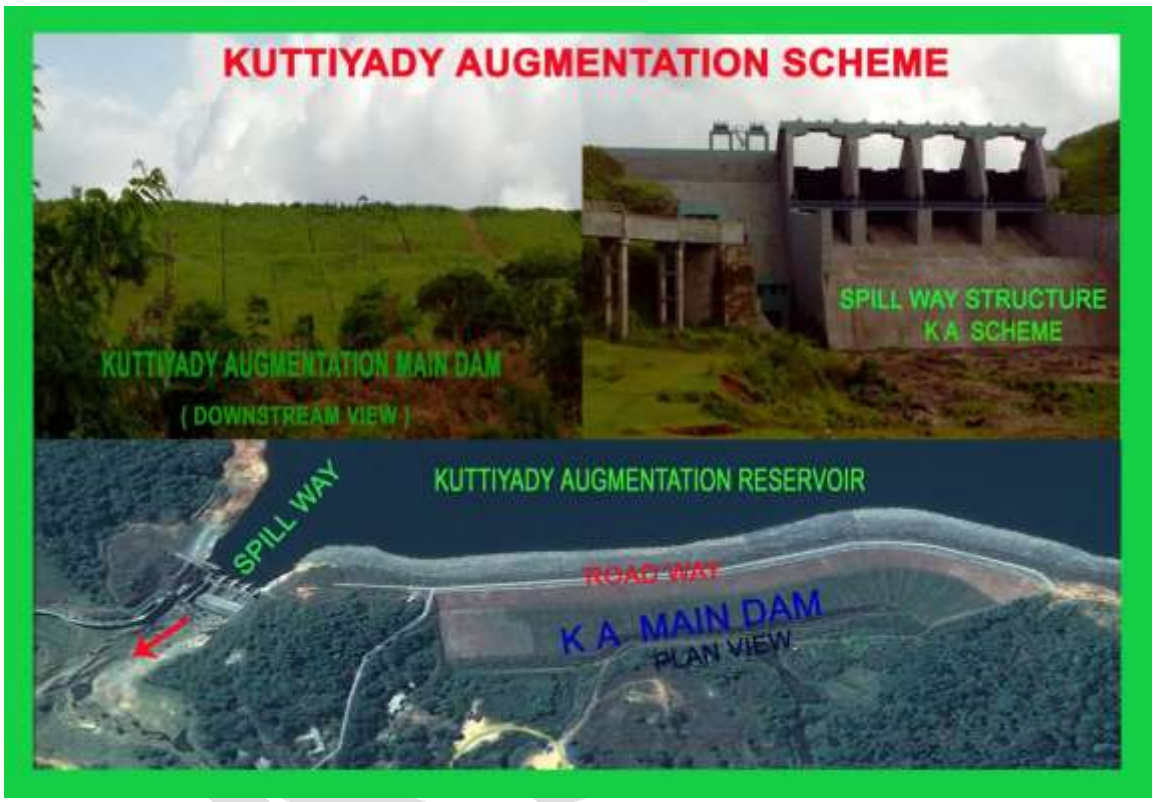
**(A Government of Kerala undertaking)**
**State of Kerala**

Front Cover Photograph: Downstream view of Spillway dam and view of Main dam.

Government of Kerala

# Operation and Maintenance Manual

# Kuttiyadi Augmentation Scheme

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**Kerala State Electricity Board Ltd**
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**February 2020**

**Government of Kerala**
**Kerala State Electricity Board Ltd**
**Dam Safety Organisation**

## Disclaimer

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

The manual was developed for the purpose of organising and managing the operation, inspection and maintenance of the dams for reducing risk and optimizing performance of the dams as a general guide.

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# Message

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

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

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

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

**Bibin Joseph,**
Director Generation (Civil),
KSEBLtd
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# Foreword

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

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

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

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

Smt. Supriya S,
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# PREFACE

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

Central Water Commission has published the guidelines for the development of new manual and updating of existing manual vide CDSO_GUD_DS_03_v1.0 Page xii January 2018. Accordingly Kerala State Electricity Board Ltd is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy Dam Safety management system.

Dams of Kuttiyadi Augmentation Scheme under KSEBL has an Operation and Maintenance Manual which is not so comprehensive according to the present standards. Hence an attempt is being made here to revise the manual as per the new guidelines by CWC.

# Team involved in preparing this O & M Manual of Kuttiyadi Augmentation Scheme

## Review and Approval

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# General Information

## 1.1 Introduction

This document represents a detailed Operation and Maintenance (O&M) Manual for Dams of Kuttiyadi Augmentation Scheme, Kerala, providing written descriptions of procedures for ensuring that the dams operate safely and is kept in a good condition by periodic inspections, repairs and maintenance in a sustainable manner. As huge amount of public money has been invested in the project, timely maintenance is important for the continued safe functioning and productive use of the dams and reservoir.

The Manual has been prepared primarily for the dam operation staff and supervisors who are assigned the responsibility of physical operation and maintenance of the dam. It contains, as a minimum, all information and instructions necessary for them to perform their allotted tasks in a safe manner. In addition to instructions for dam operation staff, the Manual includes all necessary instructions for other staff directly or indirectly involved in operating and maintaining the dam.

It is essential that the Manual or a copy of the Manual along with supporting data including all drawings and manufacturer's technical documents is available at site for ready reference.

## 1.2 Purpose, Location & Description of Kuttiyadi Augmentation Scheme

The Kuttiyadi Augmentation Scheme aims at harnessing the potential of the river Karamanthodu, a tributary of Kabani by diversion of waters to the Kuttiyadi Reservoir for increasing the power potential of Kuttiady Power Station. In addition, the scheme aims at irrigating an area in its own basin as well as Kuttiyadi basin.

The Kuttiyadi Augmentation Scheme, better known as BanasuraSagar Multipurpose scheme, is located in Karamanthodu, a tributary of Panamarampuzha in the Kabani basin which in turn is a tributary of Cauvery. The Scheme is located in Wayanad district of Kerala

State and is at a distance of 22 km from Kalpetta, the district head-quarters, and 88 km from Kozhikode via Vythiri. Major purpose of the scheme is to harness the water potential of Karamanthodu, for augmenting the reservoir of the Kuttiyadi Hydro Electric Scheme located at Kakkayam and to improve the irrigation potential in the Karamanthodu basin as well as in the Kuttiyadi basin in Kozhikode district.

The Scheme essentially consists of a reservoir of gross storage capacity of 209 Mm3 formed by constructing a homogeneous rolled earth fill dam, 38.5 m high, at Padinjarethara across Karamanthodu and six other saddle dams of height varying from 5 to 20m, in addition to a separate spillway dam. About 155.76 Mm3 of water is being diverted to the Kuttiyadi Hydel Reservoir (Kakkayam) through a 4.763 km long tunnel. Previously, the power generation at Kuttiyadi Power Station varied from 75 MW during the peak monsoon months to 14 MW during the summer, for want of sufficient storage capacity. The augmentation Scheme has increased the average annual power generation at Kuttiyadi power station from 211 Mu to 434 Mu. KSEB has also constructed two extension schemes for the old Kuttiyadi power station (50 MW + 100 MW) for better utilisation of this augmentation scheme.

The implementation of the Augmentation Scheme, has enhanced the area under three crops cultivation in Kuttiyadi basin to 5200 Ha from 2023 Ha. In the Karamanthodu basin, rain fed single crop paddy cultivation was being practiced earlier. With the completion of the irrigation project, about 3200 Ha can be converted to two crops pattern in the Karamanthodu basin and this turned to be a boon to the farmers in this locality.

Among the associated benefits, the hydel tourism program out stands above all. The Kerala Hydel Tourism Centre is operating a Tourism centre in this project area with facilities for boating in the reservoir. Being the second largest of its kind in the Asian Continent, the main earth fill dam is a major attraction. In addition, the Government has given fishing rights in the reservoir to tribal societies, for improving the livelihood of tribes in the locality and to provide them better opportunities in fish cultivation.

The Kerala Water Authority has planned a drinking water supply scheme to augment the water supply scheme in Wayanad district. The scheme envisages construction of a pump well near the periphery of the reservoir. The project is in its initial phase.

## 1.2.1. Dam site Location:

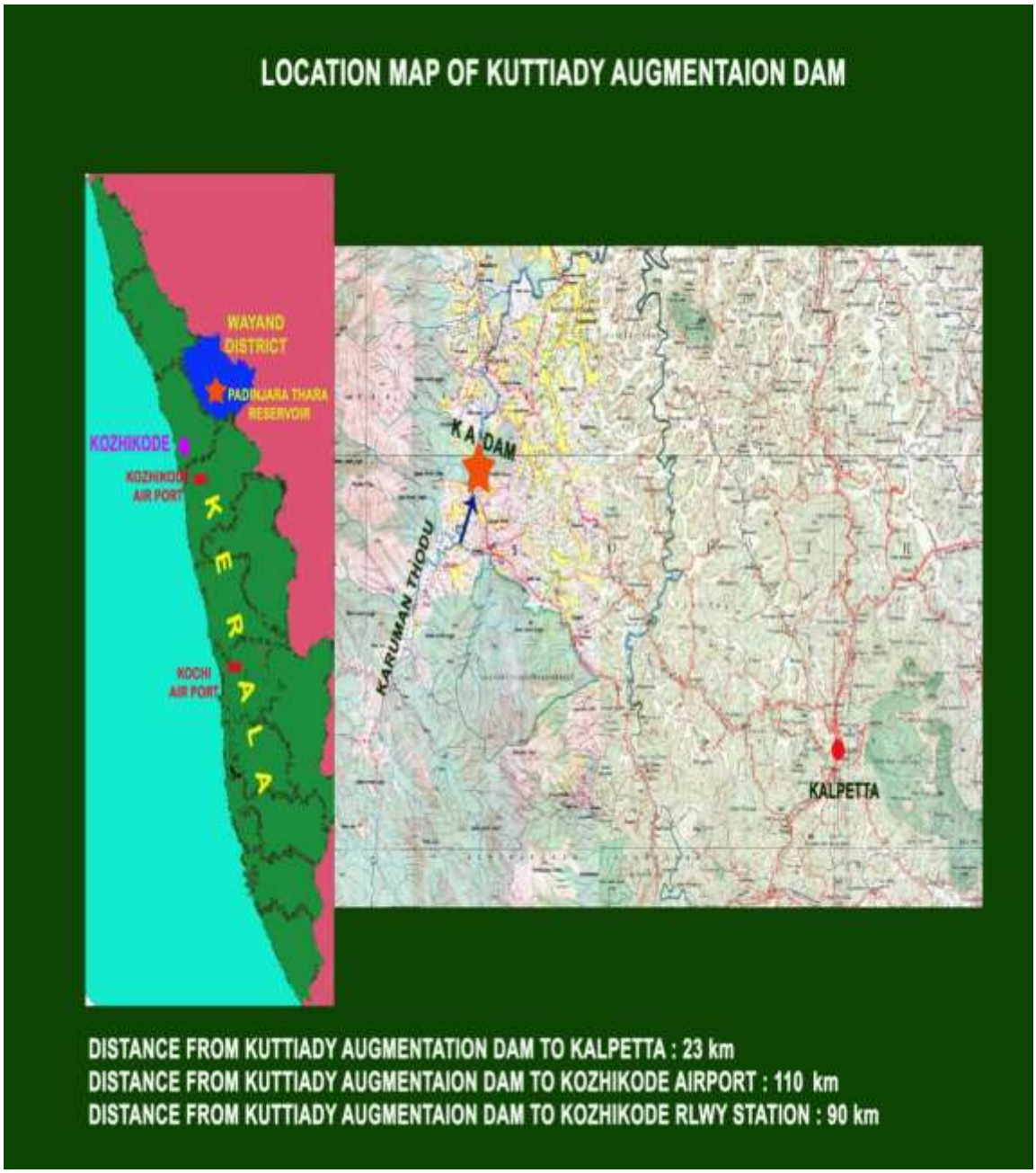


**Fig 1.1 Location Map**


**Fig 1.2 Kuttiyadi Augmentation Scheme View From Google earth.**


**Fig 1.3 Layout Plan**

## 1.3 Background Details of the Scheme

Karamanthodu, a tributary of Panamarampuzha in Waynad District flows adjacent to the catchment of Kuttiyadi reservoir in Kozhikode District and the possibility of diverting it in to Kuttiyadi reservoir was identified earlier.

The detailed investigations for the scheme were taken up in February 1971. All surveys for the subject scheme were based on the Master B.M +772 m established at the right bank of Kuttiyadi dam. Alternative proposals for firming up and augmenting the power potential of the Kuttiyadi power station were examined with the help of GTS Maps and detailed reconnaissance.

**Sankarapuzha Storage Scheme:**

Sankarapuzha Storage Scheme with a catchment of 8.03 sq. km in Sankarapuzha, a tributary of Kuttiyadi River was considered. The yield at the dam site was calculated as 42.47 Mm3. Since the storage estimated was very less (26.9 $Mm^3$) and by constructing a 91.4m high dam, it was found that the summer generation could be firmed up only to about 28 MW. So the proposal was not persued further.

**Urakuzhy Diversion:**

The Urakuzhi stream joins Kuttiyadi river downstream of Kuttiyadi dam. The yield of 22.65 $Mm^3$, from a catchment of 4.53 sq. km was considered for diversion to Kuttiyadi reservoir, by constructing a diversion dam and a tunnel of length 1219m. But the storage capacity was found to be too less and hence the scheme was not considered.

**Onipuzha Diversion:**

Pandialaparathodu and Urutttianthodu are two streams originating on the western side of the Kosani saddle and joining together at Anakuzhi. The river below this confluence point is known as Onipuzha which joins Kuttyadi river downstream of Kuttiyadi Irrigation Dam. Construction of a dam at Anakuzhi with a catchment area of 7.77 sq. km was considered. But it involved construction of a very high dam with half a dozen saddle dams which was not financially viable and hence was dropped.

**Karamanthodu diversion proposal:**

Under Karamanthodu diversion proposal, four dam sites viz. Kosani, Choorani, Kuttiyamvayal and Padinjarathara were investigated.

**Kosani dam site:**

The site was just downstream of the confluence of Karamanthodu and Perumthadathodu with catchment area of 18 sq. km. The bed level was +752.24 m.

**Choorani dam site:**

By constructing a dam at Choorani, 4km downstream of Kosani dam site, a catchment area of 29.76 sq. km could be intercepted. The river bed level at this site was +746.14m.

**Kuttiyamvayal dam site:**

Kuttiyamvayal dam site was near Thariode town, downstream of Churani dam site having a catchment area of 54.4 sq. km and bed level at+742.5 m. Fourteen saddles were required for the creation of reservoir at this site.

**Padinjarethara Dam Site:**

Padinjarethara dam site was 4 km downstream of Kuttiyamvayal dam site, the catchment area of which was calculated as 62 sq. km and the bed level was +739.75 m. Under this proposal, major saddle dams required was considerably less.

For regulation and diversion of the yield of Karamanthode at Padinjarathara for augmenting Kuttiyadi reservoir and for irrigation utilization in both Karamanthodu and Kuttiyadi basins, the gross storage required was assessed as 198.7 $Mm^3$.

The Padinjarethara dam site was preferred considering the following aspects also. The Kosani and Churani sites yield only much less quantity of water. Eventhough, Kuttiyavayal site had more catchment area and the annual yield was assessed to be more, for providing adequate storage, a very high dam and a large number of saddle dams had to be constructed.

Since Padinjarethara dam site was downstream of other sites with negligible fall in bed level, better storage facility was assessed at a lower FRL ensuring the diversion of the same quantity of water. By reducing the number of saddle dams involved and their heights much savings was ensured in the overall cost. The main disadvantage was that a part of Thariode village would be submerged. However, comparative cost studies indicated that this site was preferable to all the other sites, even after providing for compensation and rehabilitation of Thariode settlement. The upstream proposals involved too many saddle dams and with lesser construction facilities they were not as feasible or simple as the Padinjarethara proposal.

The Government of Kerala accorded sanction for implementing the Scheme, with the internal resources of the Board, in May 1980. Preliminary works were started in October 1980 and approval was given by Central Water Commission in October 1982.

## 1.4 Salient Features of the Scheme

| **General** | |
|---|---|
| Project Identification Code | KL29HH0044 |
| Survey of India Map Ref No. | 49 M 14 |
| Location | River basin : Kabani<br>Sub River basin : Karamanthodu<br>District : Wayanad<br>Panchayats : Padinjarethara and Thariyod |
| Means of access | Nearest City is Kalpetta<br>Nearest Railway station is Kozhikode<br>Nearest Airport is Calicut International Airport |
| **Geophysical features** | |
| Catchment area | 61.44 Sq. Km. |
| Nature of catchment | Comprises mostly private estates and forest land with patches of cultivated lands. |
| Climate | hot with a high degree of atmospheric humidity |
| Mean annual precipitation | 6247mm |

| | |
|---|---|
| Geological features at project site | Charnockite and Migmatite Gneiss rock type |
| **Technical Data** | |
| Type of Project | Hydro Power (Augmentation scheme for Kuttiyadi Hydro Electric Project) |
| Average Annual Energy Generation | 223 MU (At Kuttiyadi HEP) |
| Gross Storage Capacity | 209.18 $Mm^3$ |
| Dead Storage Capacity | 23.75 $Mm^3$ |
| MDDL | +754.86m |
| FRL | +775.60m |
| MWL | +775.60m |
| Water spread area at FRL | 1277Ha |
| **A. Spillway Dam** | |
| Location | Padinjarathara. |
| Latitude | $11^0$40'18" N |
| Longitude | $75^0$57'36" E |
| Type | Concrete |
| Top level of the dam | +778.50m |
| Crest level | +767.00m |
| Height of Dam above deepest foundation level | 36.50m |
| Length at top | 56.38m |
| Type of Spillway | Ski-jump |
| Length of spillway | 56.38m |
| No of Bays | 4 |
| Type of Gate | Radial |
| Size of gate | 10.97m x 9.20m |
| Total Spillway Capacity of all bays | 1664$m^3$/s |
| Gate Hoisting Arrangement | Rope-Drum Type |
| River Outlet | One number (2 m dia. circular) |
| Level of outlet | +750.75m (Centre line elevation) |

| | |
|---|---|
| Irrigation outlet | One number (2 m dia. circular) |
| Level of outlet | +759.00m (Centre line elevation) |
| Type and size of emergency gate | Vertical gate 2.85 m (W) x 3.30 m (H) |
| Type and size of valve | Circular 2 m dia. |
| **B. Main Dam** | |
| Location | Padinjarathara. |
| Latitude | $11^0$40'15" N |
| Longitude | $75^0$57'21" E |
| Type | Embankment (Homogeneous rolled earth fill) |
| Top level | +778.50m |
| River bed level | +740.00m |
| Height of Dam above bed level | 38.50m |
| Length at top | 685.00m |
| Width at top | 7m |
| Width at bottom | 245m |
| Upstream Slope | 1V : 4H with a berm of width 5 m at El +765.00 m |
| Downstream slope | 1V : 3 H with a berm at El +768.00 m |
| Spillway | No spillway arrangement |
| Outlet | Nil |
| **C. Kuttiyadi Saddle Dam** | |
| Location | Kuttiyadi |
| Latitude | $11^0$35'56" N |
| Longitude | $75^0$55'09"E |
| Type | Concrete gravity |
| Top level | +777m |
| Saddlebed level | +760.50m |
| Height of Dam above saddle level | 16.50m |
| Length at top | 121m |

| | |
|---|---|
| Width at top | 4m |
| Outlet | 2m dia.at El. 764.00 m |
| Type and size of Emergency gate | Vertical gate 2.20 m (W) x 3.05 m (H) |
| **D. Kottagiri Saddle Dam** | |
| Location | Kottagiri |
| Type | Homogeneous earth fill |
| Latitude | $11^0$36'53" N |
| Longitude | $75^0$54'58"E |
| Top level | +778.50m |
| Saddle bed level | +764m |
| Height of Dam above saddle level | 14.50m |
| Length at top | 90m |
| Width at top | 7m |
| Upstream Slope | 1 V : 4 H |
| Downstream Slope | 1 V : 3 H |
| **E. Saddle Dam Near Kottagiri** | |
| Location | Near Kottagiri Saddle |
| Latitude | $11^0$36'44" N |
| Longitude | $75^0$55'00"E |
| Type | Homogeneous earth fill |
| Top level | +778.50m |
| Saddlebed level | +767.50m |
| Height of Dam above saddle level | 11m |
| Length at top | 110m |
| Width at top | 7m |
| Upstream Slope | 1 V : 4 H |
| Downstream Slope | 1 V : 3 H |
| **F. Kosani Saddle Dam** | |
| Location | Kosani |

| | |
|---|---|
| Latitude | $11^0$37’ 09” N |
| Longitude | $75^0$55’ 14” E |
| Type | Homogeneous earth fill |
| Top level | +778.50m |
| Saddlebed level | +764.70 m |
| Height of Dam above deepest foundation level | 13.80 m |
| Length at top | 140 m |
| Width at top | 7m |
| Upstream Slope | 1 V : 4 H |
| Downstream Slope | 1 V : 3 H |
| **G. Manjoora Saddle Dam** | |
| Location | Manjoora |
| Type | Homogeneous earth fill |
| Latitude | $11^0$38’44” N |
| Longitude | $75^0$58’43”E |
| Top level | +777m |
| Saddlebed level | +773m |
| Height of Dam above saddle bed level | 4m |
| Length at top | 74m |
| Width at top | 7m |
| Upstream Slope | 1 V : 4 H |
| Downstream Slope | 1 V : 3 H |
| **H. Nayanmoola Saddle Dam** | |
| Location | Nayanmoola |
| Type | Homogeneous earth fill |
| Top level | +778.50m |
| Saddle bed level | +775 m |
| Height of Dam above saddle bed level | 3.50 m |

| | |
|---|---|
| Length at top | 24 m |
| Width at top | 7m |
| Upstream Slope | 1 V : 4 H |
| Downstream Slope | 1 V : 3 H |
| **Diversion Tunnel** | |
| Length | 4763 m |
| Inlet sill level | +750.50 m |
| Exit sill level | +739.62 m |
| Length of lined portion | 890 m |
| Size of lined portion | 2.35 m dia. circular |
| Length of unlined portion | 3873 m |
| Size of unlined portion | 2.85 m dia. D shaped |
| Discharge capacity at FRL | 11.60 cumecs |
| Velocity of flow at FRL | 1.60 m/sec |
| **Intake** | |
| Size of intake gate | 2.15 m (W) x 2.30 m (H) |
| Trash rack | Consists of 2 bays and 3 panels in each bay. |

**Table 1.1 Salient Features of Kuttiyadi Augmentation Scheme**

**Fig 1.4 Spillway dam**

**Fig 1.5 Main dam**

**Fig 1.6 Kuttiyadi saddle dam**

**Fig 1.7 Kottagiri saddle dam**

**Fig 1.8 Saddle dam near Kottagiri**

**Fig 1.9 Kosani saddle dam**

**Fig 1.10 Manjoora saddle dam**

**Fig 1.11 Nayanmoola saddle dam**

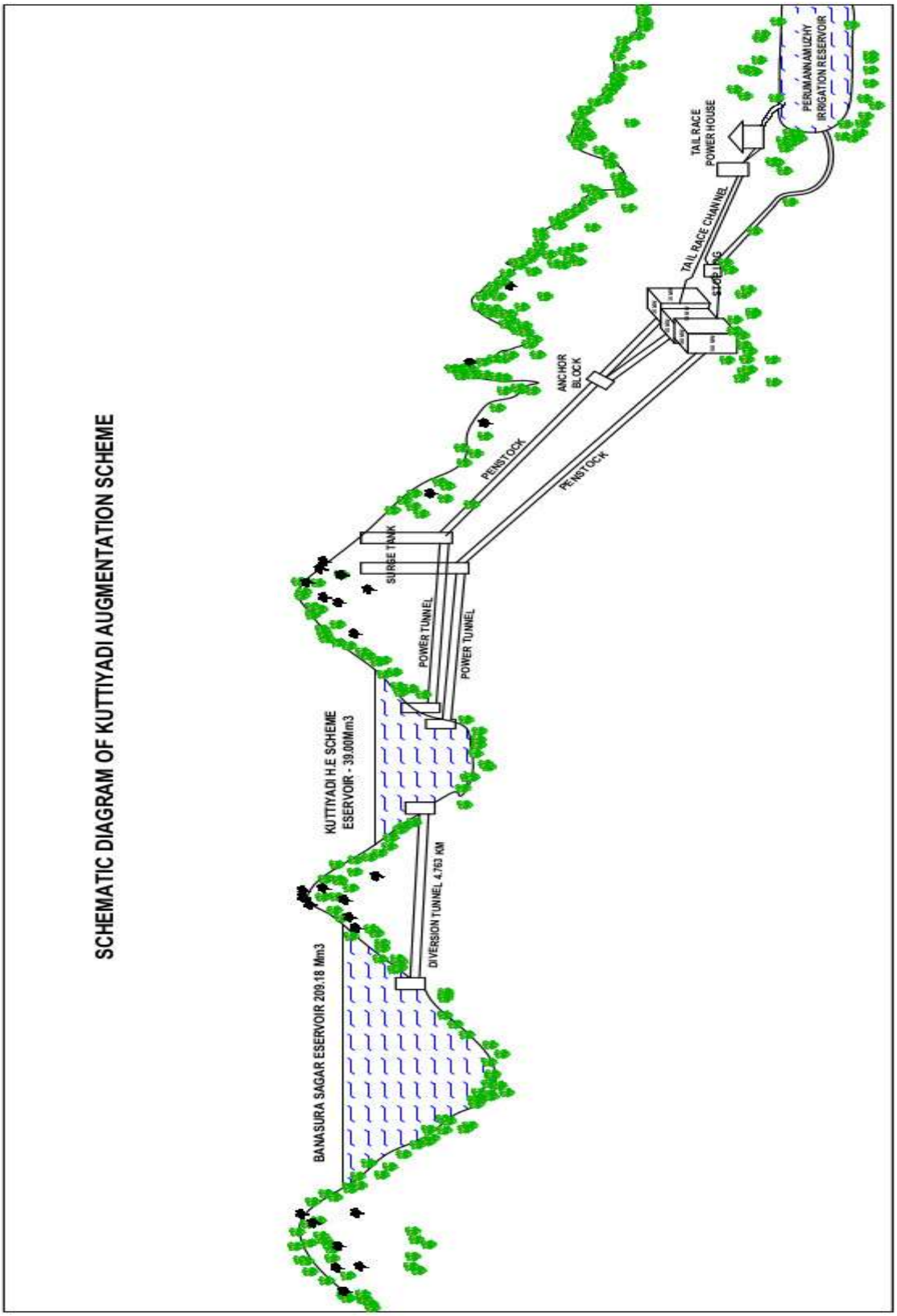


**Fig 1.12 Schematic diagram**

## 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 dams. Identification of all areas of responsibilities connected with the operation and maintenance of dams are covered in this section. The officer's responsibilities for the various functions are identified by their designation and, in particular, the responsibilities of operating personnel are specifically identified below including the regularly scheduled duties which staff personnel are required to perform as outlined in the following tables.

| Sl No | Particulars | Remarks |
|---|---|---|
| 1 | Project Administration Officer | Chairman & Managing Director, KSEB Ltd. |
| **2** | Chief Controlling Officer | Chief Engineer (Civil – DS&DRIP). |
| **3** | Authority of Spillway and Flood Releases | Chief Engineer (Civil – DS&DRIP). |
| 4 | Operation and safety of the dam | Deputy Chief Engineer, Research & Dam Safety Organization & DRIP, Pallom |
| 5 | Controlling and Operation Officer at dam site | Executive Engineer, Research & Dam Safety Division No. V, Thariyode. |
| 6 | Dam Health Engineer | Executive Engineer, Research & Dam Safety Division No. V, Thariyode. |
| 7 | Dam Maintenance Engineer | Assistant Executive Engineer, Research & Dam Safety Sub Division, Thariyode. |

**Table 1.2 – Overall Responsibilities of Dams**

### 1.5.1 Roles and Responsibilities of the AEE and AE during Monsoon

| | **Flood condition assessment, warning, flood mitigation, and other responsibilities** |
|---|---|
| 1 | Collect information on the rainfall in the catchment and inflow status and to bring it to the notice of the EE/Dy CE. |
| 2 | Assist the EE/ Dy CE /CE to issue notification to the inhabitants downstream in Newspapers, Radio, TV News channel to be alert regarding the flood situation. |
| 3 | Assist the EE/ Dy CE /CE to coordinate with the Revenue authorities (District Administration) to alert the downstream inhabitants to evacuate the flood zone to prevent loss of life and livestock. |
| 4 | Assist the EE/ Dy CE /CE to coordinate with the CWC flood monitoring authorities on the flood condition |
| 5 | Maintain the reservoir water level gauge register and to update on hourly basis during floods and report to EE/ Dy CE /Chief Engineer |
| 6 | Assess the inflows in the reservoir as per the approved reservoir operation and to prepare proforma consisting of the status of the reservoir capacity and releases from the reservoir as per the standard Performa and to submit to the EE/ Dy CE /CE |
| 7 | Submit to the EE/ Dy CE /CE on the inflows and releases from the reservoir and status of the reservoir twice in the day |
| 8 | Maintain the spillway crest gate operation log book |
| 9 | Operate the Spillway crest gates for flood mitigation as per the instructions of the EE/ Dy CE /CE and to update the Gate operation Log book |
| 10 | Observe the seepages in the drainage Gallery with respect to the reservoir head and record the seepages and to immediately bring to the notice of the EE/ Dy CE /CE in case of excessive seepage/leakage in any specific blocks. |
| 11 | Observe the gates and to see that the its drain holes are not clogged and floating debris is not deposited in the gate components |
| 12 | Monitor the condition of the Welding transformers, gas cutting sets, umbrellas, tool kits, torches, chain blocks, ropes etc. on daily basis and to see that things are in place to handle any emergency situation |

| | |
|---|---|
| 13 | Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors, pumps or vibrations in the gate |
| 14 | Observe the dam top, catwalk, approach roads are well maintained by housekeeping personnel |
| 15 | Observe the performance of the Dams and its appurtenant structures / Gates and Hoists during flood water releases and to report to the EE/ Dy CE /CE in case of any untoward incidents or malfunctioning of the gates or excessive seepages, leakages etc. |
| 16 | Assist EE/ Dy CE /CE to coordinate with the Generating staff of Kuttiyadi Powerhouse downstream in the operation and power generation. |
| 17 | Assist EE/Dy CE /CE to share the flow data and the reservoir storage details to the Media on day to day basis during flood. |

**Table 1.3 – Roles & Responsibilities of AEE & AE**

### 1.5.2 Roles and Responsibilities of the DYCE and EE during Monsoon

| SL No | Flood condition assessment, warning, flood mitigation, and other responsibilities |
|---|---|
| 1 | Conduct Periodical inspections to assess the health of the Dams and to direct the Executive Engineer for the immediate repair and maintenance. |
| 2 | Observe the performance of the Dams and its appurtenant structures/Gates and Hoists before and after monsoon and to issue necessary instructions to the Executive Engineer |
| 3 | To issue notification to the inhabitants downstream in Newspapers, Radio, TV News channel to be alert regarding the flood situation |
| 4 | Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers to evacuate the flood zone to prevent loss of life and live stock |
| 5 | Assist the CE to coordinate with the CWC flood monitoring authorities on the flood condition |
| 6 | Submit to the CE the daily inflows and releases from the reservoir and status. |
| 7 | Operate the Spillway crest gates for flood mitigation as per the instructions of the |

| | |
|---|---|
| | CE and to update the Gate operation Log book |
| 8 | Observe the seepages in the drainage Gallery with respect to the reservoir head and record the seepages and to immediately bring to the notice of the CE in case of excessive seepage, leakage in any specific blocks and porous drains |
| 9 | Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors, pumps or vibrations in the gate |
| 10 | Observe the dam top, catwalk, approach roads are well maintained by housekeeping personnel |
| 11 | Observe the performance of the Dams and its appurtenant structures/Gates and Hoists and to report to the CE in case of any untoward incidents or malfunctioning of the gates or excessive seepages, leakages etc. |

**Table 1.4 – Roles & Responsibilities of Dy. CE& EE**

### 1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

| SL No | Flood condition assessment, warning, flood mitigation, and other responsibilities |
|---|---|
| 1 | To issue sanction for flood release notification after discussing with Kerala Disaster Management Authority and Revenue Authority (District Administration). |
| 2 | Coordinate with the CWC flood monitoring authorities on the flood condition |
| 3 | Issue necessary instructions to the Engineers to Operate the reservoir based on the in-flows, rainfall data, releases from the upstream reservoirs and status of the reservoir |
| 4 | Observe the performance of the Dams and its appurtenant structures / Gates and Hoists during flood water releases and to issue necessary instructions to the Dy CE/EE |
| 5 | Conduct Pre and Post Monsoon inspections of the Dams and submit the report to CWC. |

**Table 1.5 – Roles & Responsibilities of the Chief Engineer**

## 1.6 Collection & Reporting of Dam and Reservoir Data

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

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

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

**Table 1.6 Daily Reservoir Data**

Instruction is given to the Executive Engineer for daily collection and reporting of inflow and outflow data in standard proforma as in **Table 1.6** above to the Deputy Chief Engineer.

On collecting the details in the above format, a daily reservoir status is submitted to the Chief Engineer as in the **Table 1.7**.

| Date | Water Level (m) | Previous Year Same day Water Level (m) | Rainfall (mm) | Previous Year Rainfall (mm) | Storage ($Mm^3$) | Generation (MU) | Gross Inflow ($Mm^3$) | PH Discharge + Losses ($Mm^3$) | Spill ($Mm^3$) | Net Inflow ($Mm^3$) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|

**Table 1.7 Daily Reservoir Status**

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

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

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

| | |
|---|---|
| Reservoir water surface elevation: | This is collected daily |
| Reservoir inflow: | This is calculated daily |
| Spillway outflow: | This is calculated during spill |
| Irrigation releases: | Water is not being released for irrigation as the canal work has not started |
| Hydropower releases: | The reservoir water is used for power generation |
| Weather related data: | Collected and reported daily |
| Security arrangements: | Provided at three security check posts near Dam. CCTV surveillance will be provided soon covering the dam and premises. |
| Attendance statement during normal operations | Both during monsoon and non-monsoon period maintained at field office |
| Operations of the spillway gates and Outlet works | Gate operation log book and outlet operation log books are maintained at field office |

| | |
|---|---|
| Operating hours of mechanical equipments | Maintained at field office |
| Testing/Operation of spillway gates And associated controls | The testing and operation are being carried out as per the manual and maintenance schedule. Other details maintained at field office |
| Testing/operation of Outlet gates, Valves and associated controls | Maintained at field office |
| Maintenance activities carried out | Details maintained at field office |
| Reservoir and dam inspections | Periodically inspected and details maintained at field office |
| Unusual conditions or occurrences, including acts of vandalism | Details maintained at field office |
| Attendance statement at dam during emergency operations | Details maintained at field office |
| Changes to normal operating procedure | Details maintained at field office |
| Water quality: | The quality of water is to be tested every six months |
| Communication network checks: | Regularly checked |
| Safety and special instructions: | Safety equipment provided |
| 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. Security personnel are posted for providing public notices of events and status of security of the dam and downstream river conditions.

**Access Roads**

The project is located in Wayanad District of Kerala State. The location of Main Dam site is at Padinjarethara. The nearest airport is Calicut International Airport. The distance from airport to Kuttiyady Augmentation Dam is 110 km. The nearest rail head is Kozhikode. It is about 90 km from dam site. The nearest city is Kalpetta. The Project is accessible by road from Kalpetta, the district headquarters and from Kozhikode, via Vythiri.

The distance from Kalpetta to the project site is 22 km and from Kozhikode to the project site is 88 km.

**Location of public conveniences**

An Inspection Bungalow is located near the dam. Nearest Police station is located at Padinjarethara, 3 km away from the dam. There is also a Primary Health Centre located at Padinjarethara.

**Safety equipment available at the dam**: First aid kit and fire extinguishers are available.

## 1.8 Restricted Areas

Certain areas of the dam and reservoir are restricted for entry of the general public. The purpose of restrictions is for security of the dam, public safety and uninterrupted safe operation of the dam. Sign boards are displayed at the prohibited areas of the dam.

- Confined spaces such as gallery.
- Spillway approach areas, chutes and energy dissipation areas.
- Spillway gate hoisting arrangement
- Intake gate operation area, trash rack area etc.

Sign boards are displayed at the prohibited areas of the dams i.e., at the side of road and also near to the entrance.

### 1.8.1 Details of the Security arrangements at Dam Site

Security arrangements are already provided through private agency at three security check posts near dam. Also CCTV surveillance will be provided soon covering the dams and premises.

| | | |
|---|---|---|
| Security Arrangement Existing | - | Private agency (Ex – Servicemen) |
| No of security persons engaged | - | 3 persons at a shift. |

## 1.9 Staff Position, Communication & Warning System

An engineering organizational chart for the control and safety of Dams of Kuttiyadi Augmentation Scheme is shown in **Figure 1.13** below. Means of communications both in normal and emergency situations are identified in the Communication Directory. Communication means available include land line, mobile phone and satellite phones.

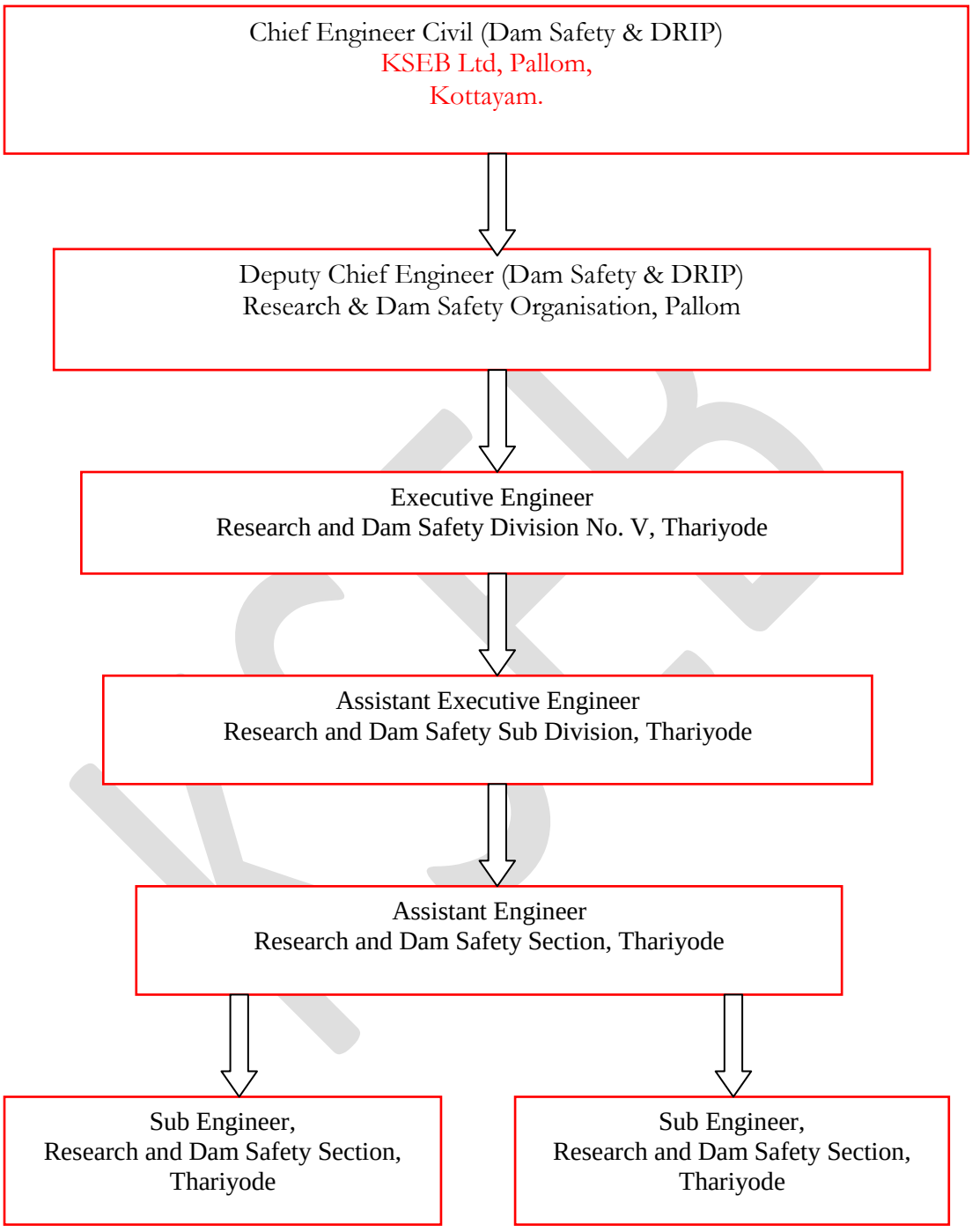


**Fig 1.13 Dam Safety Organisation Structure for Dams of Kuttiyadi Augmentation Scheme**

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

| Designation &Office Address | Contact number | e-mail |
|---|---|---|
| Chief Engineer Civil (Dam safety & DRIP), KSEBL, Pallom, Kottayam | 9496018719 | cedamsafety@kseb.in, cedamsafety@gmail.com |
| Deputy Chief Engineer, Research & Dam Safety Organization, Pallom | 9446008492, 0481-2432290, 9496011540 | dirroplm2@gmail.com. |
| Executive Engineer, Research & Dam Safety Division No. V, Thariyode | 9446008415 | eerdskkm@gmail.com. |
| Assistant Executive Engineer, Research & Dam Safety Sub Division, Thariyode | 9496004480 | aeedsswyd@gmail.com |
| Assistant Engineer, Research & Dam Safety Section, Thariyode | 9496005761 | |

**Table 1.8 Controlling officers and their contacts**

**Spillway flood releases**

Spillway of Banasurasagar Reservoir is provided in Kuttiady Augmentation Spillway dam adjacent to the main earth dam. Banasurasagar Main dam has no spillway gates. The Banasurasagar Reservoir is being operated based on "Guidelines for Operation of Reservoirs" (IS 7323:1994) and Gate Operation Manual.

As per the guidelines issued by the Central Water Commission for developing Emergency Action Plan for Dams issued in February, 2016 (Doc. No. CDSO_GUD_DS_01_v2.0), a three colour alert system (Blue, Orange and Red) shall be issued by the dam owner on detecting a distress in the dam according to the nature of the emergency level, to the various statutory authorities in charge of district administration, disaster management etc. in order to take appropriate action to reduce the risk to lives and

property from the consequences of potential dam failures. The above guidelines also envisage using the alerts in the case of a large controlled release from the dam due to severe weather and emergency conditions. A three stage/colour alert system is issued for the major reservoirs of KSEBL modelled on the above for a controlled release through the spillway for enabling the district administration to take disaster mitigation measures.

In Banasurasagar reservoir, the first warning (Blue Alert) as water level reaches 1.50m below the rule level, second warning (Orange Alert) as water level reaches 1.0 m below the rule level and third warning (Red Alert) as water level reaches 0.50m below the rule level are given for opening of spillway gates. Warnings are given in local media including TV etc. regarding the possible opening of spillway gates, continuously up to rule level. Also intimations are given to Disaster Management, District Administration, and Police Department etc. Spillway gates are opened at rule level based on "Guidelines for Operation of Reservoirs" (IS 7323:1994) and Gate Operation Manual. As per the revised Upper Rule Levels it is proposed to keep the water level at/below 768m (close to crest level of spillway of 767m) on June 10$^{th}$ and 775.6m (FRL) on 20$^{th}$ November. The gate of the control shaft from Banasurasagar reservoir to Kakkayam reservoir shall be operated judiciously to operate the reservoirs.

The different stage/colour alert levels are fixed considering the normal rainfall intensity and for general guidance. In the case of extreme rainfall event or identifying any distress in the dam, appropriate protective action shall be initiated by the Dam managers. Sanction has to be obtained from the District Collector for spilling the water. Evacuation is required only in the case of large release/extreme rainfall event.

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

Water from the Banasurasagar reservoir is diverted to Kakkayam for power generation at Kuttiyadi Power Station of KSEBL through a tunnel with gate arrangements at Control Shaft. Water let out at Kakkayam after generation of power is utilized by the State Irrigation Department for irrigation release at Peruvannamoozhi dam. A new Small Hydro Project is also being constructed for utilizing the water for power generation when irrigation release is not required. Water from Peruvannamoozhi reservoir is also used for augmenting the drinking water supply in Kozhikode district.

**Routine inspection.**

Usually monthly inspection and quarterly inspections as per KDSA are carried out by the operating/controlling officers. Pre-monsoon inspection and Post-monsoon inspection as per CWC are carried out and reports intimated to CWC. The pre-monsoon and post-monsoon reports are to be updated in DHARMA web site.

**Maintenance**

Routine maintenance is carried out for the dams and other appurtenant structures before the onset of monsoon. Details are given under the Chapter - Project Maintenance.

## 1.10 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned official are tabulated below in **Table 1.9.**

| 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 | Daily | Sub Engineer/Dam operators on contract |
| 2 | Record water surface elevation, reservoir inflow and spillway discharge. | Daily (Hourly basis during monsoon) | Sub Engineer/Dam operators on contract |
| 3 | Record meteorological data, Record releases from outlets /sluices | Daily | Sub Engineer/Dam operators on contract |
| 4 | Check security and safety devices, Complete logbook / site register which include the above information. | Daily | Assistant Engineer |
| 5 | Record seepage from drainage systems etc. and record meteorological data. | Weekly | Sub Engineer/Dam operators on contract |
| 6 | Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements | Weekly | Assistant Engineer |

| | | | |
|---|---|---|---|
| 7 | Check stand by generator (DG Sets), Drainage systems etc. | Weekly | Assistant Engineer |
| 8 | Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements | Fort nightly | Assistant Executive Engineer |
| 9 | Check security and safety devices, logbook and site register which include the above information. | Fort nightly | Assistant Executive Engineer |
| 10 | Check stand by generator (DG Sets), Drainage systems, etc. | Fort nightly | Assistant Executive Engineer |
| 11 | Measuring devices, communication devices, status of instruments, vegetation growth | Fort nightly | Assistant Executive Engineer |
| 12 | Check Sign/Warning display boards near vulnerable locations | Fort nightly | Assistant Executive Engineer |
| 13 | Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements | Monthly | Executive Engineer |
| 14 | Check measuring devices/Instruments, Security and safety devices, Communication Devices, Status of Vegetation growth – rectification, if needed. | Monthly | Executive Engineer |
| 15 | Check Sign/Warning display boards near vulnerable locations | Monthly | Executive Engineer |
| 16 | Replace fuse light bulbs, Inspect to maintain ventilation system, cleaning of control panel boards. | Monthly | Assistant Engineer |
| 17 | Check outlet works, updating operating instruction, check gate air vents, clean gate control switchboxes, check operation of gates, grease gate hanger/dogging | Quarterly | Executive Engineer |
| 18 | Check condition of Outlet works and its Energy Dissipation Arrangement | Quarterly | Executive Engineer |
| 19 | Check condition of spillway, log | Quarterly | Executive Engineer |

| | | | |
|---|---|---|---|
| | and safety boom, Check for debris in inlet channel, Check operation of gates, Check for damages in spillway glacis, energy dissipation arrangement, d/s area etc., Check and clear spillway bridge drains, Clean inside of motor control cabinet. | | |
| 20 | Check for adherence to instrumentation schedule, Record pertinent information in Operation of Gates, Check condition of V-notch/seepage measuring devices, Check hydro mechanical components. | Quarterly | Executive Engineer |
| 21 | Inspection of Spillway & outlet works, hydro mechanical components, Check paint on gates, Check lubrication of wire ropes and application of cardium compound, Check mechanical hoist bearings and flexible coupling bearings, Check gear systems, Exercise gates and valves, Check oil reservoir level in hydraulic system, Check pressure release valve, Check lubrication of gate rollers, Check rubber seals and seal clamp bar. | Half yearly (Pre and Post Monsoon) | Deputy Chief Engineer along with Executive Engineer in charge of dam |
| 22 | Submission of Inspection report to State DSO, CWC and uploading into DHARMA. | Half yearly | Chief Engineer/Deputy Chief Engineer |
| 23 | Comprehensive inspections | Annually | Dam Safety Authority along with Dam Owners |
| 24 | Inspect dam and gate structures and stilling basin / energy dissipation arrangement, which normally are underwater (by dewatering or by divers/ROV as necessary). Review Dam operation procedures and EAP and update as necessary. | Five Yearly | Chief Engineer/Deputy Chief Engineer |
| 25 | Comprehensive inspection of performance of the dam and gate structures and reservoirs and stilling basin/energy dissipation arrangement. | Ten Yearly | DSRP |

**Table 1.9 Schedule of duties/inspections**

## 1.11 Hydro-Mechanical Inspections / Checks.

Frequency of inspections / checks for hydro-mechanical components and necessary actions to be taken up during maintenance

1. Radial Crest Gates - 4 Nos.

a. Embedded Parts

| Sl. No | Embedded Part | Frequency |
|---|---|---|
| 1 | Checking of seal beams. Seal Seats, Guide track & all other exposed embedded parts with respect to their alignment, distortion :if any due to continuous use, pitting and un-necessary cracks due to wear & carrying out requisite repairs, rectification by welding, grinding etc. | Half Yearly |
| 2 | Removing debris & other foreign material deposited on embedded parts& cleaning the same. | Monthly |
| 3 | All cracks & defective weld joints to be ascertained & rectified. | Half Yearly |
| 4 | All dirt, debris, grit, foreign material etc. to be removed from trunnion assemblies as well as trunnion chair and lubricate trunnion bearing & the sliding surface on trunnion chair with specified lubricant/ grade to ensure smooth sliding movement of trunnion. | Monthly |
| 5 | All nut bolts connecting Trunnion Assembly & Trunnion Chair and Trunnion & Yoke, girder Trunnion pin lock plate to be checked & Tightened and replacement the same if found defective. | Monthly |

**b. Gate structure**

| Sl. No | Embedded Part | Frequency |
|---|---|---|
| 1 | Regular inspection of the gate along with the hoist to be carried out daily to ensure that there is no unusual development/ observation | Daily |
| 2 | Check all welding for soundness & rectify defects | Quarterly |
| 3 | Check welding between arms & horizontal girders as well as arms & Trunnion with the help of magnifying glass for cracks/ defects and rectify the defects | Quarterly |

| | | |
|---|---|---|
| 4 | Clean all drain boles including those in end arms, horizontal girders & defective nuts & bolts | Quarterly |
| 5 | Check all nuts & bolts provided and tighten them, and replace the defective nuts & bolts | Quarterly |
| 6 | Check upstream face of Skin plate for pitting, scaling and corrosion. Scaling formation are to be removed. Pitting shall be filled with weld and corroded surface shall be cleaned & painted | Yearly |
| 7 | Joints of side & bottom rubber seals to be checked for their proper alignment and fixing & to be rectified/ adjusted if there is leakage through joints | Monthly |
| 8 | Nuts & bolts for rubber seal connection to be tightened and damaged nuts and bolts to be replaced | Quarterly |
| 9 | The excessive or widespread leakages if any shall be reported to the Engineer in charge. If the seals are required to be replaced the same shall be carried out. | Quarterly |
| 10 | The guide roller pin is to be lubricated | Quarterly |

**Table 1.10 Frequency of inspection of Hydro Mechanical components**

## 1.12 Distribution of Operation & Maintenance Manuals

The list of officers to whom the O&M Manual is required to be distributed is shown in the table below.

| Sl. No. | Officer | Number of Manual Distribution |
|---|---|---|
| 1 | Director Generation (Civil),<br>KSEBL, Vydyuthi Bhavan, Thiruvananthapuram | 1 |
| 2 | Chief Engineer Civil (Dam Safety & DRIP),<br>KSEBL, Pallom, Kottayam | 1 |
| 3 | Deputy Chief Engineer,<br>Research & Dam Safety Organization,<br>Pallom | 1 |
| 4 | Executive Engineer,<br>Research &Dam Safety Division No. V, Thariyode | 1 |
| 5 | Assistant Executive Engineer, | 1 |

| | | |
|---|---|---|
| | Research & Dam Safety Sub Division, Thariyode | |
| 6 | Assistant Engineer,<br>Research & Dam Safety Section,<br>Thariyode | 1 |
| 7 | Officer at dam site | 1 |

**Table 1.11 Distribution of O&M Manual and Revisions**

## 1.13 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 dams, reservoir and appurtenant works shown below are available at the dam control room:

- Emergency Action Plan (EAP)
- Detailed drawings of the Project
- Latest Hydrology Review Report
- Latest DSRP Report
- Gate Manufacturer's manual and drawings
- Flood forecasting and operating criteria
- Basin or river operating plan
- Administrative procedures
- Reservoir / River pollution contingency plan
- Maintenance schedules
- Regional communication directory
- Instrumentation reports / results

# Chapter 2

# Project Operation

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

## 2.1 Basic Data

The Kuttiyadi Augmentation Scheme operation plan consists of step-by-step instructions for operating the dam and reservoir during routine (normal) and emergency conditions. The operating procedures for normal operations are discussed in this chapter. The operation of a dam involves regulation of its reservoir as per rule curve/project specific requirements. This includes the use of elevation storage curve and design flood; both are described below.

### 2.1.1 Elevation Storage curve

The elevation storage curve for Kuttiyadi Augmentation Scheme in tabular and graphical form are shown in **Fig 2.1** and **Table 2.1**.

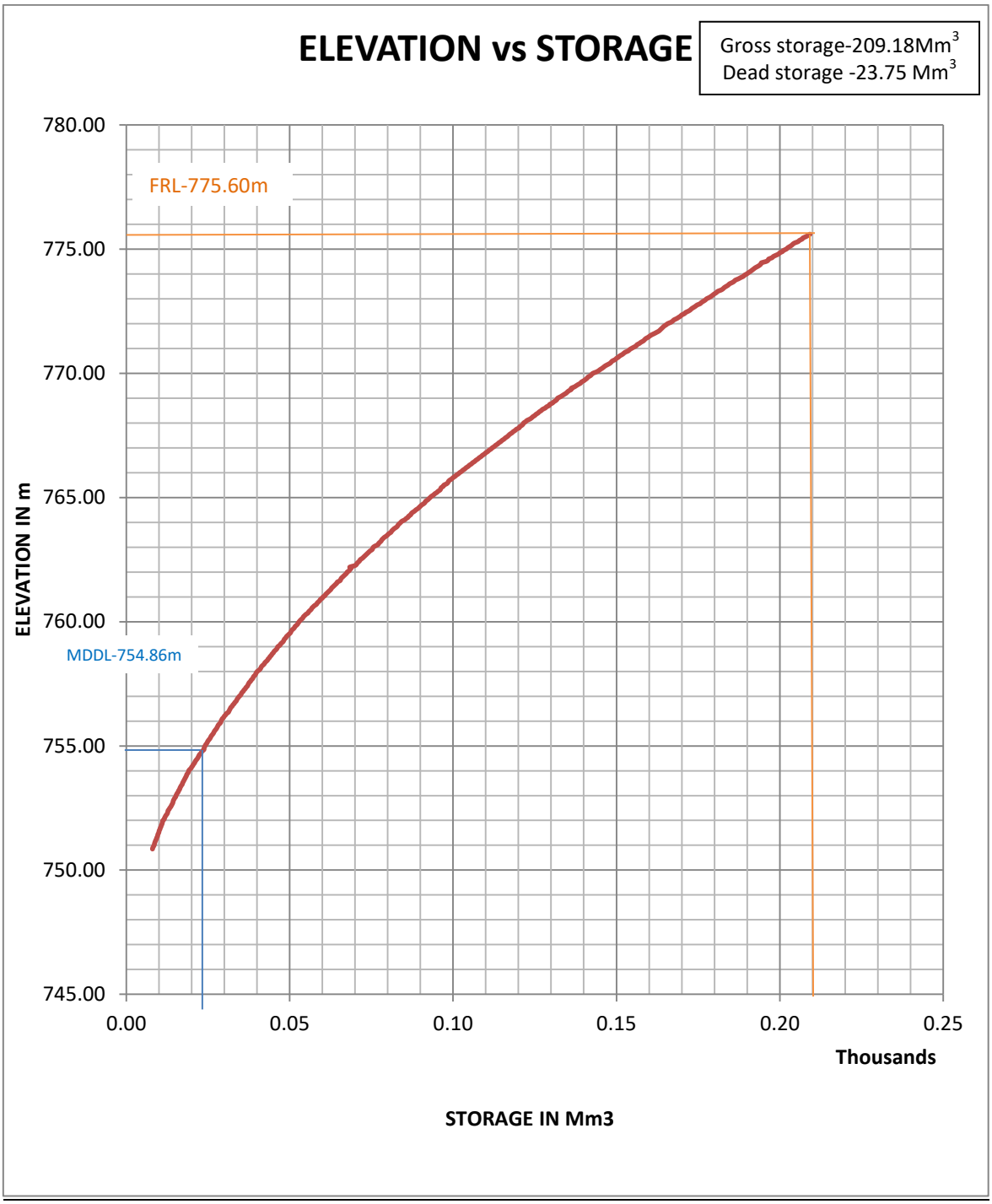


**Fig 2.1 Elevation storage curve for Kuttiyadi Augmentation Scheme**

| ELEVATION - CAPACITY OF KUTTIYADI AUGMENTATION SCHEME | | | |
|---|---|---|---|
| **Sl. No.** | **Reservoir water level in m** | **Gross Storage in $Mm^3$** | **Storage diff in Mm3** |
| 1 | 750.85 | 8.00 | 0.00 |
| 2 | 750.90 | 8.10 | 0.10 |
| 3 | 750.95 | 8.30 | 0.20 |
| 4 | 751.00 | 8.50 | 0.20 |
| 5 | 751.05 | 8.60 | 0.10 |
| 6 | 751.10 | 8.70 | 0.10 |
| 7 | 751.20 | 9.00 | 0.30 |
| 8 | 751.25 | 9.20 | 0.20 |
| 9 | 751.30 | 9.30 | 0.10 |
| 10 | 751.35 | 9.50 | 0.20 |
| 11 | 751.40 | 9.60 | 0.10 |
| 12 | 751.45 | 9.70 | 0.10 |
| 13 | 751.50 | 9.90 | 0.20 |
| 14 | 751.55 | 10.00 | 0.10 |
| 15 | 751.60 | 10.10 | 0.10 |
| 16 | 751.65 | 10.30 | 0.20 |
| 17 | 751.70 | 10.40 | 0.10 |
| 18 | 751.75 | 10.60 | 0.20 |
| 19 | 751.80 | 10.70 | 0.10 |
| 20 | 751.85 | 10.90 | 0.20 |
| 21 | 751.90 | 11.00 | 0.10 |
| 22 | 751.95 | 11.10 | 0.10 |
| 23 | 752.00 | 11.20 | 0.10 |
| 24 | 752.05 | 11.60 | 0.40 |
| 25 | 752.10 | 11.70 | 0.10 |
| 26 | 752.15 | 11.90 | 0.20 |
| 27 | 752.20 | 12.10 | 0.20 |
| 28 | 752.25 | 12.40 | 0.30 |
| 29 | 752.30 | 12.60 | 0.20 |
| 30 | 752.35 | 12.70 | 0.10 |
| 31 | 752.40 | 12.80 | 0.10 |
| 32 | 752.45 | 13.10 | 0.30 |
| 33 | 752.50 | 13.30 | 0.20 |
| 34 | 752.55 | 13.60 | 0.30 |

| | | | |
|---|---|---|---|
| 35 | 752.60 | 13.80 | 0.20 |
| 36 | 752.65 | 14.00 | 0.20 |
| 37 | 752.70 | 14.20 | 0.20 |
| 38 | 752.75 | 14.30 | 0.10 |
| 39 | 752.80 | 14.40 | 0.10 |
| 40 | 752.85 | 14.60 | 0.20 |
| 41 | 752.90 | 14.80 | 0.20 |
| 42 | 752.95 | 15.10 | 0.30 |
| 43 | 753.00 | 15.20 | 0.10 |
| 44 | 753.05 | 15.40 | 0.20 |
| 45 | 753.10 | 15.60 | 0.20 |
| 46 | 753.15 | 15.90 | 0.30 |
| 47 | 753.20 | 16.00 | 0.10 |
| 48 | 753.25 | 16.30 | 0.30 |
| 49 | 753.30 | 16.40 | 0.10 |
| 50 | 753.35 | 16.60 | 0.20 |
| 51 | 753.40 | 16.80 | 0.20 |
| 52 | 753.45 | 17.10 | 0.30 |
| 53 | 753.50 | 17.20 | 0.10 |
| 54 | 753.55 | 17.40 | 0.20 |
| 55 | 753.60 | 17.60 | 0.20 |
| 56 | 753.65 | 17.80 | 0.20 |
| 57 | 753.70 | 18.00 | 0.20 |
| 58 | 753.75 | 18.20 | 0.20 |
| 59 | 753.80 | 18.40 | 0.20 |
| 60 | 753.85 | 18.50 | 0.10 |
| 61 | 753.90 | 18.80 | 0.30 |
| 62 | 753.95 | 19.00 | 0.20 |
| 63 | 754.00 | 19.10 | 0.10 |
| 64 | 754.05 | 19.40 | 0.30 |
| 65 | 754.10 | 19.80 | 0.40 |
| 66 | 754.15 | 20.00 | 0.20 |
| 67 | 754.20 | 20.30 | 0.30 |
| 68 | 754.25 | 20.50 | 0.20 |
| 69 | 754.30 | 20.80 | 0.30 |
| 70 | 754.35 | 21.00 | 0.20 |
| 71 | 754.40 | 21.20 | 0.20 |
| 72 | 754.45 | 21.50 | 0.30 |
| 73 | 754.50 | 21.80 | 0.30 |
| 74 | 754.55 | 22.00 | 0.20 |
| 75 | 754.60 | 22.20 | 0.20 |

| | | | |
|---|---|---|---|
| 76 | 754.65 | 22.40 | 0.20 |
| 77 | 754.70 | 22.80 | 0.40 |
| 78 | 754.75 | 23.00 | 0.20 |
| 79 | 754.80 | 23.30 | 0.30 |
| 80 | **754.85** | **23.75** | 0.45 |
| 81 | 754.90 | 23.80 | 0.05 |
| 82 | 754.95 | 23.90 | 0.10 |
| 83 | 755.00 | 24.10 | 0.20 |
| 84 | 755.05 | 24.30 | 0.20 |
| 85 | 755.10 | 24.60 | 0.30 |
| 86 | 755.15 | 24.80 | 0.20 |
| 87 | 755.20 | 25.00 | 0.20 |
| 88 | 755.25 | 25.30 | 0.30 |
| 89 | 755.30 | 25.60 | 0.30 |
| 90 | 755.35 | 25.80 | 0.20 |
| 91 | 755.40 | 26.00 | 0.20 |
| 92 | 755.45 | 26.30 | 0.30 |
| 93 | 755.50 | 26.60 | 0.30 |
| 94 | 755.55 | 26.80 | 0.20 |
| 95 | 755.60 | 27.00 | 0.20 |
| 96 | 755.65 | 27.30 | 0.30 |
| 97 | 755.70 | 27.60 | 0.30 |
| 98 | 755.75 | 27.80 | 0.20 |
| 99 | 755.80 | 28.00 | 0.20 |
| 100 | 755.85 | 28.20 | 0.20 |
| 101 | 755.90 | 28.60 | 0.40 |
| 102 | 755.95 | 28.90 | 0.30 |
| 103 | 756.00 | 29.00 | 0.10 |
| 104 | 756.05 | 29.20 | 0.20 |
| 105 | 756.10 | 29.40 | 0.20 |
| 106 | 756.15 | 29.80 | 0.40 |
| 107 | 756.20 | 30.00 | 0.20 |
| 108 | 756.25 | 30.40 | 0.40 |
| 109 | 756.30 | 30.60 | 0.20 |
| 110 | 756.35 | 31.20 | 0.60 |
| 111 | 756.40 | 31.40 | 0.20 |
| 112 | 756.45 | 31.60 | 0.20 |
| 113 | 756.50 | 31.80 | 0.20 |
| 114 | 756.55 | 32.00 | 0.20 |
| 115 | 756.60 | 32.40 | 0.40 |
| 116 | 756.65 | 32.60 | 0.20 |

| | | | |
|---|---|---|---|
| 117 | 756.70 | 33.00 | 0.40 |
| 118 | 756.75 | 33.20 | 0.20 |
| 119 | 756.80 | 33.60 | 0.40 |
| 120 | 756.85 | 33.80 | 0.20 |
| 121 | 756.90 | 34.00 | 0.20 |
| 122 | 756.95 | 34.30 | 0.30 |
| 123 | 757.00 | 34.60 | 0.30 |
| 124 | 757.05 | 35.00 | 0.40 |
| 125 | 757.10 | 35.20 | 0.20 |
| 126 | 757.15 | 35.40 | 0.20 |
| 127 | 757.20 | 35.80 | 0.40 |
| 128 | 757.25 | 36.00 | 0.20 |
| 129 | 757.30 | 36.40 | 0.40 |
| 130 | 757.35 | 36.60 | 0.20 |
| 131 | 757.40 | 37.00 | 0.40 |
| 132 | 757.45 | 37.20 | 0.20 |
| 133 | 757.50 | 37.40 | 0.20 |
| 134 | 757.55 | 37.60 | 0.20 |
| 135 | 757.60 | 38.00 | 0.40 |
| 136 | 757.65 | 38.20 | 0.20 |
| 137 | 757.70 | 38.60 | 0.40 |
| 138 | 757.75 | 38.80 | 0.20 |
| 139 | 757.80 | 39.00 | 0.20 |
| 140 | 757.85 | 39.40 | 0.40 |
| 141 | 757.90 | 39.60 | 0.20 |
| 142 | 757.95 | 39.80 | 0.20 |
| 143 | 758.00 | 40.10 | 0.30 |
| 144 | 758.05 | 40.60 | 0.50 |
| 145 | 758.10 | 41.00 | 0.40 |
| 146 | 758.15 | 41.20 | 0.20 |
| 147 | 758.20 | 41.40 | 0.20 |
| 148 | 758.25 | 41.80 | 0.40 |
| 149 | 758.30 | 42.20 | 0.40 |
| 150 | 758.35 | 42.40 | 0.20 |
| 151 | 758.40 | 42.80 | 0.40 |
| 152 | 758.45 | 43.20 | 0.40 |
| 153 | 758.50 | 43.40 | 0.20 |
| 154 | 758.55 | 43.80 | 0.40 |
| 155 | 758.60 | 44.00 | 0.20 |
| 156 | 758.65 | 44.40 | 0.40 |
| 157 | 758.70 | 44.60 | 0.20 |

| | | | |
|---|---|---|---|
| 158 | 758.75 | 45.00 | 0.40 |
| 159 | 758.80 | 45.20 | 0.20 |
| 160 | 758.85 | 45.60 | 0.40 |
| 161 | 758.90 | 46.00 | 0.40 |
| 162 | 758.95 | 46.20 | 0.20 |
| 163 | 759.00 | 46.40 | 0.20 |
| 164 | 759.05 | 47.00 | 0.60 |
| 165 | 759.10 | 47.20 | 0.20 |
| 166 | 759.15 | 47.60 | 0.40 |
| 167 | 759.20 | 48.00 | 0.40 |
| 168 | 759.25 | 48.20 | 0.20 |
| 169 | 759.30 | 48.40 | 0.20 |
| 170 | 759.35 | 48.80 | 0.40 |
| 171 | 759.40 | 49.00 | 0.20 |
| 172 | 759.45 | 49.40 | 0.40 |
| 173 | 759.50 | 49.80 | 0.40 |
| 174 | 759.55 | 50.20 | 0.40 |
| 175 | 759.60 | 50.40 | 0.20 |
| 176 | 759.65 | 50.60 | 0.20 |
| 177 | 759.70 | 51.00 | 0.40 |
| 178 | 759.75 | 51.40 | 0.40 |
| 179 | 759.80 | 51.60 | 0.20 |
| 180 | 759.85 | 52.00 | 0.40 |
| 181 | 759.90 | 52.40 | 0.40 |
| 182 | 759.95 | 52.60 | 0.20 |
| 183 | 760.00 | 52.90 | 0.30 |
| 184 | 760.05 | 53.20 | 0.30 |
| 185 | 760.10 | 53.60 | 0.40 |
| 186 | 760.15 | 54.00 | 0.40 |
| 187 | 760.20 | 54.20 | 0.20 |
| 188 | 760.25 | 54.60 | 0.40 |
| 189 | 760.30 | 55.00 | 0.40 |
| 190 | 760.35 | 55.60 | 0.60 |
| 191 | 760.40 | 55.80 | 0.20 |
| 192 | 760.45 | 56.20 | 0.40 |
| 193 | 760.50 | 56.60 | 0.40 |
| 194 | 760.55 | 56.80 | 0.20 |
| 195 | 760.60 | 57.20 | 0.40 |
| 196 | 760.65 | 57.60 | 0.40 |
| 197 | 760.70 | 58.20 | 0.60 |
| 198 | 760.75 | 58.40 | 0.20 |

| | | | |
|---|---|---|---|
| 199 | 760.80 | 58.80 | 0.40 |
| 200 | 760.85 | 59.20 | 0.40 |
| 201 | 760.90 | 59.40 | 0.20 |
| 202 | 760.95 | 60.00 | 0.60 |
| 203 | 761.00 | 60.20 | 0.20 |
| 204 | 761.05 | 60.80 | 0.60 |
| 205 | 761.10 | 61.00 | 0.20 |
| 206 | 761.15 | 61.40 | 0.40 |
| 207 | 761.20 | 61.80 | 0.40 |
| 208 | 761.25 | 62.20 | 0.40 |
| 209 | 761.30 | 62.60 | 0.40 |
| 210 | 761.35 | 62.80 | 0.20 |
| 211 | 761.40 | 63.20 | 0.40 |
| 212 | 761.45 | 63.60 | 0.40 |
| 213 | 761.50 | 64.00 | 0.40 |
| 214 | 761.55 | 64.40 | 0.40 |
| 215 | 761.60 | 64.60 | 0.20 |
| 216 | 761.65 | 65.40 | 0.80 |
| 217 | 761.70 | 65.60 | 0.20 |
| 218 | 761.75 | 65.80 | 0.20 |
| 219 | 761.80 | 66.20 | 0.40 |
| 220 | 761.85 | 66.60 | 0.40 |
| 221 | 761.90 | 67.00 | 0.40 |
| 222 | 761.95 | 67.40 | 0.40 |
| 223 | 762.00 | 67.60 | 0.20 |
| 224 | 762.05 | 68.20 | 0.60 |
| 225 | 762.10 | 68.40 | 0.20 |
| 226 | 762.15 | 68.80 | 0.40 |
| 227 | 762.20 | 69.40 | 0.60 |
| 228 | 762.25 | 69.80 | 1.40 |
| 229 | 762.30 | 70.40 | 0.60 |
| 230 | 762.35 | 70.60 | 0.20 |
| 231 | 762.40 | 71.00 | 0.40 |
| 232 | 762.45 | 71.40 | 0.40 |
| 233 | 762.50 | 71.60 | 0.20 |
| 234 | 762.55 | 72.20 | 0.60 |
| 235 | 762.60 | 72.60 | 0.40 |
| 236 | 762.65 | 73.00 | 0.40 |
| 237 | 762.70 | 73.40 | 0.40 |
| 238 | 762.75 | 73.80 | 0.40 |
| 239 | 762.80 | 74.20 | 0.40 |

| | | | |
|---|---|---|---|
| 240 | 762.85 | 74.60 | 0.40 |
| 241 | 762.90 | 75.20 | 0.60 |
| 242 | 762.95 | 75.40 | 0.20 |
| 243 | 763.00 | 75.60 | 0.20 |
| 244 | 763.05 | 76.20 | 0.60 |
| 245 | 763.10 | 77.00 | 0.80 |
| 246 | 763.15 | 77.20 | 0.20 |
| 247 | 763.20 | 77.60 | 0.40 |
| 248 | 763.25 | 78.00 | 0.40 |
| 249 | 763.30 | 78.20 | 0.20 |
| 250 | 763.35 | 78.60 | 0.40 |
| 251 | 763.40 | 79.00 | 0.40 |
| 252 | 763.45 | 79.60 | 0.60 |
| 253 | 763.50 | 80.00 | 0.40 |
| 254 | 763.55 | 80.40 | 0.40 |
| 255 | 763.60 | 81.00 | 0.60 |
| 256 | 763.65 | 81.20 | 0.20 |
| 257 | 763.70 | 81.60 | 0.40 |
| 258 | 763.75 | 82.00 | 0.40 |
| 259 | 763.80 | 82.60 | 0.60 |
| 260 | 763.85 | 83.00 | 0.40 |
| 261 | 763.90 | 83.20 | 0.20 |
| 262 | 763.95 | 83.60 | 0.40 |
| 263 | 764.00 | 84.00 | 0.40 |
| 264 | 764.05 | 84.40 | 0.40 |
| 265 | 764.10 | 85.20 | 0.80 |
| 266 | 764.15 | 85.60 | 0.40 |
| 267 | 764.20 | 86.20 | 0.60 |
| 268 | 764.25 | 86.40 | 0.20 |
| 269 | 764.30 | 87.00 | 0.60 |
| 270 | 764.35 | 87.20 | 0.20 |
| 271 | 764.40 | 87.60 | 0.40 |
| 272 | 764.45 | 88.20 | 0.60 |
| 273 | 764.50 | 88.60 | 0.40 |
| 274 | 764.55 | 89.20 | 0.60 |
| 275 | 764.60 | 89.60 | 0.40 |
| 276 | 764.65 | 90.00 | 0.40 |
| 277 | 764.70 | 90.40 | 0.40 |
| 278 | 764.75 | 91.00 | 0.60 |
| 279 | 764.80 | 91.40 | 0.40 |
| 280 | 764.85 | 91.60 | 0.20 |

| | | | |
|---|---|---|---|
| 281 | 764.90 | 92.20 | 0.60 |
| 282 | 764.95 | 92.60 | 0.40 |
| 283 | 765.00 | 93.00 | 0.40 |
| 284 | 765.05 | 93.40 | 0.40 |
| 285 | 765.10 | 94.00 | 0.60 |
| 286 | 765.15 | 94.40 | 0.40 |
| 287 | 765.20 | 95.00 | 0.60 |
| 288 | 765.25 | 95.40 | 0.40 |
| 289 | 765.30 | 96.00 | 0.60 |
| 290 | 765.35 | 96.20 | 0.20 |
| 291 | 765.40 | 96.40 | 0.20 |
| 292 | 765.45 | 97.00 | 0.60 |
| 293 | 765.50 | 97.20 | 0.20 |
| 294 | 765.55 | 98.00 | 0.80 |
| 295 | 765.60 | 98.40 | 0.40 |
| 296 | 765.65 | 98.60 | 0.20 |
| 297 | 765.70 | 99.00 | 0.40 |
| 298 | 765.75 | 99.60 | 0.60 |
| 299 | 765.80 | 100.00 | 0.40 |
| 300 | 765.85 | 100.60 | 0.60 |
| 301 | 765.90 | 101.00 | 0.40 |
| 302 | 765.95 | 101.60 | 0.60 |
| 303 | 766.00 | 102.00 | 0.40 |
| 304 | 766.05 | 102.60 | 0.60 |
| 305 | 766.10 | 103.00 | 0.40 |
| 306 | 766.15 | 103.60 | 0.60 |
| 307 | 766.20 | 104.00 | 0.40 |
| 308 | 766.25 | 104.60 | 0.60 |
| 309 | 766.30 | 105.00 | 0.40 |
| 310 | 766.35 | 105.60 | 0.60 |
| 311 | 766.40 | 106.00 | 0.40 |
| 312 | 766.45 | 106.60 | 0.60 |
| 313 | 766.50 | 107.00 | 0.40 |
| 314 | 766.55 | 107.60 | 0.60 |
| 315 | 766.60 | 108.00 | 0.40 |
| 316 | 766.65 | 108.60 | 0.60 |
| 317 | 766.70 | 109.00 | 0.40 |
| 318 | 766.75 | 109.60 | 0.60 |
| 319 | 766.80 | 110.00 | 0.40 |
| 320 | 766.85 | 110.60 | 0.60 |
| 321 | 766.90 | 111.00 | 0.40 |

| | | | |
|---|---|---|---|
| 322 | 766.95 | 111.60 | 0.60 |
| 323 | 767.00 | 112.00 | 0.40 |
| 324 | 767.05 | 112.60 | 0.60 |
| 325 | 767.10 | 113.00 | 0.40 |
| 326 | 767.15 | 113.60 | 0.60 |
| 327 | 767.20 | 114.00 | 0.40 |
| 328 | 767.25 | 114.60 | 0.60 |
| 329 | 767.30 | 115.00 | 0.40 |
| 330 | 767.35 | 115.60 | 0.60 |
| 331 | 767.40 | 116.00 | 0.40 |
| 332 | 767.45 | 116.60 | 0.60 |
| 333 | 767.50 | 117.00 | 0.40 |
| 334 | 767.55 | 117.40 | 0.40 |
| 335 | 767.60 | 118.00 | 0.60 |
| 336 | 767.65 | 118.40 | 0.40 |
| 337 | 767.70 | 119.00 | 0.60 |
| 338 | 767.75 | 119.40 | 0.40 |
| 339 | 767.80 | 120.20 | 0.80 |
| 340 | 767.85 | 120.40 | 0.20 |
| 341 | 767.90 | 121.00 | 0.60 |
| 342 | 767.95 | 121.40 | 0.40 |
| 343 | 768.00 | 121.60 | 0.20 |
| 344 | 768.05 | 122.20 | 0.60 |
| 345 | 768.10 | 122.60 | 0.40 |
| 346 | 768.15 | 123.40 | 0.80 |
| 347 | 768.20 | 124.00 | 0.60 |
| 348 | 768.25 | 124.40 | 0.40 |
| 349 | 768.30 | 125.00 | 0.60 |
| 350 | 768.35 | 125.40 | 0.40 |
| 351 | 768.40 | 126.00 | 0.60 |
| 352 | 768.45 | 126.40 | 0.40 |
| 353 | 768.50 | 127.00 | 0.60 |
| 354 | 768.55 | 127.40 | 0.40 |
| 355 | 768.60 | 128.20 | 0.80 |
| 356 | 768.65 | 128.60 | 0.40 |
| 357 | 768.70 | 129.40 | 0.80 |
| 358 | 768.75 | 129.60 | 0.20 |
| 359 | 768.80 | 130.40 | 0.80 |
| 360 | 768.85 | 130.80 | 0.40 |
| 361 | 768.90 | 131.40 | 0.60 |
| 362 | 768.95 | 131.80 | 0.40 |

| | | | |
|---|---|---|---|
| 363 | 769.00 | 132.00 | 0.20 |
| 364 | 769.05 | 132.80 | 0.80 |
| 365 | 769.10 | 133.40 | 0.60 |
| 366 | 769.15 | 134.00 | 0.60 |
| 367 | 769.20 | 134.60 | 0.60 |
| 368 | 769.25 | 135.00 | 0.40 |
| 369 | 769.30 | 135.50 | 0.50 |
| 370 | 769.35 | 136.20 | 0.70 |
| 371 | 769.40 | 136.20 | 0.00 |
| 372 | 769.45 | 137.10 | 0.90 |
| 373 | 769.50 | 137.70 | 0.60 |
| 374 | 769.55 | 138.30 | 0.60 |
| 375 | 769.60 | 139.00 | 0.70 |
| 376 | 769.65 | 139.30 | 0.30 |
| 377 | 769.70 | 140.00 | 0.70 |
| 378 | 769.75 | 140.50 | 0.50 |
| 379 | 769.80 | 141.00 | 0.50 |
| 380 | 769.85 | 141.30 | 0.30 |
| 381 | 769.90 | 142.00 | 0.70 |
| 382 | 769.95 | 142.40 | 0.40 |
| 383 | 770.00 | 142.80 | 0.40 |
| 384 | 770.05 | 143.80 | 1.00 |
| 385 | 770.10 | 144.50 | 0.70 |
| 386 | 770.15 | 145.00 | 0.50 |
| 387 | 770.20 | 145.60 | 0.60 |
| 388 | 770.25 | 146.10 | 0.50 |
| 389 | 770.30 | 146.60 | 0.50 |
| 390 | 770.35 | 147.30 | 0.70 |
| 391 | 770.40 | 148.00 | 0.70 |
| 392 | 770.45 | 148.40 | 0.40 |
| 393 | 770.50 | 148.80 | 0.40 |
| 394 | 770.55 | 149.60 | 0.80 |
| 395 | 770.60 | 150.00 | 0.40 |
| 396 | 770.65 | 150.60 | 0.60 |
| 397 | 770.70 | 151.00 | 0.40 |
| 398 | 770.75 | 151.70 | 0.70 |
| 399 | 770.80 | 152.20 | 0.50 |
| 400 | 770.85 | 152.70 | 0.50 |
| 401 | 770.90 | 153.60 | 0.90 |
| 402 | 770.95 | 154.00 | 0.40 |
| 403 | 771.00 | 154.60 | 0.60 |

| | | | |
|---|---|---|---|
| 404 | 771.05 | 155.30 | 0.70 |
| 405 | 771.10 | 156.00 | 0.70 |
| 406 | 771.15 | 156.30 | 0.30 |
| 407 | 771.20 | 157.00 | 0.70 |
| 408 | 771.25 | 157.50 | 0.50 |
| 409 | 771.30 | 158.20 | 0.70 |
| 410 | 771.35 | 158.60 | 0.40 |
| 411 | 771.40 | 159.00 | 0.40 |
| 412 | 771.45 | 159.70 | 0.70 |
| 413 | 771.50 | 160.20 | 0.50 |
| 414 | 771.55 | 160.80 | 0.60 |
| 415 | 771.60 | 161.60 | 0.80 |
| 416 | 771.65 | 162.30 | 0.70 |
| 417 | 771.70 | 163.00 | 0.70 |
| 418 | 771.75 | 163.40 | 0.40 |
| 419 | 771.80 | 163.80 | 0.40 |
| 420 | 771.85 | 164.20 | 0.40 |
| 421 | 771.90 | 164.60 | 0.40 |
| 422 | 771.95 | 165.20 | 0.60 |
| 423 | 772.00 | 165.70 | 0.50 |
| 424 | 772.05 | 166.60 | 0.90 |
| 425 | 772.10 | 167.20 | 0.60 |
| 426 | 772.15 | 167.60 | 0.40 |
| 427 | 772.20 | 168.40 | 0.80 |
| 428 | 772.25 | 169.00 | 0.60 |
| 429 | 772.30 | 169.60 | 0.60 |
| 430 | 772.35 | 170.00 | 0.40 |
| 431 | 772.40 | 170.80 | 0.80 |
| 432 | 772.45 | 171.20 | 0.40 |
| 433 | 772.50 | 172.00 | 0.80 |
| 434 | 772.55 | 172.60 | 0.60 |
| 435 | 772.60 | 173.00 | 0.40 |
| 436 | 772.65 | 173.60 | 0.60 |
| 437 | 772.70 | 174.20 | 0.60 |
| 438 | 772.75 | 174.70 | 0.50 |
| 439 | 772.80 | 175.60 | 0.90 |
| 440 | 772.85 | 176.00 | 0.40 |
| 441 | 772.90 | 176.60 | 0.60 |
| 442 | 772.95 | 177.20 | 0.60 |
| 443 | 773.00 | 177.60 | 0.40 |
| 444 | 773.05 | 178.40 | 0.80 |

| | | | |
|---|---|---|---|
| 445 | 773.10 | 179.00 | 0.60 |
| 446 | 773.15 | 179.50 | 0.50 |
| 447 | 773.20 | 180.00 | 0.50 |
| 448 | 773.25 | 180.60 | 0.60 |
| 449 | 773.30 | 181.00 | 0.40 |
| 450 | 773.35 | 182.00 | 1.00 |
| 451 | 773.40 | 182.60 | 0.60 |
| 452 | 773.45 | 183.00 | 0.40 |
| 453 | 773.50 | 183.60 | 0.60 |
| 454 | 773.55 | 184.20 | 0.60 |
| 455 | 773.60 | 184.60 | 0.40 |
| 456 | 773.65 | 185.40 | 0.80 |
| 457 | 773.70 | 186.00 | 0.60 |
| 458 | 773.75 | 186.40 | 0.40 |
| 459 | 773.80 | 187.30 | 0.90 |
| 460 | 773.85 | 188.00 | 0.70 |
| 461 | 773.90 | 188.80 | 0.80 |
| 462 | 773.95 | 189.20 | 0.40 |
| 463 | 774.00 | 189.90 | 0.70 |
| 464 | 774.05 | 190.40 | 0.50 |
| 465 | 774.10 | 191.00 | 0.60 |
| 466 | 774.15 | 191.50 | 0.50 |
| 467 | 774.20 | 192.00 | 0.50 |
| 468 | 774.25 | 192.50 | 0.50 |
| 469 | 774.30 | 193.20 | 0.70 |
| 470 | 774.35 | 193.80 | 0.60 |
| 471 | 774.40 | 194.20 | 0.40 |
| 472 | 774.45 | 194.40 | 0.20 |
| 473 | 774.50 | 195.80 | 1.40 |
| 474 | 774.55 | 196.40 | 0.60 |
| 475 | 774.60 | 196.60 | 0.20 |
| 476 | 774.65 | 197.60 | 1.00 |
| 477 | 774.70 | 198.00 | 0.40 |
| 478 | 774.75 | 198.80 | 0.80 |
| 479 | 774.80 | 199.60 | 0.80 |
| 480 | 774.85 | 200.00 | 0.40 |
| 481 | 774.90 | 200.80 | 0.80 |
| 482 | 774.95 | 201.20 | 0.40 |
| 483 | 775.00 | 202.00 | 0.80 |
| 484 | 775.05 | 202.40 | 0.40 |
| 485 | 775.10 | 203.00 | 0.60 |

| | | | |
|---|---|---|---|
| 486 | 775.15 | 203.60 | 0.60 |
| 487 | 775.20 | 204.00 | 0.40 |
| 488 | 775.25 | 204.60 | 0.60 |
| 489 | 775.30 | 205.60 | 1.00 |
| 490 | 775.35 | 206.00 | 0.40 |
| 491 | 775.40 | 206.80 | 0.80 |
| 492 | 775.45 | 207.10 | 0.30 |
| 493 | 775.50 | 208.00 | 0.90 |
| 494 | 775.55 | 208.60 | 0.60 |
| 495 | **775.60** | **209.18** | 0.58 |

**Table 2.1 Elevation – Capacity of Kuttiyadi Augmentation Scheme**

## 2.2 Operation Plan

An effective operation plan and schedule is required for the safe project operation for which the project specific features shall be known. Salient features of the Reservoir are given below.

| | | |
|---|---|---|
| 1 | Catchment area at Dam site | 61.44 sq. km |
| 2 | FRL | +775.60m |
| 3 | MWL | +775.60m |
| 4 | MDDL | +754.86m |
| 5 | Dead Storage Level | +754.86m |
| 6 | Gross Storage Capacity | 209.18$Mm^3$ |
| 7 | Live Storage Capacity | 185.43$Mm^3$ |
| 8 | Water spread Area at FRL | 12.77sq km |

**Table 2.2 Salient features of Reservoir**

### 2.2.1 Data of the historic floods

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

The SW monsoon of the year 2018 in the State was similar to that of 1924 Devikulam storm and Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted in severe flooding in 13 out of 14 districts in the State. It is seen that the 2-day and 3-day rainfall depths of 15 -17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. Out of 758.6 mm rainfall from 1 August 2018 to 19 August 2018, about 414 mm rainfall occurred in just three days viz. 15-17, August 2018, which created severe flooding in the state, while the same during 16-18, July 1924 was 443 mm. The three day rainfall of 15-17August 2018 at Kuttiyadi Augmentation Dam site was 831.1 mm. Moreover, the dam site experienced a rainfall of 881.9 mm during 8-10 August 2018.

The spillway shutters were opened during 2006, 2007, 2009, 2011, 2013, 2014 & 2018 for excess flood moderation. Spill details of the above years are tabulated below in **Table 2.3**.

| Date | Water Level | Rainfall | storage | Gross Inflow | Outflow | |
|---|---|---|---|---|---|---|
| | | | | | Tunnel/ PH | Spill |
| | m | mm | MCM | MCM | | |
| 15/07/2006 | 772.20 | 78.30 | 168.4 | 5.44 | 0.92 | 0.72 |
| 16/07/2006 | 772.35 | 62.20 | 170 | 4.81 | 0.92 | 2.29 |
| 17/07/2006 | 772.60 | 61.30 | 173 | 13.21 | 0.93 | 9.28 |
| 18/07/2006 | 772.30 | 138.60 | 169.6 | 4.37 | 0.92 | 6.85 |
| 19/07/2006 | 772.25 | 134.70 | 169 | 7.10 | 0.92 | 6.78 |
| 20/07/2006 | 772.10 | 28.00 | 167.2 | 1.76 | 0.92 | 2.64 |
| 21/07/2006 | 772.10 | 78.20 | 167.2 | 3.17 | 0.92 | 2.25 |
| 22/07/2006 | 772.15 | 28.20 | 167.6 | 3.59 | 0.92 | 2.26 |
| 23/07/2006 | 772.15 | 17.00 | 167.6 | 3.19 | 0.93 | 2.26 |
| 24/07/2006 | 772.05 | 28.80 | 166.6 | 1.36 | 0.93 | 1.42 |
| 25/07/2006 | 772.05 | - | 166.6 | 1.25 | 0.95 | 0.30 |
| 27/07/2006 | 772.40 | 125.70 | 170.8 | 5.11 | 0.95 | 0.56 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 28/07/2006 | 772.60 | 86.70 | 173 | 4.65 | 0.95 | 1.50 |
| 29/07/2006 | 772.75 | 36.30 | 174.7 | 4.85 | 0.95 | 2.19 |
| 30/07/2006 | 772.70 | 32.40 | 174.2 | 2.84 | 0.96 | 2.38 |
| 31/07/2006 | 772.70 | 23.10 | 174.2 | 4.54 | 0.97 | 3.58 |
| 01/08/2006 | 772.45 | 15.40 | 171.2 | -0.87 | 0.96 | 1.17 |
| 06/08/2006 | 772.70 | 10.60 | 174.2 | 3.13 | 0.98 | 0.95 |
| 07/08/2006 | 772.65 | 12.40 | 173.6 | 1.27 | 0.98 | 0.89 |
| 08/08/2006 | 772.60 | - | 173 | 0.67 | 0.98 | 0.29 |
| 10/08/2006 | 772.65 | 24.40 | 173.6 | 1.12 | 1.00 | 0.12 |
| 11/08/2006 | 772.80 | 156.40 | 175.6 | 5.87 | 0.99 | 2.88 |
| 12/08/2006 | 772.95 | 122.00 | 177.2 | 8.30 | 0.02 | 6.68 |
| 13/08/2006 | 772.75 | 92.00 | 174.7 | 4.06 | 0.00 | 6.56 |
| 14/08/2006 | 772.60 | 118.00 | 173 | 2.64 | 0.00 | 4.34 |
| 15/08/2006 | 772.55 | 75.00 | 172.6 | 3.11 | 0.00 | 3.51 |
| 16/08/2006 | 772.70 | 90.00 | 174.2 | 6.18 | 0.00 | 4.58 |
| 17/08/2006 | 772.80 | 69.10 | 175.6 | 6.17 | 0.00 | 4.77 |
| 18/08/2006 | 772.75 | 75.60 | 174.7 | 3.85 | 0.00 | 4.75 |
| 19/08/2006 | 772.50 | 14.60 | 172 | 0.59 | 0.00 | 3.29 |
| 20/08/2006 | 772.50 | 5.10 | 172 | 2.32 | 0.00 | 2.32 |
| 21/08/2006 | 772.40 | 9.70 | 170.8 | 1.94 | 0.84 | 2.30 |
| 17/09/2006 | 772.55 | 91.50 | 172.6 | 4.63 | 0.00 | 1.03 |
| 18/09/2006 | 772.80 | 58.50 | 175.6 | 4.72 | 0.00 | 1.72 |
| 19/09/2006 | 772.90 | 50.50 | 176.6 | 2.81 | 0.00 | 1.81 |
| 20/09/2006 | 772.95 | 35.50 | 177.2 | 3.64 | 0.00 | 3.04 |
| 21/09/2006 | 772.90 | 25.20 | 176.6 | 2.40 | 0.00 | 3.00 |
| 22/09/2006 | 772.75 | 63.30 | 174.7 | 1.09 | 0.00 | 2.99 |
| 26/09/2006 | 772.80 | 77.50 | 175.6 | 2.38 | 0.00 | 0.98 |
| **Total Spill 2006** | | | | | | **111.25** |
| 04/08/2007 | 774.10 | 39.50 | 191 | 2.38 | 0 | 1.28 |
| 05/08/2007 | 774.20 | 97.80 | 192 | 6.92 | 0 | 5.92 |
| 06/08/2007 | 774.30 | 182.40 | 193.2 | 9.04 | 0 | 7.84 |
| 07/08/2007 | 774.05 | 54.50 | 190.4 | 1.75 | 0 | 4.55 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 08/08/2007 | 774.10 | 165.90 | 191 | 5.69 | 0 | 5.09 |
| 09/08/2007 | 774.05 | 97.70 | 190.4 | 4.65 | 0 | 5.25 |
| 10/08/2007 | 774.20 | 177.00 | 192 | 8.99 | 0 | 7.39 |
| 11/08/2007 | 774.05 | 63.20 | 190.4 | 3.02 | 0 | 4.62 |
| 12/08/2007 | 773.95 | 54.30 | 189.2 | 3.08 | 0 | 4.28 |
| 13/08/2007 | 774.00 | 17.10 | 189.9 | 4.98 | 0 | 4.28 |
| 14/08/2007 | 774.00 | 12.20 | 189.9 | 4.28 | 0 | 4.28 |
| 15/08/2007 | 774.00 | 2.10 | 189.9 | 4.28 | 0 | 4.28 |
| 16/08/2007 | 774.00 | - | 189.9 | 4.28 | 0 | 4.28 |
| 17/08/2007 | 774.00 | 10.40 | 189.9 | 4.28 | 0 | 4.28 |
| 18/08/2007 | 774.00 | 15.30 | 189.9 | 4.28 | 0 | 4.28 |
| 19/08/2007 | 774.00 | 22.30 | 189.9 | 4.28 | 0 | 4.28 |
| 20/08/2007 | 774.15 | 9.50 | 191.5 | 2.85 | 0 | 1.25 |
| 21/08/2007 | 774.15 | 26.50 | 191.5 | 0.61 | 0 | 0.61 |
| 22/08/2007 | 774.25 | 105.00 | 192.5 | 1.61 | 0 | 0.61 |
| 23/08/2007 | 774.40 | 31.10 | 194.2 | 2.31 | 0 | 0.61 |
| 24/08/2007 | 774.45 | 5.30 | 194.4 | 0.81 | 0 | 0.61 |
| 25/08/2007 | 774.45 | 30.50 | 194.4 | 0.61 | 0 | 0.61 |
| 26/08/2007 | 774.35 | 81.40 | 193.8 | 0.01 | 0 | 0.61 |
| 27/08/2007 | 774.25 | 60.60 | 192.5 | -0.69 | 0 | 0.61 |
| 28/08/2007 | 774.20 | 10.00 | 192 | 0.11 | 0 | 0.61 |
| 29/08/2007 | 774.20 | 36.00 | 192 | 0.61 | 0 | 0.61 |
| 30/08/2007 | 774.25 | 50.00 | 192.5 | 1.11 | 0 | 0.61 |
| 01/09/2007 | 774.30 | 26.00 | 193.2 | 0.61 | 0 | 0.61 |
| 02/09/2007 | 774.25 | - | 192.5 | -0.09 | 0 | 0.61 |
| 03/09/2007 | 774.45 | - | 194.4 | 2.51 | 0 | 0.61 |
| 04/09/2007 | 774.35 | - | 193.8 | 0.01 | 0 | 0.61 |
| 05/09/2007 | 774.15 | - | 191.5 | -1.69 | 0 | 0.61 |
| 06/09/2007 | 774.20 | - | 192 | 1.11 | 0 | 0.61 |
| 07/09/2007 | 774.20 | - | 192 | 0.61 | 0 | 0.61 |
| 08/09/2007 | 774.20 | - | 192 | 0.61 | 0 | 0.61 |
| 09/09/2007 | 774.20 | - | 192 | 0.61 | 0 | 0.61 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10/09/2007 | 774.15 | - | 191.5 | 0.11 | 0 | 0.61 |
| 11/09/2007 | 774.15 | - | 191.5 | 0.61 | 0 | 0.61 |
| 12/09/2007 | 774.25 | - | 192.5 | 1.61 | 0 | 0.61 |
| 13/09/2007 | 774.25 | - | 192.5 | 0.61 | 0 | 0.61 |
| 14/09/2007 | 774.25 | - | 192.5 | 0.61 | 0 | 0.61 |
| 15/09/2007 | 774.30 | - | 193.2 | 0.89 | 0 | 0.19 |
| 17/09/2007 | 774.40 | - | 194.2 | 0.47 | 0 | 0.47 |
| 18/09/2007 | 774.50 | - | 195.8 | 2.20 | 0 | 0.60 |
| 19/09/2007 | 774.45 | - | 194.4 | -1.24 | 0 | 0.16 |
| 20/09/2007 | 774.40 | - | 194.2 | 1.45 | 0 | 1.65 |
| 21/09/2007 | 774.40 | - | 194.2 | 1.65 | 0 | 1.65 |
| 22/09/2007 | 774.45 | - | 194.4 | 2.47 | 0 | 2.27 |
| 23/09/2007 | 774.50 | - | 195.8 | 4.37 | 0 | 2.97 |
| 24/09/2007 | 774.45 | - | 194.4 | 2.92 | 0 | 4.32 |
| 25/09/2007 | 774.55 | - | 196.4 | 6.28 | 0 | 4.28 |
| 26/09/2007 | 774.45 | - | 194.4 | 1.38 | 0 | 3.38 |
| 27/09/2007 | 774.25 | - | 192.5 | 1.40 | 0 | 3.30 |
| 28/09/2007 | 774.05 | - | 190.4 | -0.67 | 0 | 1.43 |
| 29/09/2007 | 774.05 | - | 190.4 | 0.66 | 0 | 0.66 |
| 30/09/2007 | 774.05 | - | 190.4 | 0.66 | 0 | 0.66 |
| 01/10/2007 | 774.05 | 98.00 | 190.4 | 0.66 | 0 | 0.66 |
| 02/10/2007 | 774.20 | 28.30 | 192 | 2.26 | 0 | 0.66 |
| 03/10/2007 | 774.20 | 9.20 | 192 | 0.66 | 0 | 0.66 |
| 04/10/2007 | 774.25 | 25.50 | 192.5 | 1.16 | 0 | 0.66 |
| 05/10/2007 | 774.20 | 29.30 | 192 | -0.25 | 0 | 0.25 |
| **Total Spill 2007** | | | | | | **122.99** |
| 05/09/2009 | 775.30 | 214.70 | 205.6 | 7.72 | 1.12532 | 0.59 |
| 06/09/2009 | 775.60 | 65.60 | 209.25 | 7.93 | 1.09265 | 3.19 |
| 07/09/2009 | 775.60 | 94.20 | 209.25 | 5.99 | 1.05724 | 4.94 |
| 08/09/2009 | 775.60 | 20.80 | 209.25 | 3.22 | 1.04002 | 2.18 |
| 09/09/2009 | 775.60 | - | 209.25 | 1.31 | 1.02953 | 0.28 |
| 03/10/2009 | 775.20 | 193.20 | 204 | 4.88 | 1.01794 | 0.66 |

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|---|---|---|---|---|---|---|
| 04/10/2009 | 775.60 | 49.20 | 209.25 | 7.73 | 1.02073 | 1.46 |
| 05/10/2009 | 775.60 | 22.20 | 209.25 | 2.13 | 1.02895 | 1.10 |
| 06/10/2009 | 775.60 | 23.60 | 209.25 | 1.81 | 1.02895 | 0.78 |
| **Total Spill 2009** | | | | | | **15.17** |
| 29/08/2011 | 775.35 | 38.25 | 206 | 2.57 | 1.03 | 0.14 |
| 30/08/2011 | 775.60 | 72.00 | 209.25 | 5.58 | 1.03 | 1.30 |
| 31/08/2011 | 775.60 | 42.75 | 209.25 | 2.68 | 1.03 | 1.65 |
| 01/09/2011 | 775.60 | 66.30 | 209.25 | 3.44 | 1.03 | 2.41 |
| 02/09/2011 | 775.60 | 106.00 | 209.25 | 5.40 | 1.03 | 4.38 |
| 03/09/2011 | 775.60 | 77.75 | 209.25 | 4.25 | 1.03 | 3.22 |
| 04/09/2011 | 775.60 | 58.60 | 209.25 | 3.28 | 1.03 | 2.25 |
| 05/09/2011 | 775.60 | 27.60 | 209.25 | 2.36 | 1.03 | 1.33 |
| 06/09/2011 | 775.60 | 7.50 | 209.25 | 3.23 | 1.03 | 2.21 |
| 07/09/2011 | 775.60 | 15.90 | 209.25 | 1.92 | 1.03 | 0.89 |
| 08/09/2011 | 775.60 | 8.25 | 209.25 | 1.74 | 1.03 | 0.71 |
| 09/09/2011 | 775.60 | 17.40 | 209.25 | 1.40 | 1.03 | 0.37 |
| 10/09/2011 | 775.60 | 28.20 | 209.25 | 1.42 | 1.03 | 0.39 |
| 11/09/2011 | 775.60 | 24.55 | 209.25 | 2.85 | 1.03 | 1.82 |
| 12/09/2011 | 775.60 | 6.00 | 209.25 | 1.45 | 1.03 | 0.42 |
| 13/09/2011 | 775.60 | 7.50 | 209.25 | 1.40 | 1.03 | 0.37 |
| 14/09/2011 | 775.60 | 10.50 | 209.25 | 1.40 | 1.03 | 0.37 |
| 15/09/2011 | 775.60 | 6.00 | 209.25 | 1.40 | 1.03 | 0.37 |
| 16/09/2011 | 775.60 | 26.35 | 209.25 | 1.40 | 1.03 | 0.37 |
| 17/09/2011 | 775.60 | 3.00 | 209.25 | 1.57 | 1.03 | 0.54 |
| 18/09/2011 | 775.60 | - | 209.25 | 1.40 | 1.03 | 0.37 |
| 19/09/2011 | 775.55 | - | 208.6 | 0.40 | 1.03 | 0.02 |
| 20/09/2011 | 775.50 | 20.45 | 208 | 0.54 | 1.03 | 0.11 |
| **Total Spill 2011** | | | | | | **26.00** |
| 21/07/2013 | 775.30 | 202.20 | 205.6 | 7.27 | 1.03 | 0.24 |
| 22/07/2013 | 775.60 | 86.60 | 209.25 | 6.94 | 1.03 | 2.26 |
| 23/07/2013 | 775.60 | 100.80 | 209.25 | 4.20 | 1.03 | 3.17 |

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|---|---|---|---|---|---|---|
| 24/07/2013 | 775.60 | 91.00 | 209.25 | 2.92 | 1.03 | 1.89 |
| 25/07/2013 | 775.60 | 99.00 | 209.25 | 7.83 | 1.03 | 6.80 |
| 26/07/2013 | 775.60 | 137.20 | 209.25 | 5.46 | 1.03 | 4.43 |
| 27/07/2013 | 775.60 | 120.80 | 209.25 | 4.59 | 1.03 | 3.56 |
| 28/07/2013 | 775.60 | 55.40 | 209.25 | 4.19 | 1.03 | 3.16 |
| 29/07/2013 | 775.60 | 37.60 | 209.25 | 2.55 | 1.03 | 1.52 |
| 30/07/2013 | 775.60 | 4.40 | 209.25 | 1.49 | 1.03 | 0.46 |
| 31/07/2013 | 775.60 | 87.60 | 209.25 | 5.84 | 1.03 | 4.81 |
| 01/08/2013 | 775.60 | 115.00 | 209.25 | 17.25 | 1.03 | 16.22 |
| 02/08/2013 | 775.60 | 281.80 | 209.25 | 12.01 | 1.03 | 10.98 |
| 03/08/2013 | 775.60 | 84.60 | 209.25 | 3.95 | 1.03 | 2.92 |
| 04/08/2013 | 775.60 | 62.20 | 209.25 | 3.17 | 1.03 | 2.14 |
| 05/08/2013 | 775.60 | 72.00 | 209.25 | 3.79 | 1.03 | 2.76 |
| 06/08/2013 | 775.60 | 41.80 | 209.25 | 2.26 | 1.03 | 1.23 |
| 07/08/2013 | 775.60 | 34.20 | 209.25 | 1.34 | 1.03 | 0.31 |
| **Total Spill 2013** | | | | | | **68.84** |
| 03/08/2014 | 775.60 | 107.6 | 209.25 | 7.88 | 1.03 | 1.60 |
| 04/08/2014 | 775.60 | 100.8 | 209.25 | 4.19 | 1.03 | 3.16 |
| 05/08/2014 | 775.60 | 169.8 | 209.25 | 6.37 | 1.03 | 5.34 |
| 06/08/2014 | 775.60 | 147.4 | 209.25 | 4.65 | 1.03 | 3.62 |
| 07/08/2014 | 775.60 | 75.6 | 209.25 | 3.66 | 1.03 | 2.63 |
| 08/08/2014 | 775.60 | 26.8 | 209.25 | 2.16 | 1.03 | 1.13 |
| 09/08/2014 | 775.60 | 38.8 | 209.25 | 2.50 | 1.03 | 1.47 |
| 10/08/2014 | 775.60 | 20.6 | 209.25 | 2.50 | 1.03 | 1.47 |
| 11/08/2014 | 775.60 | 13.2 | 209.25 | 2.01 | 1.03 | 0.98 |
| 12/08/2014 | 775.60 | 34.8 | 209.25 | 2.50 | 1.03 | 1.47 |
| 13/08/2014 | 775.60 | 16 | 209.25 | 1.99 | 1.03 | 0.97 |
| 14/08/2014 | 775.60 | 4 | 209.25 | 1.26 | 1.03 | 0.23 |
| 07/09/2014 | 775.60 | 51.6 | 209.25 | 2.06 | 1.03 | 0.38 |
| 08/09/2014 | 775.60 | 22.8 | 209.25 | 1.77 | 1.03 | 0.74 |
| 09/09/2014 | 775.60 | 5.8 | 209.25 | 1.77 | 1.03 | 0.74 |
| 10/09/2014 | 775.60 | 8.8 | 209.25 | 1.77 | 1.03 | 0.74 |

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|---|---|---|---|---|---|---|
| 11/09/2014 | 775.60 | 49 | 209.25 | 1.77 | 1.03 | 0.74 |
| 12/09/2014 | 775.60 | 2.8 | 209.25 | 1.77 | 1.03 | 0.74 |
| **Total Spill 2014** | | | | | | **28.13** |
| 15/07/2018 | 775.20 | 72 | 204 | 9.78 | 1.03 | 0.55 |
| 16/07/2018 | 775.60 | 144.4 | 209.25 | 11.02 | 1.03 | 4.74 |
| 17/07/2018 | 775.60 | 141.7 | 209.25 | 10.51 | 1.03 | 9.48 |
| 18/07/2018 | 775.60 | 116.6 | 209.25 | 9.24 | 1.03 | 8.21 |
| 19/07/2018 | 775.60 | 89.1 | 209.25 | 6.59 | 1.03 | 5.56 |
| 20/07/2018 | 775.60 | 107.2 | 209.25 | 5.58 | 1.03 | 4.55 |
| 21/07/2018 | 775.60 | 87.6 | 209.25 | 6.16 | 1.03 | 5.13 |
| 22/07/2018 | 775.60 | 86.2 | 209.25 | 6.16 | 1.03 | 5.13 |
| 23/07/2018 | 775.60 | 10.8 | 209.25 | 3.75 | 1.03 | 2.73 |
| 24/07/2018 | 775.60 | 97.9 | 209.25 | 3.15 | 1.03 | 2.13 |
| 25/07/2018 | 775.60 | 91.3 | 209.25 | 5.54 | 1.03 | 4.51 |
| 26/07/2018 | 775.60 | 112.4 | 209.25 | 6.16 | 1.03 | 5.13 |
| 27/07/2018 | 775.60 | 64.1 | 209.25 | 5.46 | 1.03 | 4.43 |
| 28/07/2018 | 775.60 | 32.7 | 209.25 | 4.22 | 1.03 | 3.19 |
| 29/07/2018 | 775.60 | 150.8 | 209.25 | 3.97 | 1.03 | 2.94 |
| 30/07/2018 | 775.60 | 29.4 | 209.25 | 3.97 | 1.03 | 2.94 |
| 31/07/2018 | 775.60 | 166.3 | 209.25 | 4.64 | 1.03 | 3.61 |
| 01/08/2018 | 775.60 | 27.6 | 209.25 | 5.66 | 1.03 | 4.63 |
| 02/08/2018 | 775.60 | 120.5 | 209.25 | 6.16 | 1.03 | 5.13 |
| 03/08/2018 | 775.60 | 52.7 | 209.25 | 5.95 | 1.03 | 4.92 |
| 04/08/2018 | 775.60 | 18 | 209.25 | 3.13 | 1.03 | 2.10 |
| 05/08/2018 | 775.60 | 55.7 | 209.25 | 1.47 | 1.03 | 0.44 |
| 06/08/2018 | 775.60 | 15.1 | 209.25 | 1.03 | 1.03 | 0.00 |
| 07/08/2018 | 775.60 | 79.2 | 209.25 | 2.24 | 1.03 | 1.21 |
| 08/08/2018 | 775.60 | 278.4 | 209.25 | 12.35 | 1.03 | 11.32 |
| 09/08/2018 | 775.60 | 442.6 | 209.25 | 20.70 | 1.03 | 19.67 |
| 10/08/2018 | 775.60 | 160.9 | 209.25 | 10.78 | 1.03 | 9.75 |
| 11/08/2018 | 775.60 | 46.5 | 209.25 | 7.11 | 1.03 | 6.08 |
| 12/08/2018 | 775.60 | 75 | 209.25 | 7.62 | 1.03 | 6.59 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13/08/2018 | 775.60 | 151.7 | 209.25 | 9.13 | 1.03 | 8.10 |
| 14/08/2018 | 775.60 | 205.4 | 209.25 | 15.53 | 1.03 | 14.50 |
| 15/08/2018 | 775.60 | 304.9 | 209.25 | 19.51 | 1.03 | 18.48 |
| 16/08/2018 | 775.00 | 343.9 | 202 | 12.37 | 1.03 | 18.59 |
| 17/08/2018 | 774.60 | 182.3 | 196.6 | 10.21 | 1.03 | 14.59 |
| 18/08/2018 | 775.60 | 161.6 | 209.25 | 16.92 | 1.03 | 3.24 |
| 19/08/2018 | 774.50 | 77.4 | 195.8 | -10.21 | 1.03 | 2.21 |
| 20/08/2018 | 774.65 | 88 | 197.6 | 5.04 | 1.03 | 2.21 |
| 21/08/2018 | 774.80 | 60.3 | 199.6 | 4.49 | 1.03 | 1.46 |
| 22/08/2018 | 774.85 | 16.3 | 200 | 2.17 | 1.03 | 0.74 |
| 23/08/2018 | 774.90 | 23.1 | 200.8 | 2.57 | 1.03 | 0.74 |
| 24/08/2018 | 774.90 | 1 | 200.8 | 1.77 | 1.03 | 0.74 |
| 25/08/2018 | 774.85 | 2.3 | 200 | 0.97 | 1.03 | 0.74 |
| 26/08/2018 | 774.75 | 0 | 198.8 | 0.57 | 1.03 | 0.74 |
| 27/08/2018 | 774.65 | 7.3 | 197.6 | 0.57 | 1.03 | 0.74 |
| 28/08/2018 | 774.60 | 39.5 | 196.6 | 0.77 | 1.03 | 0.74 |
| 29/08/2018 | 774.55 | 80.8 | 196.4 | 1.57 | 1.03 | 0.74 |
| 30/08/2018 | 774.50 | 20.8 | 195.8 | 1.17 | 1.03 | 0.74 |
| 31/08/2018 | 774.40 | 48.2 | 194.2 | 0.17 | 1.03 | 0.74 |
| 01/09/2018 | 774.40 | 48.3 | 194.2 | 1.77 | 1.03 | 0.74 |
| 02/09/2018 | 774.30 | 8.6 | 193.2 | 0.77 | 1.03 | 0.74 |
| 03/09/2018 | 774.20 | 4.1 | 192 | 0.57 | 1.03 | 0.74 |
| 04/09/2018 | 774.10 | 0 | 191 | 0.77 | 1.03 | 0.74 |
| 05/09/2018 | 773.95 | 0 | 189.2 | -0.03 | 1.03 | 0.74 |
| 06/09/2018 | 773.80 | 0 | 187.3 | -0.13 | 1.03 | 0.74 |
| 07/09/2018 | 773.70 | 0 | 186 | 0.14 | 1.03 | 0.41 |
| 05/10/2018 | 771.60 | 15.2 | 161.6 | -0.20 | 1.03 | 0.17 |
| 06/10/2018 | 771.60 | 63.3 | 161.6 | 1.57 | 1.03 | 0.54 |
| 07/10/2018 | 771.55 | 9.5 | 160.8 | 0.62 | 1.05 | 0.39 |
| **Total Spill 2018** | | | | | | **243.50** |

**Table 2.3 Spill Details**

## 2.2.2 Design Flood and Features Related to Safety

## Hydrology

The Kuttiyadi Augmentation Scheme aims at harnessing the potential of the river Karamanthodu, a tributary of Kabani by diversion of waters to the Kuttiyadi reservoir for increasing the power potential of Kuttiyadi Hydro Electric Scheme located at Kakkayam. The Kuttiyadi Hydro Electric Project is situated in Kuttiyadi river basin. Kuttiyadi river is a major tributary of Kuttiadypuzha originating from the Kakkayam Hills at about elevation +1340 m. The Kuttiyadi reservoir at FRL 758.04 m submerges an area of 279 hectares. The catchment area of Kattiyadi reservoir is approximately 38.50 sq. km. The catchment receives comparatively good rains almost throughout the year. It is observed that the rains contributed by South-West monsoon are comparatively heavier than the rain precipitated during North-East monsoon. The average annual rainfall of Kuttiyadi Hydro Electric Project is 6710 mm and the average annual runoff is estimated as 209.50 $Mm^3$.

## Kuttiyadi Augmentation Scheme

**i) Catchment:**

The catchment area of the project is 6144 Ha, of which 2345 Ha is forest land and the balance 3799 Ha is agricultural and other land. Out of this, an extent of 1427 Ha is submersible and the balance 4717 Ha is the exposed catchment.

Karamanthodu flows very close to the catchment of Kuttiyadi reservoir and hence has been selected for diversion to Kuttiyadi reservoir. The project envisages the utilization of part of the water from 61.44 sq. km of the Karamanthodu catchment for firming up the power generation at Kuttiyadi power station along with the extension of irrigation facilities for 5200 hectares for third crop in Kuttiyadi basin and irrigating 2800 hectares for two crops in Karamanthodu basin. Best use of the available data has been made for the assessment of water availability for both the Kuttiyadi and Karamanthodu catchments. The Estimation of water availability from the catchments on a long term basis forms the most important item in the study of hydrology.

The Karamanthodu locally known as Churanipuzha takes its origin on the eastern slopes of the Wayanad hills. It joins Vennyottupuzha after flowing in an easterly direction. The river below this confluence is known as Panamarampuzha, a tributary of Kabani. The catchment area of the stream at proposed dam site at Padinjarathara is 61.44 sq. km. The Kuttiyadi river originates on the western slopes of the Wayanad hill ranges at 915 m to 1065 m above MSL. After flowing in North-South direction it takes a sharp turn towards West. The dam constructed is a little upstream of the bend. The catchment area is 39 sq. km. The area comprises mainly forest land except for a stretch of abandoned cardamom plantations.

**ii) Winds:**

Prevailing winds are largely due to monsoon currents and their directions are therefore south west to north east during the period April to September, north east to south east during October to January and variable or generally windless during the rest of the period. It is fairly estimated that the wind speed will not exceed 50 km/hr., barring heavy storms. There will not be much effect of wind on the wave formation since the configuration of the water spread gives little fetch with reference to the dam.

**iii) Rainfall:**

Both catchments receive almost 90% of the annual rainfall from the south-west and north-east monsoons as usual with Western Ghats catchments. Of these nearly two thirds of the monsoon rain fall is due to south west monsoon which occur from middle of May to September. The north east monsoon is experienced from October to December. The period of the year from January to April has scanty rainfall.

In the Kuttiyadi catchment there is a departmental rain gauge station established near the dam site. The maximum recorded annual rainfall was 8611 mm in the year 1959-60 the minimum 4345 mm was in the year 1972-73 and the average rainfall over the period of 16 years is 6602 mm. In the Karamanthodu catchment, the Thariode estate rain gauge station located more or less in the center is taken as a representative station. Here the maximum rainfall is recorded in the year 1961-62 and was 9183 mm. Minimum was in the year 1972-73 and is 4419 mm and the average for the 15 years is 6247 mm. The other rain gauge stations considered are Bhagyalakshmi estate station, Thariode departmental station and Kuttiyadi departmental station of which Kuttiyadi departmental station alone falls

outside the catchment. Among the rain gauge stations inside the catchment, only Thariode estate station has data for a fairly long period. The weighted average rainfall for the period from 1971-72 to 1974-75 was worked out by Theisson Polygon method considering all the four rain gauge stations. The equation for the line of the best fit is worked out using the long term rain fall data of Thariode estate station.

The equation obtained is Y = 0.57x+70.92; Where y is the weighted average rainfall for Karamanthodu catchment at any particular year and x is the rainfall recorded at Thariode Estate station in that particular year.

From the weighted average rainfall for Karamanthodu catchment for the period (1960-61 to 1970-71), weighted average rainfall was tabulated for all the 15 year period from 1960-61 to 1974-75. According to this, the maximum rain fall is 7035.8 mm in the year 1972-73. The average for the catchment over 15 years is worked out to 5378 mm and this is less than the average rainfall at Thariode estate station for the 15 years period which is 6247mm.

**iv) Runoff:**

In the Panamaram River the parent stream of the Karamanthodu is being gauged by the PWD, about 400 m upstream of the Panamaram Bridge since 1965. The catchment area of the stream at the gauging site is 448 sq. km. With the gauging results at this point as well as at other points one in Mananthavady river and the other in Bavalipuzha, the applicability of the Ingli's formula for the rain fall runoff relationship for the Kabani basin has been established.

The rainfall and runoff of the scheme catchment have been established as described above. The nature of catchment, its configuration elevation – area distribution, the vegetation of the catchment, the magnitude and pattern of occurrence of rainfall etc. are more or less identical for both the Kuttiyadi and Karamanthodu catchments and the Ingli's formula for runoff = 0.85 rainfall -12 would be equally applicable for both Karamanthodu and Kuttiyadi catchments.

For Kuttiyadi the maximum runoff was in the year 1959-60 and was 272.4 $Mm^3$ and the minimum was that occurred in the year 1972-73 ie. 131.66 $Mm^3$. The average run off over the 16 years is 206.43 $Mm^3$ which works out to 5.31 Mm3/sq. km.

Similarly for Karamanthodu, the maximum run off was in the year 1961-62 and was 353.17 $Mm^3$ and the minimum was in the year 1972-73 and was 197.00 $Mm^3$. The average run off over the 15 years was 264 $Mm^3$ which works out to 4.297 $Mm^3$/sq. km.

For storage studies, the monthly runoff figures are required. The annual runoff figures for Karamanthodu have been split into monthly flows and the pattern has been used as such and for the other years the monthly flow pattern of the years having the nearest total annual runoff has been followed. Same pattern was adopted for Kuttiyadi basin also.

**v) Temperature data:**

The temperature data was available over a considerable period at Kuttiyadi.

**vi) Evaporation loss:**

There were no evaporation observations in the scheme catchment. An annual evaporation of 1016 mm has been taken for Kuttiyadi project on the basis of the recommendation made by Central Water & Power Commission for Sabarigiri project. The same evaporation loss has been suggested by Central Water & Power Commission for Mananthody project in the Kabani basin also and hence for this project also.

## Design Flood Studies

As per BIS: 11223-1985 criteria, the dam is classified as large dam and therefore, qualifies for PMF as design flood. The project was originally designed for1275$m^3$/s flood. The unit hydrograph of one hour duration was derived synthetically by project authorities using Flood Estimation Reportfor West coast region Konkan and Malabar coasts – sub zone 5(a &b). One day point PMP of 52.2 cm was adopted as design storm based on the PMP value adopted for Kuttiyadi dam by CWC. Loss rate of 0.1 cm/hr, base flow of 0.15$m^3$/s/sq km and 24 hour time distribution have been adopted from FER for West coast region Konkan and Malabar coasts – sub zone 5(a &b).

## Hydrology review carried out in DRIP

As a pre requisite for DRIP, the design flood of Kuttiyadi Augmentation Scheme was reviewed in 2014. The revised design flood is estimated as per FER 5 (a) & (b) published by Central Water Commission and IS-11223. One day PMP of 57.6 cm has been adopted as design storm. Time distribution of 12 hr rain has been assessed based on the SRRG data available in the regions of severe rainfall events and the same is adopted in the flood study of the project. Unit hydrograph of the catchment ofKuttiyadi Augmentation Dam bas been worked out using FER sub zone 5(a &b). The loss rate of rainfall and base flow have been taken as 0.1 cm/hr and 0.15$m^3$/s/sq. km from FER sub zone 5(a &b). The peak value of PMP works out as 1023 $m^3$/s. The computation of design flood hydrograph is enclosed as Annexure 2. As the original design flood was 1275 $m^3$/sec which is more than the revised design flood, the Central Water Commission recommended considering 1275 $m^3$/s for the dam safety review of the project. The revised design flood has been approved by the CWC vide letter No.16/3/KSEB – Design Flood Review/DSRD (DRIP)/2013 1411-1412 dated 18th September 2014. The flood routing study is attached as **Annexure 2**.

## 2.2.3 Spillway Operation

When the main dam was re-designed as a homogeneous rolled earth fill dam, it became imperative to provide a separate spillway portion to let out the flood waters. This was decided to be placed on the saddle on the right flank of the main dam.

## 2.3A Design Features and Components of Spillway Dam

The spillway dam is a concrete structure. The top level of dam is +778.50 m. The height of the dam above deepest foundation level is 36.50 m and the length at top is 56.38 m. The spillway is Ski-jump type. The spillway has 4 bays and is provided with four radial gates with crest level fixed at +767 m. Size of gate is 10.97 m x 9.20 m. Total Spillway Capacity of all bays is 1664 $m^3$/s. Overflow section of spillway is shown in **Annexure 1**.

In the spillway drainage gallery, pressure gauges are installed for recording uplift pressure. Further, to measure the seepage along spillway dam one V-notch is installed inside the gallery.

**Fig 2.2 Spillway**

## 2.3.1A Hoisting Arrangements for Radial Crest Gates

The main component of hoisting system (rope drum hoists) for operation of the crest gates of spillway is mounted on the spillway hoist bridge. The spillway is provided with radial gates of size 10.97 m x 9.20 m which can be operated both by power and manually. Stop log gates are not provided for the spillway. The gates are operated and tested in every season when the water is below the crest level. Periodical maintenance like painting, greasing, oiling etc. is also done from time to time.

**Fig 2.3 Radial Gates Hoist Bridge**

**Fig. 2.4 Radial Gate Hoisting Mechanism**

**Fig 2.5 Radial Gate Hoist Rope Drum**

### 2.3.2A River Outlet Works

A river outlet is provided in the Spillway Dam at an elevation of +750.75 m for letting out water. The outlet is circular in shape having 2 m diameter. Disperser valve and vertical gate are provided in the outlet. The river outlet has a maximum discharge capacity of 28 cumecs. Cross section through river outlet is shown in **Annexure 1**.

**Fig. 2.6 River Outlet Disperser Valve**

**Fig. 2.7 River Outlet Disperser Valve Opening Mechanism**


**Fig. 2.8 River Outlet Vertical Gate Hoisting Mechanism**

## 2.3.3A Irrigation Outlet Works

One irrigation outlet is provided in the Spillway Dam at an elevation of +759 m for letting out water for irrigation purpose. The outlet is circular in shape having 2 m diameter. Disperser valve and vertical gate are provided in the outlet. Cross section through irrigation outlet is shown in **Annexure 1**.


**Fig. 2.9 Irrigation Outlet Vertical Gate Hoisting Mechanism**


**Fig. 2.10 Hoisting Mechanism of Vertical Gates of River and Irrigation Outlets**

## 2.3.4A Salient Features of Spillway Dam

| | |
|---|---|
| Location | Padinjarethara. |
| Latitude | $11^0$40'18" N |
| Longitude | $75^0$57'36" E |
| Type | Concrete |
| Top level of the dam | +778.50m |
| Crest level | +767.00m |
| Height of Dam above deepest foundation level | 36.50m |
| Length at top | 56.38m |
| Type of Spillway | Ski-jump |
| Length of spillway | 56.38m |
| No of Bays | 4 |
| Type of Gate | Radial |
| Size of gate | 10.97m x 9.20m |
| Total Spillway Capacity of all bays | 1664$m^3$/s |
| Gate Hoisting Arrangement | Rope-Drum Type |
| River Outlet | One number (2 m dia. circular) |
| Level of outlet | +750.75m |
| Irrigation outlet | One number (2 m dia. circular) |
| Level of outlet | +759.00m |

**Table 2.4 Salient features of Spillway Dam**

## 2.3 B Design Features and Components of Main Dam:

The main dam across Karamanthodu was originally proposed as a composite dam of masonry and rolled earth fill. But due to the adverse permeability characteristics of the soil in the foundation, availability of earth quarries around dam site, non-availability of rock at shallow depth at the proposed location of Spillway and complexities involved in the construction of composite dam, a modified proposal of construction of an earthen dam across Karamanthodu with auxiliary structures like spillway, river outlet, irrigation outlet etc. located on an adjacent saddle on the right bank was drawn up.

In order to increase the benefit of power generation by converting this Augmentation Reservoir as a balancing reservoir with the proposed Mananthavady and

existing Kuttiyadi reservoirs, it was decided to increase the height of the dam by 4 m. As a result two additional saddle dams at Nayanmoola and Manjoora also became necessary in addition to the four saddle dams already proposed. Simultaneous with the change in alignment, the hydrology of the catchment area was also studied in detail and it was found that by increasing the height of dam by 4 m, diversion of more water will be possible and would be highly beneficial to the additional power generation.

Construction works of the main dam was started on 26.04.1982 and completed on 24.06.2006.

## 2.3.1B Construction Procedure

Tested earth from approved earth quarries are used for the construction. Undesirable elements viz. roots, oversize rocks etc. are removed in all stages of construction viz. dumping, levelling and rolling. Earth is dumped and levelled to get a consolidated thickness of about 20cm. Tests were conducted at each level for consolidation and for field density. Wherever possible, usable earth from formation excavation was used as earth fill. Core wall was provided as rock was available only from chainage 174.00 to 540.00. Partial cut off was provided beyond chainage 540.00 towards left abutment on technical and economical considerations.

The earth fill so deposited was rolled at 98% maximum dry density, arriving at rolling the material at OMC. The variation in moisture content was limited to 2% on either side of OMC. However it was ensured that at least 50% of the material rolled in was at or below OMC.

Also the difference between the quarry OMC and field moisture content was restricted to +1 to +2%. The soil sample was tested for compaction in the laboratory using proctor compaction method and optimum moisture content versus dry density relationship for the type of soil were determined. Each layer was tested and only after ensuring that the layer confirms to the standard specified, further layers of earth were placed. In case a zone fails compaction test, re rolling was done for the entire zone and not for the area where the test was taken.

The spreading of earth in each layer was carried out using D155, heavy bull dozer and D80, small bull dozer . The compaction was carried out using Sheep foot rollers. It was ensured that the moisture content of the compacted back fill at the time of compaction was such that it gave maximum consolidation of the material. In case the water content was less, water was added by uniform sprinkling in advance of the compaction of each layer. The amount of sprinkling was controlled so that no free water appeared at the surface during the subsequent compaction. For proper compaction , the materials were aerated so that the optimum moisture content was obtained.

**Constraints during construction of Main Dam**

**1. Excess moisture in the earth**

During construction of the Main dam, due to excess moisture in the earth, two layers of rolled fill in the right bank upstream portion were done. Further fill could not be carried out since moisture content of the fill placed was above allowable limits by 5 to 6%. A 3% increase in the lower layer of fill was suggested in this portion by Prof. Ramanathan for structural reasons. Even with this, the moisture content was on the higher side. All efforts for draining and letting the fill to dry, failed to bring down the moisture content, possibly on account of capillary action of the soil especially since the fill was below water level in the river. In the circumstances, another one to two layers of fill of 20cm each was attempted and moisture content tested again, and filling resumed subsequently.

**2. Providing a temporary earthen bund up to +760.00 elevation against dam overtopping:**

The all out efforts to raise the dam up to elevation +760.00m before the 1990 monsoon failed due to an unprecedented early south west monsoon shower, resulting in an impending threat to the safety of the earth dam by an overtopping due to flood water. To tackle the situation, a temporary earthen bund up to elevation +760.00 was constructed.

The following were the items carried out for the bund construction.

1. Forming a temporary bund by collecting and transporting earth to site from quarries, spreading and levelling using dozer, including simultaneous consolidation by dozer.
2. Covering the upstream slope and top of bund with polythene sheet.

3. Putting earth filled bags over the polythene covering on the upstream slope and top of bund.
4. Putting sand filled bags in the submersible slopes of bund.

## 2.3.2B Components

Main Dam is founded on permeable foundation. The main problem posed by this type of foundation is excessive seepage. This anticipated seepage was arrested by providing an upstream blanket in conjunction with positive cut off.

**i) Upstream blanket:**

The length of blanket provided is 8H with impervious materials to reduce the seepage pressure and seepage quantities by increasing the path of seepage. The thickness of blanket is 3 m at ends and 4.5 m at junction with toe.

**ii) Open cut off:**

This was formed by excavating an open cut off trench beneath the impervious zone of dam up to rock. The trench is compacted with impervious material. Bottom width of cut off trench provided is 5 m with height varying from 10 to 20 m as per topography of ground.

**Slope protection:**

**Upstream slope:**

Good quality rock was available at reasonable distance and so upstream slope was protected with dumped rip rap. Thickness of rip rap is 60 cm and is provided up to the dam top and duly keyed to the bed support. Graded filter is also provided below the rip rap for a thickness of 45 cm. Purpose of upstream rip rap is for providing protection from wave action.

**Downstream slope:**

Turfing is done on downstream slope of dam for protection.

**iii) Relief wells:**

In earth dams uplift is usually controlled by providing a positive cut off up to impervious structure consisting of either bed rock or clayey materials. But this may not be

possible where the over burden is deep and a compromise has to be usually arrived at, by providing a partial cut off or upstream blanket and a pressure relief system. A relief well consists of a small drainage well (45 cm dia. to 90 cm dia. as per IS Code) sunk near the downstream toe of an earth dam, with a pipe (10 cm dia. to 15 cm dia.) having narrow slots, placed in the center and surrounded by graded filter media which permits the increase of seepage water into the well allowing it raise to the out fall level where the pressure gets relieved.

To ensure safety of an earthen dam in cases where the cut off is partial, reliance is placed on an upstream blanket for controlling under seepage. It is generally necessary to control the pressures developed below the downstream toe of the dam, especially if a pervious layer is overlain by an impervious layer of soil at the top. This may be effectively done by installing a system of relief wells suitably placed which will relieve the intensity of under seepage. Pressure relief wells render seepage water practically harmless where it may conveniently lead to a natural drainage channel. Three relief wells are provided at the downstream toe of the main dam.

**Fig 2.11 Down Stream View of Main Dam**

**Fig 2.12 Top View of Main Dam**

### 2.3.3B River outlet Works

There are no river outlet works for Main Dam

### 2.3.4 B Salient Features of Main Dam

| | |
|---|---|
| Location | Padinjarathara |
| Latitude | $11^0$40'15" N |
| Longitude | $75^0$57'21" E |
| Type | Embankment (Homogeneous rolled earth fill) |
| Top level | +778.50m |
| River bed level | +740.00m |
| Height of Dam above bed level | 38.50m |
| Length at top | 685.00m |
| Width at top | 7m |
| Width at bottom | 245m |
| Upstream Slope | 1V : 4H with a berm of width 5 m at El +765.00 m |
| Downstream slope | 1V : 3 H with a berm at El +768.00 m |
| Spillway | No spillway arrangement |
| Outlet | Nil |
| Total earth content | Total earth content<br>31 lakhs $m^3$ |

**Table 2.5 Salient Features of Main Dam**

## 2.3C Kuttiyadi Saddle Dam

Kuttiyadi saddle dam is a concrete gravity dam. Bed level varies from +777.00 m to +760.50 m. There is an outlet of diameter 2 m at El + 764.00 m at C/L. The outlet is provided with a vertical gate. There is no spillway arrangement in the dam. No instruments are installed in the dam.

**Constraints during construction of Kuttiyadi Saddle Dam**

During foundation excavation of Kuttiyadi saddle, a fault zone was met with between chainage 38.5 m and 45.0 m. This foundation problem was taken up with geologist and the corrective measures suggested were done.

| | |
|---|---|
| Location | Kuttiyadi |
| Latitude | $11^0$35'56" N |
| Longitude | $75^0$55'09"E |
| Type | Concrete gravity |
| Top level | +777m |
| Saddle level | +760.50m |
| Height of Dam above saddle level | 16.50m |
| Length at top | 121m |
| Width at top | 4m |
| Outlet | 2m dia. |
| Total concrete content | 8400 $m^3$ |

**Table 2.6 Salient Features of Kuttiyadi Saddle Dam**

**Fig 2.13 Upstream view of Kuttiyadi Saddle Dam**

**Fig 2.14 Downstream view of Kuttiyadi Saddle Dam**

## 2.3D Kottagiri Saddle Dam

Kottagiri saddle dam is a rolled earth fill dam. Bed level varies from +779 m to +764 m. Upstream slope is 1V: 4H and downstream slope is 1V : 3 H . At downstream end a rock toe is provided and a rubble packing is provided in the upstream sloped portion. There is no spillway arrangement or outlet in the dam. No instruments are installed in the dam.

**Constraints during construction of Kottagiri Saddle Dam**

At Kottagiri saddle site, during excavation, heavy springs were encountered. Dental concreting was done at such locations before the commencement of earth filling.

| | |
|---|---|
| Location | Kottagiri |
| Type | Homogeneous earth fill |
| Latitude | $11^0$36'53" N |
| Longitude | $75^0$54'58"E |
| Top level | +778.50m |
| Saddle level | +764m |
| Height of Dam above saddle level | 14.50m |
| Length at top | 90m |
| Width at top | 7m |
| Total earth content | 0.63lakhs $m^3$ |

**Table 2.7 Salient Features of Kottagiri Saddle Dam**

**Fig 2.15 Upstream view of Kottagiri Saddle Dam**

**Fig 2.16 Rubble packing – upstream side of Kottagiri saddle dam**

## 2.3E Saddle Dam "Near Kottagiri"

Near Kottagiri saddle dam is a rolled earth fill dam. Upstream slope is 1V: 4H and downstream slope is 1V: 3 H. Bed level varies from +779 m to 767.50 m. At downstream end a rock toe is provided and a rubble packing is provided in the upstream sloped portion. No spillway or outlet is provided in the dam. No instruments are installed in the dam.

| | |
|---|---|
| Location | Near Kottagiri Saddle |
| Latitude | $11^0$36'44" N |
| Longitude | $75^0$55'00"E |
| Type | Homogeneous earth fill |
| Top level | +778.50m |
| Saddle level | +767.50m |
| Height of Dam above saddle level | 11m |
| Length at top | 110m |
| Width at top | 7m |
| Total earth content | 0.78 lakhs $m^3$ |

**Table 2.8 Salient Features of Saddle Dam Near Kottagiri**

**Fig 2.17 Upstream view of saddle dam near Kottagiri**

**Fig 2.18 Rubble packing – upstream side of saddle dam near Kottagiri**

## 2.3F Kosani Saddle Dam

Kosani saddle dam is a rolled earth fill dam. Upstream slope is 1V: 4H and downstream slope is 1V : 3 H. Bed Level varies from +779 m to +764.70 m. At downstream end, a rock toe is provided and a rubble packing is provided in the upstream sloped portion. There is no spillway arrangement or outlet in the dam. No instruments are installed in the dam.

| | |
|---|---|
| Location | Kosani |
| Latitude | $11^0$37'09" N |
| Longitude | $75^0$55'14"E |
| Type | Homogeneous earth fill |
| Top level | +778.50m |
| Saddle level | +764.70m |
| Height of Dam above deepest foundation level | 13.80m |
| Length at top | 140m |
| Width at top | 7m |
| Total earth content | Total earth content<br>1.10 lakhs $m^3$ |

**Table 2.9 Salient Features of Kosani Saddle Dam**

**Fig 2.19 Upstream view of Kosani Saddle Dam**

**Fig 2.20 Rubble packing – upstream side of Kosani Saddle Dam**

## 2.3G Manjoora Saddle Dam

Manjoora saddle dam is a rolled earth fill dam. Bed level varies from +777 m to +774 m. Upstream slope is 1V: 4H and downstream slope is 1V : 3 H . At the upstream sloped portion, rubble packing is provided. There is no spillway arrangement or outlet in the dam. No instruments are installed in the dam.

| | |
|---|---|
| Location | Manjoora |
| Type | Homogeneous earth fill |
| Latitude | $11^0$38'44" N |
| Longitude | $75^0$58'43"E |
| Top level | +777m |
| Saddle level | +773m |
| Height of Dam above saddle level | 4m |
| Length at top | 74m |
| Width at top | 7m |
| Total earth content | 0.032lakhs $m^3$ |

**Table 2.10 Salient Features of Manjoora Saddle Dam**

**Fig 2.21 Upstream view of Manjoora Saddle Dam**

## 2.3H Nayanmoola Saddle Dam

Nayanmoola saddle dam is a rolled earth fill dam. Bed level varies from +779 m to +775 m. Upstream slope is 1V: 4H and downstream slope is 1V : 3 H. There is no spillway arrangement or outlet in the dam. No instruments are installed in the dam.

| | |
|---|---|
| Location | Nayanmoola |
| Type | Homogeneous earth fill |
| Top level | +778.50m |
| Saddle level | +775m |
| Height of Dam above saddle level | 3.50m |
| Length at top | 24m |
| Width at top | 7m |
| Total earth content | 0.01lakhs $m^3$ |

**Table 2.11 Salient Features of Nayanmoola Saddle Dam**

## 2.4 Normal Operation of the Reservoir

### 2.4.1 Operation of Control Mechanisms

The spillway gates hoist motors are having 10 HP capacities and the tunnel intake hoist motor is having 7.50 HP capacity. The disperser valve vertical gate hoist motors of river outlet and irrigation outlet are having 7.50 HP capacity each. The Operation Procedure of gates is attached as **Annexure 7**.

### 2.4.2 Operation of the Reservoir

Banasurasagar reservoir is being operated as per "Guidelines for Operation of Reservoirs" (IS 7323:1994), for storage reservoirs for conservation purposes like power generation. The reservoir water is released through spillway gates as per rule levels fixed. Discharge through single spillway for different reservoir levels with different gate openings is tabulated in **Table 2.12**. Discharge (Rating) curve for single spillway is given in **Fig. 2.22**.

| BANASURA SAGAR DAM - DISCHARGE THROUGH SINGLE SPILLWAY GATE FOR DIFFERENT RESERVOIR LEVEL AND DIFFERENT GATE OPENINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Gate Opening (m)** | **0.3** | **0.6** | **0.9** | **1.2** | **1.5** | **1.8** | **2.1** | **2.4** | **2.7** |
| **Reservoir Level (m)** | **DISCHARGE IN CUMECS** | | | | | | | | |
| 767.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 767.10 | 0.728 | 0.728 | 0.728 | 0.728 | 0.728 | 0.728 | 0.728 | 0.728 | 0.729 |
| 767.20 | 2.058 | 2.058 | 2.058 | 2.058 | 2.058 | 2.058 | 2.058 | 2.060 | 2.062 |
| 767.30 | 3.781 | 3.781 | 3.781 | 3.781 | 3.781 | 3.781 | 3.781 | 3.783 | 3.787 |
| 767.40 | 4.880 | 5.820 | 5.820 | 5.820 | 5.820 | 5.820 | 5.820 | 5.823 | 5.829 |
| 767.50 | 5.773 | 8.132 | 8.132 | 8.132 | 8.132 | 8.132 | 8.132 | 8.137 | 8.144 |
| 767.60 | 6.545 | 10.687 | 10.687 | 10.687 | 10.687 | 10.687 | 10.687 | 10.694 | 10.704 |
| 767.70 | 7.234 | 12.338 | 13.465 | 13.465 | 13.465 | 13.465 | 13.465 | 13.473 | 13.486 |
| 767.80 | 7.863 | 13.792 | 16.448 | 16.448 | 16.448 | 16.448 | 16.448 | 16.458 | 16.474 |
| 767.90 | 8.444 | 15.106 | 19.623 | 19.623 | 19.623 | 19.623 | 19.623 | 19.635 | 19.654 |
| 768.00 | 8.988 | 16.313 | 21.690 | 22.979 | 22.979 | 22.979 | 22.979 | 22.993 | 23.015 |
| 768.10 | 9.500 | 17.436 | 23.575 | 26.505 | 26.505 | 26.505 | 26.505 | 26.522 | 26.547 |
| 768.20 | 9.986 | 18.491 | 25.319 | 30.195 | 30.195 | 30.195 | 30.195 | 30.214 | 30.243 |
| 768.30 | 10.449 | 19.487 | 26.950 | 32.608 | 34.041 | 34.041 | 34.041 | 34.062 | 34.095 |
| 768.40 | 10.892 | 20.435 | 28.486 | 34.854 | 38.036 | 38.036 | 38.036 | 38.060 | 38.096 |
| 768.50 | 11.317 | 21.339 | 29.942 | 36.961 | 42.176 | 42.176 | 42.176 | 42.202 | 42.243 |
| 768.60 | 11.726 | 22.207 | 31.330 | 38.953 | 44.891 | 46.454 | 46.454 | 46.483 | 46.528 |
| 768.70 | 12.122 | 23.041 | 32.657 | 40.847 | 47.450 | 50.868 | 50.868 | 50.899 | 50.948 |
| 768.80 | 12.505 | 23.845 | 33.932 | 42.656 | 49.876 | 55.411 | 55.411 | 55.446 | 55.499 |
| 768.90 | 12.876 | 24.623 | 35.160 | 44.389 | 52.187 | 58.398 | 60.081 | 60.119 | 60.176 |
| 769.00 | 13.236 | 25.376 | 36.346 | 46.056 | 54.399 | 61.237 | 64.875 | 64.915 | 64.977 |
| 769.10 | 13.586 | 26.107 | 37.493 | 47.664 | 56.523 | 63.948 | 69.788 | 69.831 | 69.898 |
| 769.20 | 13.928 | 26.817 | 38.605 | 49.218 | 58.568 | 66.547 | 73.022 | 74.864 | 74.936 |
| 769.30 | 14.261 | 27.509 | 39.686 | 50.724 | 60.543 | 69.047 | 76.117 | 80.011 | 80.088 |
| 769.40 | 14.586 | 28.183 | 40.737 | 52.185 | 62.454 | 71.457 | 79.088 | 85.270 | 85.352 |
| 769.50 | 14.904 | 28.841 | 41.761 | 53.605 | 64.307 | 73.787 | 81.950 | 88.736 | 90.725 |
| 769.60 | 15.215 | 29.484 | 42.759 | 54.987 | 66.107 | 76.044 | 84.713 | 92.069 | 96.205 |
| 769.70 | 15.520 | 30.112 | 43.734 | 56.335 | 67.857 | 78.234 | 87.387 | 95.283 | 101.790 |
| 769.80 | 15.818 | 30.728 | 44.687 | 57.650 | 69.563 | 80.363 | 89.980 | 98.390 | 105.473 |
| 769.90 | 16.111 | 31.330 | 45.620 | 58.935 | 71.226 | 82.436 | 92.498 | 101.399 | 109.030 |
| 770.00 | 16.398 | 31.921 | 46.533 | 60.192 | 72.850 | 84.456 | 94.948 | 104.320 | 112.471 |
| 770.10 | 16.680 | 32.501 | 47.428 | 61.422 | 74.438 | 86.428 | 97.334 | 107.159 | 115.808 |
| 770.20 | 16.957 | 33.070 | 48.306 | 62.626 | 75.991 | 88.354 | 99.662 | 109.922 | 119.049 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 770.30 | 17.230 | 33.630 | 49.167 | 63.808 | 77.512 | 90.238 | 101.934 | 112.616 | 122.202 |
| 770.40 | 17.498 | 34.179 | 50.013 | 64.967 | 79.003 | 92.082 | 104.156 | 115.245 | 125.273 |
| 770.50 | 17.762 | 34.720 | 50.844 | 66.105 | 80.465 | 93.888 | 106.329 | 117.814 | 128.269 |
| 770.60 | 18.022 | 35.252 | 51.662 | 67.222 | 81.900 | 95.659 | 108.458 | 120.325 | 131.194 |
| 770.70 | 18.278 | 35.775 | 52.466 | 68.321 | 83.309 | 97.396 | 110.544 | 122.784 | 134.053 |
| 770.80 | 18.530 | 36.291 | 53.257 | 69.401 | 84.694 | 99.102 | 112.589 | 125.193 | 136.850 |
| 770.90 | 18.779 | 36.799 | 54.036 | 70.464 | 86.055 | 100.778 | 114.597 | 127.554 | 139.589 |
| 771.00 | 19.024 | 37.300 | 54.804 | 71.511 | 87.395 | 102.425 | 116.569 | 129.871 | 142.274 |
| 771.10 | 19.266 | 37.793 | 55.560 | 72.542 | 88.713 | 104.045 | 118.506 | 132.145 | 144.907 |
| 771.20 | 19.505 | 38.280 | 56.305 | 73.557 | 90.011 | 105.638 | 120.411 | 134.380 | 147.491 |
| 771.30 | 19.740 | 38.761 | 57.041 | 74.558 | 91.289 | 107.207 | 122.285 | 136.576 | 150.029 |
| 771.40 | 19.973 | 39.235 | 57.766 | 75.545 | 92.549 | 108.753 | 124.129 | 138.736 | 152.522 |
| 771.50 | 20.203 | 39.704 | 58.482 | 76.519 | 93.791 | 110.275 | 125.945 | 140.861 | 154.974 |
| 771.60 | 20.430 | 40.166 | 59.189 | 77.479 | 95.016 | 111.776 | 127.734 | 142.953 | 157.386 |
| 771.70 | 20.655 | 40.623 | 59.887 | 78.427 | 96.224 | 113.255 | 129.497 | 145.013 | 159.759 |
| 771.80 | 20.877 | 41.074 | 60.576 | 79.363 | 97.416 | 114.715 | 131.235 | 147.043 | 162.096 |
| 771.90 | 21.096 | 41.521 | 61.257 | 80.288 | 98.594 | 116.155 | 132.948 | 149.044 | 164.399 |
| 772.00 | 21.313 | 41.962 | 61.930 | 81.201 | 99.756 | 117.576 | 134.639 | 151.017 | 166.667 |
| 772.10 | 21.528 | 42.398 | 62.595 | 82.103 | 100.904 | 118.979 | 136.308 | 152.963 | 168.904 |
| 772.20 | 21.740 | 42.830 | 63.253 | 82.995 | 102.039 | 120.365 | 137.955 | 154.883 | 171.110 |
| 772.30 | 21.950 | 43.256 | 63.904 | 83.877 | 103.160 | 121.734 | 139.581 | 156.779 | 173.286 |
| 772.40 | 22.158 | 43.679 | 64.547 | 84.749 | 104.268 | 123.087 | 141.188 | 158.650 | 175.433 |
| 772.50 | 22.364 | 44.097 | 65.184 | 85.612 | 105.364 | 124.424 | 142.775 | 160.498 | 177.553 |
| 772.60 | 22.568 | 44.511 | 65.814 | 86.465 | 106.448 | 125.746 | 144.344 | 162.323 | 179.646 |
| 772.70 | 22.770 | 44.920 | 66.438 | 87.309 | 107.520 | 127.054 | 145.895 | 164.127 | 181.714 |
| 772.80 | 22.970 | 45.326 | 67.055 | 88.145 | 108.580 | 128.347 | 147.428 | 165.910 | 183.757 |
| 772.90 | 23.168 | 45.728 | 67.667 | 88.972 | 109.630 | 129.626 | 148.944 | 167.673 | 185.776 |
| 773.00 | 23.364 | 46.126 | 68.272 | 89.791 | 110.669 | 130.892 | 150.444 | 169.416 | 187.772 |
| 773.10 | 23.559 | 46.520 | 68.872 | 90.602 | 111.697 | 132.144 | 151.928 | 171.141 | 189.745 |
| 773.20 | 23.752 | 46.911 | 69.466 | 91.405 | 112.715 | 133.384 | 153.397 | 172.846 | 191.697 |
| 773.30 | 23.943 | 47.298 | 70.054 | 92.200 | 113.724 | 134.612 | 154.851 | 174.534 | 193.627 |
| 773.40 | 24.132 | 47.681 | 70.637 | 92.988 | 114.723 | 135.827 | 156.290 | 176.204 | 195.537 |
| 773.50 | 24.320 | 48.062 | 71.215 | 93.769 | 115.712 | 137.031 | 157.714 | 177.858 | 197.427 |
| 773.60 | 24.506 | 48.439 | 71.788 | 94.543 | 116.692 | 138.224 | 159.125 | 179.494 | 199.298 |
| 773.70 | 24.691 | 48.813 | 72.356 | 95.310 | 117.664 | 139.405 | 160.523 | 181.115 | 201.150 |
| 773.80 | 24.874 | 49.184 | 72.919 | 96.071 | 118.627 | 140.576 | 161.907 | 182.721 | 202.984 |
| 773.90 | 25.056 | 49.551 | 73.478 | 96.824 | 119.581 | 141.736 | 163.279 | 184.311 | 204.800 |
| 774.00 | 25.236 | 49.916 | 74.031 | 97.572 | 120.527 | 142.886 | 164.638 | 185.886 | 206.598 |
| 774.10 | 25.415 | 50.278 | 74.581 | 98.313 | 121.465 | 144.026 | 165.985 | 187.447 | 208.380 |
| 774.20 | 25.592 | 50.637 | 75.125 | 99.048 | 122.395 | 145.156 | 167.321 | 188.994 | 210.146 |
| 774.30 | 25.768 | 50.993 | 75.666 | 99.777 | 123.317 | 146.277 | 168.644 | 190.528 | 211.895 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 774.40 | 25.943 | 51.347 | 76.202 | 100.500 | 124.232 | 147.388 | 169.957 | 192.047 | 213.629 |
| 774.50 | 26.117 | 51.697 | 76.734 | 101.218 | 125.140 | 148.490 | 171.258 | 193.554 | 215.347 |
| 774.60 | 26.289 | 52.046 | 77.262 | 101.930 | 126.040 | 149.583 | 172.549 | 195.048 | 217.051 |
| 774.70 | 26.460 | 52.391 | 77.786 | 102.636 | 126.933 | 150.667 | 173.829 | 196.530 | 218.740 |
| 774.80 | 26.629 | 52.734 | 78.306 | 103.338 | 127.819 | 151.743 | 175.098 | 197.999 | 220.415 |
| 774.90 | 26.798 | 53.075 | 78.823 | 104.033 | 128.699 | 152.810 | 176.358 | 199.457 | 222.076 |
| 775.00 | 26.965 | 53.413 | 79.335 | 104.724 | 129.572 | 153.869 | 177.608 | 200.902 | 223.723 |
| 775.10 | 27.132 | 53.749 | 79.844 | 105.410 | 130.438 | 154.920 | 178.848 | 202.337 | 225.357 |
| 775.20 | 27.297 | 54.082 | 80.349 | 106.091 | 131.298 | 155.964 | 180.078 | 203.760 | 226.978 |
| 775.30 | 27.461 | 54.413 | 80.851 | 106.767 | 132.152 | 156.999 | 181.300 | 205.172 | 228.587 |
| 775.40 | 27.623 | 54.742 | 81.349 | 107.438 | 133.000 | 158.027 | 182.512 | 206.574 | 230.183 |
| 775.50 | 27.785 | 55.069 | 81.844 | 108.104 | 133.841 | 159.048 | 183.715 | 207.965 | 231.767 |
| 775.60 | 27.946 | 55.393 | 82.336 | 108.766 | 134.677 | 160.061 | 184.910 | 209.346 | 233.339 |
| 775.70 | 28.106 | 55.716 | 82.824 | 109.424 | 135.507 | 161.067 | 186.096 | 210.717 | 234.899 |
| 775.80 | 28.264 | 56.036 | 83.309 | 110.077 | 136.331 | 162.066 | 187.274 | 212.077 | 236.448 |
| 775.90 | 28.422 | 56.354 | 83.791 | 110.725 | 137.150 | 163.059 | 188.443 | 213.428 | 237.985 |
| 776.00 | 28.578 | 56.670 | 84.270 | 111.370 | 137.963 | 164.044 | 189.604 | 214.770 | 239.512 |

| **BANASURA SAGAR DAM - DISCHARGE THROUGH SINGLE SPILLWAY GATE FOR DIFFERENT RESERVOIR LEVEL AND DIFFERENT GATE OPENINGS** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Gate Opening (m)** | **3** | **3.3** | **3.6** | **3.9** | **4.2** | **4.5** | **4.8** | **5.1** |
| **Reservoir Level (m)** | **DISCHARGE IN CUMECS** | | | | | | | |
| 767.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 767.10 | 0.730 | 0.730 | 0.731 | 0.731 | 0.732 | 0.732 | 0.733 | 0.733 |
| 767.20 | 2.063 | 2.065 | 2.067 | 2.068 | 2.070 | 2.071 | 2.072 | 2.074 |
| 767.30 | 3.790 | 3.793 | 3.796 | 3.799 | 3.802 | 3.804 | 3.807 | 3.809 |
| 767.40 | 5.834 | 5.838 | 5.844 | 5.848 | 5.853 | 5.856 | 5.860 | 5.863 |
| 767.50 | 8.151 | 8.158 | 8.165 | 8.172 | 8.178 | 8.183 | 8.188 | 8.192 |
| 767.60 | 10.713 | 10.721 | 10.731 | 10.740 | 10.748 | 10.755 | 10.761 | 10.766 |
| 767.70 | 13.497 | 13.508 | 13.521 | 13.532 | 13.541 | 13.550 | 13.558 | 13.565 |
| 767.80 | 16.488 | 16.501 | 16.516 | 16.530 | 16.541 | 16.552 | 16.561 | 16.570 |
| 767.90 | 19.670 | 19.686 | 19.704 | 19.720 | 19.734 | 19.747 | 19.758 | 19.768 |
| 768.00 | 23.034 | 23.052 | 23.073 | 23.092 | 23.109 | 23.124 | 23.137 | 23.149 |
| 768.10 | 26.569 | 26.590 | 26.615 | 26.637 | 26.656 | 26.673 | 26.688 | 26.702 |
| 768.20 | 30.268 | 30.292 | 30.320 | 30.345 | 30.366 | 30.386 | 30.403 | 30.419 |
| 768.30 | 34.123 | 34.150 | 34.181 | 34.209 | 34.234 | 34.256 | 34.275 | 34.293 |
| 768.40 | 38.128 | 38.158 | 38.193 | 38.225 | 38.252 | 38.276 | 38.298 | 38.318 |
| 768.50 | 42.277 | 42.311 | 42.350 | 42.385 | 42.415 | 42.442 | 42.466 | 42.488 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 768.60 | 46.566 | 46.603 | 46.646 | 46.684 | 46.718 | 46.748 | 46.774 | 46.798 |
| 768.70 | 50.990 | 51.030 | 51.078 | 51.119 | 51.156 | 51.189 | 51.218 | 51.244 |
| 768.80 | 55.545 | 55.588 | 55.640 | 55.685 | 55.725 | 55.761 | 55.793 | 55.821 |
| 768.90 | 60.226 | 60.273 | 60.329 | 60.379 | 60.422 | 60.461 | 60.495 | 60.526 |
| 769.00 | 65.031 | 65.082 | 65.142 | 65.196 | 65.243 | 65.284 | 65.321 | 65.355 |
| 769.10 | 69.956 | 70.011 | 70.076 | 70.133 | 70.184 | 70.228 | 70.268 | 70.304 |
| 769.20 | 74.998 | 75.057 | 75.127 | 75.188 | 75.242 | 75.290 | 75.333 | 75.372 |
| 769.30 | 80.154 | 80.217 | 80.292 | 80.358 | 80.415 | 80.467 | 80.513 | 80.554 |
| 769.40 | 85.423 | 85.490 | 85.569 | 85.639 | 85.701 | 85.756 | 85.804 | 85.848 |
| 769.50 | 90.800 | 90.871 | 90.956 | 91.030 | 91.096 | 91.154 | 91.206 | 91.253 |
| 769.60 | 96.285 | 96.360 | 96.450 | 96.529 | 96.598 | 96.660 | 96.715 | 96.764 |
| 769.70 | 101.874 | 101.954 | 102.049 | 102.132 | 102.206 | 102.271 | 102.329 | 102.382 |
| 769.80 | 107.566 | 107.650 | 107.751 | 107.839 | 107.916 | 107.985 | 108.047 | 108.102 |
| 769.90 | 113.359 | 113.448 | 113.553 | 113.646 | 113.728 | 113.801 | 113.865 | 113.924 |
| 770.00 | 119.251 | 119.344 | 119.455 | 119.553 | 119.639 | 119.715 | 119.784 | 119.845 |
| 770.10 | 123.139 | 125.338 | 125.455 | 125.557 | 125.647 | 125.728 | 125.799 | 125.864 |
| 770.20 | 126.905 | 131.427 | 131.550 | 131.657 | 131.752 | 131.836 | 131.911 | 131.978 |
| 770.30 | 130.561 | 137.610 | 137.739 | 137.851 | 137.950 | 138.038 | 138.117 | 138.188 |
| 770.40 | 134.114 | 141.693 | 144.020 | 144.138 | 144.242 | 144.334 | 144.416 | 144.490 |
| 770.50 | 137.573 | 145.658 | 150.393 | 150.516 | 150.624 | 150.720 | 150.806 | 150.883 |
| 770.60 | 140.944 | 149.516 | 156.855 | 156.983 | 157.097 | 157.197 | 157.286 | 157.367 |
| 770.70 | 144.234 | 153.273 | 161.124 | 163.540 | 163.657 | 163.762 | 163.855 | 163.939 |
| 770.80 | 147.449 | 156.939 | 165.279 | 170.183 | 170.306 | 170.414 | 170.511 | 170.599 |
| 770.90 | 150.593 | 160.517 | 169.330 | 176.912 | 177.040 | 177.153 | 177.254 | 177.344 |
| 771.00 | 153.670 | 164.015 | 173.283 | 181.358 | 183.859 | 183.976 | 184.081 | 184.175 |
| 771.10 | 156.684 | 167.438 | 177.145 | 185.695 | 190.761 | 190.883 | 190.992 | 191.089 |
| 771.20 | 159.640 | 170.790 | 180.922 | 189.930 | 197.746 | 197.873 | 197.985 | 198.086 |
| 771.30 | 162.539 | 174.074 | 184.618 | 194.069 | 202.363 | 204.944 | 205.060 | 205.165 |
| 771.40 | 165.386 | 177.296 | 188.240 | 198.118 | 206.873 | 212.095 | 212.216 | 212.325 |
| 771.50 | 168.182 | 180.457 | 191.790 | 202.084 | 211.283 | 219.326 | 219.451 | 219.564 |
| 771.60 | 170.931 | 183.562 | 195.274 | 205.970 | 215.600 | 224.106 | 226.765 | 226.881 |
| 771.70 | 173.634 | 186.613 | 198.694 | 209.782 | 219.830 | 228.783 | 234.157 | 234.276 |
| 771.80 | 176.294 | 189.613 | 202.053 | 213.523 | 223.976 | 233.362 | 241.625 | 241.748 |
| 771.90 | 178.912 | 192.564 | 205.356 | 217.197 | 228.044 | 237.850 | 246.562 | 249.296 |
| 772.00 | 181.490 | 195.468 | 208.603 | 220.807 | 232.038 | 242.252 | 251.399 | 256.920 |
| 772.10 | 184.031 | 198.327 | 211.798 | 224.356 | 235.961 | 246.572 | 256.141 | 264.617 |
| 772.20 | 186.535 | 201.144 | 214.944 | 227.848 | 239.818 | 250.814 | 260.793 | 269.706 |
| 772.30 | 189.004 | 203.920 | 218.042 | 231.284 | 243.610 | 254.983 | 265.360 | 274.697 |
| 772.40 | 191.440 | 206.656 | 221.094 | 234.667 | 247.342 | 259.081 | 269.847 | 279.595 |
| 772.50 | 193.843 | 209.355 | 224.103 | 238.000 | 251.015 | 263.113 | 274.257 | 284.406 |
| 772.60 | 196.215 | 212.017 | 227.069 | 241.284 | 254.633 | 267.081 | 278.594 | 289.133 |
| 772.70 | 198.557 | 214.645 | 229.995 | 244.522 | 258.197 | 270.988 | 282.861 | 293.780 |
| 772.80 | 200.870 | 217.238 | 232.882 | 247.716 | 261.710 | 274.837 | 287.062 | 298.352 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 772.90 | 203.154 | 219.800 | 235.732 | 250.866 | 265.175 | 278.630 | 291.200 | 302.852 |
| 773.00 | 205.412 | 222.330 | 238.545 | 253.975 | 268.592 | 282.369 | 295.276 | 307.282 |
| 773.10 | 207.644 | 224.829 | 241.324 | 257.044 | 271.963 | 286.056 | 299.294 | 311.646 |
| 773.20 | 209.850 | 227.299 | 244.069 | 260.074 | 275.291 | 289.694 | 303.255 | 315.947 |
| 773.30 | 212.031 | 229.741 | 246.781 | 263.067 | 278.577 | 293.284 | 307.163 | 320.186 |
| 773.40 | 214.189 | 232.156 | 249.462 | 266.025 | 281.821 | 296.828 | 311.019 | 324.368 |
| 773.50 | 216.324 | 234.543 | 252.113 | 268.948 | 285.027 | 300.327 | 314.824 | 328.493 |
| 773.60 | 218.436 | 236.905 | 254.733 | 271.837 | 288.195 | 303.784 | 318.582 | 332.563 |
| 773.70 | 220.527 | 239.242 | 257.326 | 274.694 | 291.325 | 307.199 | 322.293 | 336.582 |
| 773.80 | 222.596 | 241.555 | 259.890 | 277.519 | 294.421 | 310.574 | 325.958 | 340.550 |
| 773.90 | 224.644 | 243.844 | 262.428 | 280.314 | 297.481 | 313.911 | 329.581 | 344.470 |
| 774.00 | 226.673 | 246.109 | 264.939 | 283.079 | 300.509 | 317.210 | 333.161 | 348.342 |
| 774.10 | 228.682 | 248.353 | 267.425 | 285.815 | 303.503 | 320.472 | 336.701 | 352.169 |
| 774.20 | 230.672 | 250.575 | 269.886 | 288.523 | 306.467 | 323.699 | 340.201 | 355.953 |
| 774.30 | 232.644 | 252.775 | 272.324 | 291.204 | 309.400 | 326.892 | 343.663 | 359.693 |
| 774.40 | 234.598 | 254.955 | 274.737 | 293.859 | 312.303 | 330.052 | 347.088 | 363.393 |
| 774.50 | 236.534 | 257.115 | 277.128 | 296.488 | 315.177 | 333.179 | 350.477 | 367.052 |
| 774.60 | 238.453 | 259.256 | 279.497 | 299.092 | 318.023 | 336.275 | 353.831 | 370.673 |
| 774.70 | 240.355 | 261.377 | 281.844 | 301.671 | 320.842 | 339.341 | 357.151 | 374.255 |
| 774.80 | 242.241 | 263.479 | 284.170 | 304.227 | 323.634 | 342.376 | 360.438 | 377.802 |
| 774.90 | 244.110 | 265.564 | 286.475 | 306.759 | 326.400 | 345.383 | 363.693 | 381.312 |
| 775.00 | 245.965 | 267.630 | 288.761 | 309.269 | 329.141 | 348.362 | 366.916 | 384.788 |
| 775.10 | 247.804 | 269.680 | 291.026 | 311.757 | 331.857 | 351.313 | 370.109 | 388.230 |
| 775.20 | 249.628 | 271.712 | 293.272 | 314.223 | 334.549 | 354.237 | 373.272 | 391.640 |
| 775.30 | 251.437 | 273.727 | 295.500 | 316.668 | 337.218 | 357.136 | 376.407 | 395.017 |
| 775.40 | 253.232 | 275.727 | 297.709 | 319.093 | 339.864 | 360.008 | 379.513 | 398.364 |
| 775.50 | 255.013 | 277.710 | 299.901 | 321.497 | 342.487 | 362.856 | 382.592 | 401.680 |
| 775.60 | 256.781 | 279.678 | 302.074 | 323.882 | 345.088 | 365.680 | 385.644 | 404.966 |
| 775.70 | 258.535 | 281.631 | 304.231 | 326.248 | 347.668 | 368.480 | 388.669 | 408.224 |
| 775.80 | 260.276 | 283.569 | 306.371 | 328.595 | 350.227 | 371.256 | 391.669 | 411.453 |
| 775.90 | 262.004 | 285.492 | 308.494 | 330.923 | 352.766 | 374.010 | 394.644 | 414.655 |
| 776.00 | 263.720 | 287.401 | 310.602 | 333.234 | 355.285 | 376.742 | 397.595 | 417.829 |

**Table 2.12 Spillway discharge**

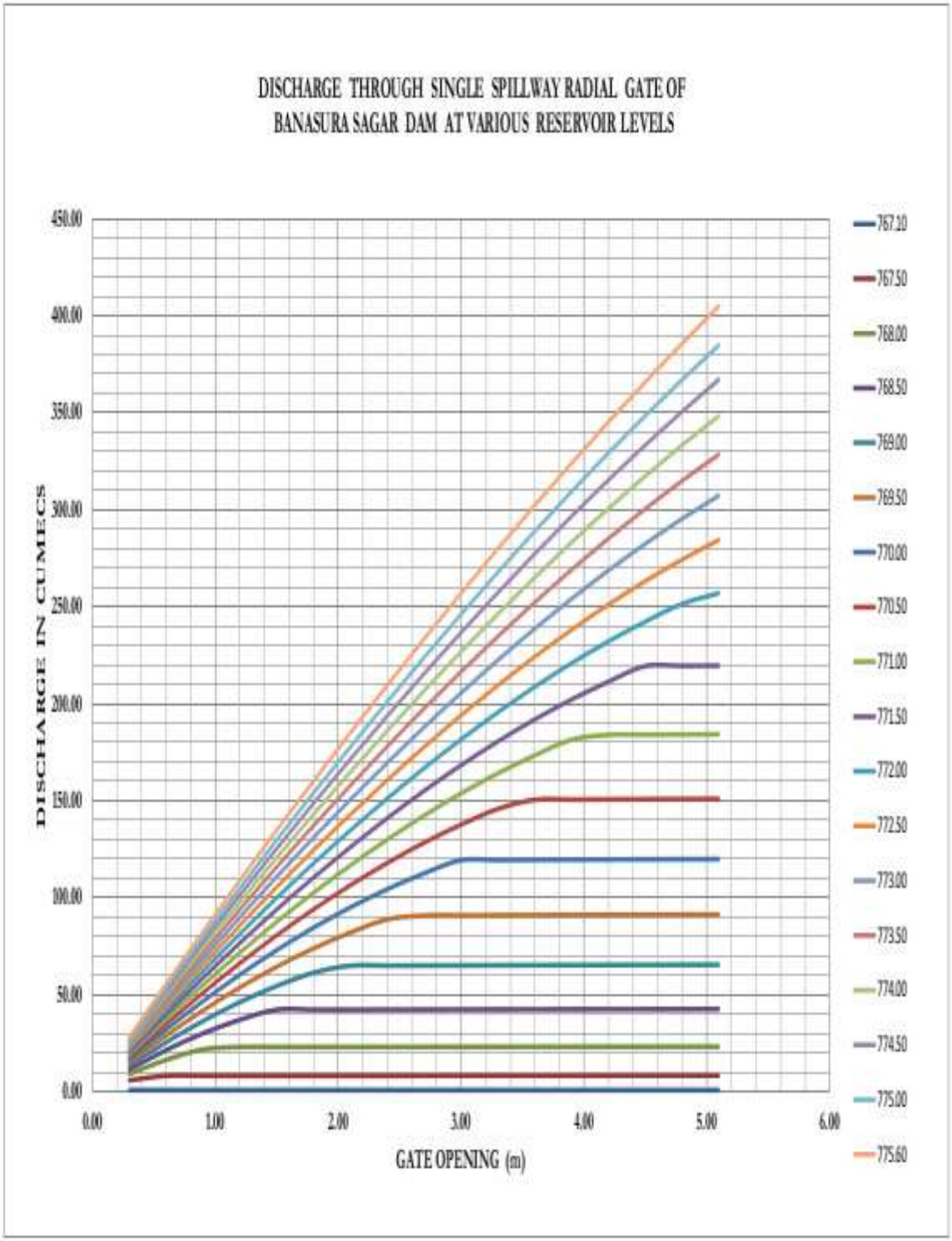


**Fig. 2.22 Discharge Curve for Single Spillway**

### 2.4.3 Rule levels of Banasurasagar Reservoir

As per the Kerala flood study report of August 2018, CWC has recommended for reviewing the rule curves of all the reservoirs in Kerala. The rule curves need to be formulated for both conservation as well as operations during the flood, in case of storage reservoirs also, particularly for the reservoirs having the live storage capacity of more than 200 $Mm^3$ in order to create some dynamic flood cushion for moderating the floods of lower return periods particularly in the early period of monsoon. Accordingly, rule levels for reservoirs under KSEB Ltd are arrived.

Rule Levels of Banasurasagar reservoir are arrived as follows:

A comparison of daily inflow to Banasurasagar reservoir during the year 2018 (very wet year) is made with the inflow for the year 2008(very dry year), 2012 (normal year), 2013(very wet year) and is shown in the graph below. The extreme peak of inflow in the year 2018 is very well depicted in the graphical representation of the series.

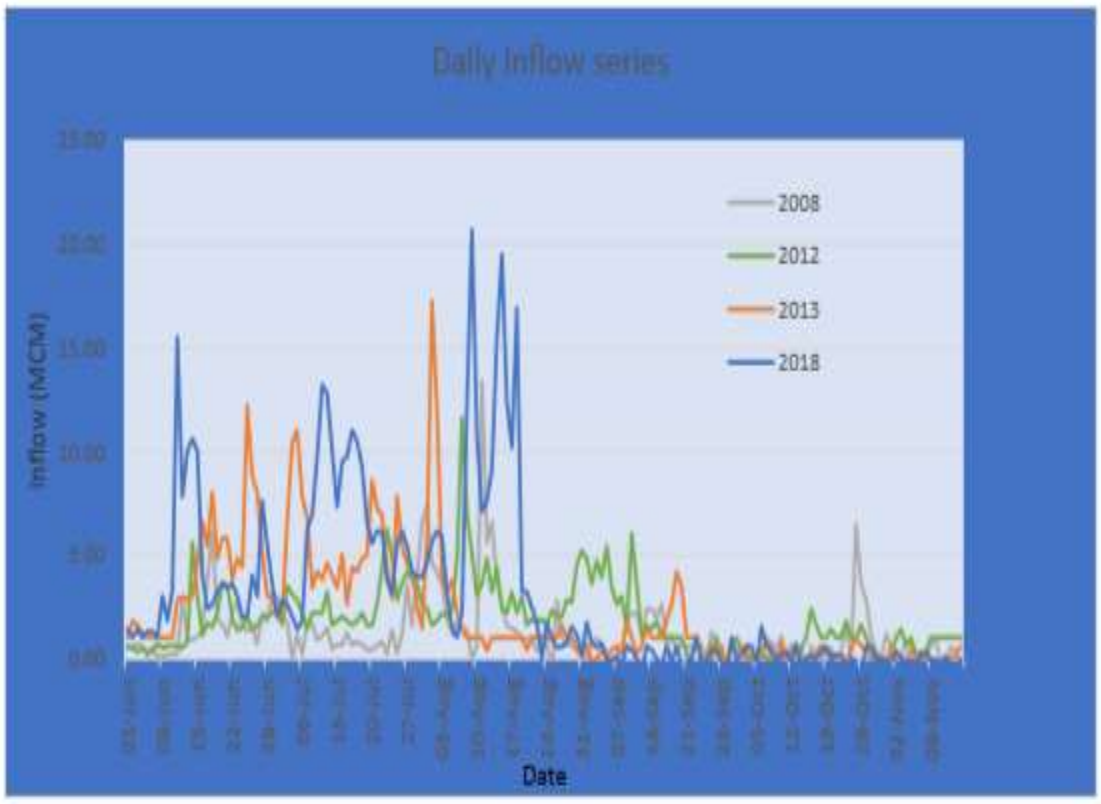


**Fig 2.23 Daily inflow series of various years**

The inflow series with 50% dependability is tabulated as below

| Time step | 50% dependable inflow (Mm3) |
|---|---|
| June 10th | 5.09 |
| June 20th | 20.99 |
| June 30th | 19.79 |
| July 10th | 23.89 |
| July 20th | 19.49 |
| July 31st | 41.32 |
| Aug 10th | 41.69 |
| Aug 20th | 30.89 |
| Aug 31st | 28.92 |
| Sep 10th | 39.09 |
| Sep 20th | 14.69 |

**Table 2.13 50% dependable 10-Daily Inflow series (Cumulative) ($Mm^3$)**

The following parameters are considered for fixing the rule levels:

1. MWL of reservoir – 775.60m
2. FRL of reservoir – 775.60m
3. Crest level of spillway - 767.00m
4. As there is no release power generation directly from Banasurasagar reservoir, lower rule curve is not developed.
5. The target date and level set for deriving upper rule levels are 20th September and 775.00 m, as decided.

From the storage corresponding to target level 775.00 m on September 20th, the storage at previous time steps are worked out for the inflow corresponding to 50% dependable inflow. From the rule levels corresponding to 50% dependable inflow as well as the peaks in the historical water levels, the intermediate upper rule levels are judiciously arrived.

| Date | Rule Storage in $Mm^3$ | Rule Level in m | 50% dependable inflow in $Mm^3$ | 50% dependable tunnel discharge in $Mm^3$ |
|---|---|---|---|---|
| June 10th | 26.20 | 755.43 | 5.090 | 10.29 |
| June 20th | 36.90 | 757.38 | 20.990 | 10.29 |
| June 30th | 46.40 | 758.99 | 19.790 | 10.29 |
| July 10th | 60.00 | 760.94 | 23.890 | 10.29 |
| July 20th | 69.20 | 762.22 | 19.490 | 10.29 |
| July 31st | 99.20 | 765.71 | 41.318 | 11.318 |
| Aug 10th | 130.60 | 768.82 | 41.690 | 10.29 |
| Aug 20th | 151.20 | 770.71 | 30.89 | 10.29 |
| Aug 31st | 168.80 | 772.23 | 28.918 | 11.318 |
| Sep 10th | 197.60 | 774.64 | 39.09 | 10.29 |
| Sep 20th | 202.00 | 775.00 | 14.690 | 10.29 |

**Table 2.14 Rule levels corresponding to 50% dependable inflow**

From the rule levels derived based on 50% dependable inflow, the upper rule levels for the period from June 1st to September 20th is judiciously arrived at by setting the target level in the reservoir on September 20th as 775.00m. The target level in the initial time step is taken as 767m (Crest Level of spillway -767m). Reservoir is allowed to rise upto FRL (ie. 775.60m) on Oct 20th. The storage corresponding to rule level and the flood space available at respective levels is shown in the table below.

| Time Step | Date | Upper Rule Levels in m | Rule storage in $Mm^3$ | Flood space upto FRL in $Mm^3$ | Percentage Gross Storage in % |
|---|---|---|---|---|---|
| 1 | June 10th | 767.00 | 112.00 | 97.25 | 53.5% |
| 2 | June 20th | 767.00 | 112.00 | 97.25 | 53.5% |
| 3 | June 30th | 768.00 | 121.60 | 87.65 | 58.1% |
| 4 | July 10th | 771.00 | 154.60 | 54.65 | 73.9% |
| 5 | July 20th | 773.50 | 183.60 | 25.65 | 87.7% |

| | | | | | |
|---|---|---|---|---|---|
| 6 | July 31st | 773.50 | 183.60 | 25.65 | 87.7% |
| 7 | Aug 10th | 774.00 | 189.90 | 19.35 | 90.8% |
| 8 | Aug 20th | 774.50 | 195.80 | 13.45 | 93.6% |
| 9 | Aug 31st | 774.50 | 195.80 | 13.45 | 93.6% |
| 10 | Sep 10th | 775.00 | 202.00 | 7.25 | 96.5% |
| 11 | Sep 20th | 775.00 | 202.00 | 7.25 | 96.5% |
| 12 | Sep 30th | 775.00 | 202.00 | 7.25 | 96.5% |
| 13 | Oct 10th | 775.00 | 202.00 | 7.25 | 96.5% |
| 14 | Oct 20th | 775.60 | 209.25 | 0.00 | 100.0% |
| 15 | Oct 31st | 775.60 | 209.25 | 0.00 | 100.0% |

**Table 2.15 Upper Rule levels**

Flood hydrograph with 100-year return period was routed through the reservoir with impinging level as 775.0 m, the rule level in the active monsoon period. It is found that the reservoir level is not encroaching the FRL after allowing a spill within the spillway capacity.

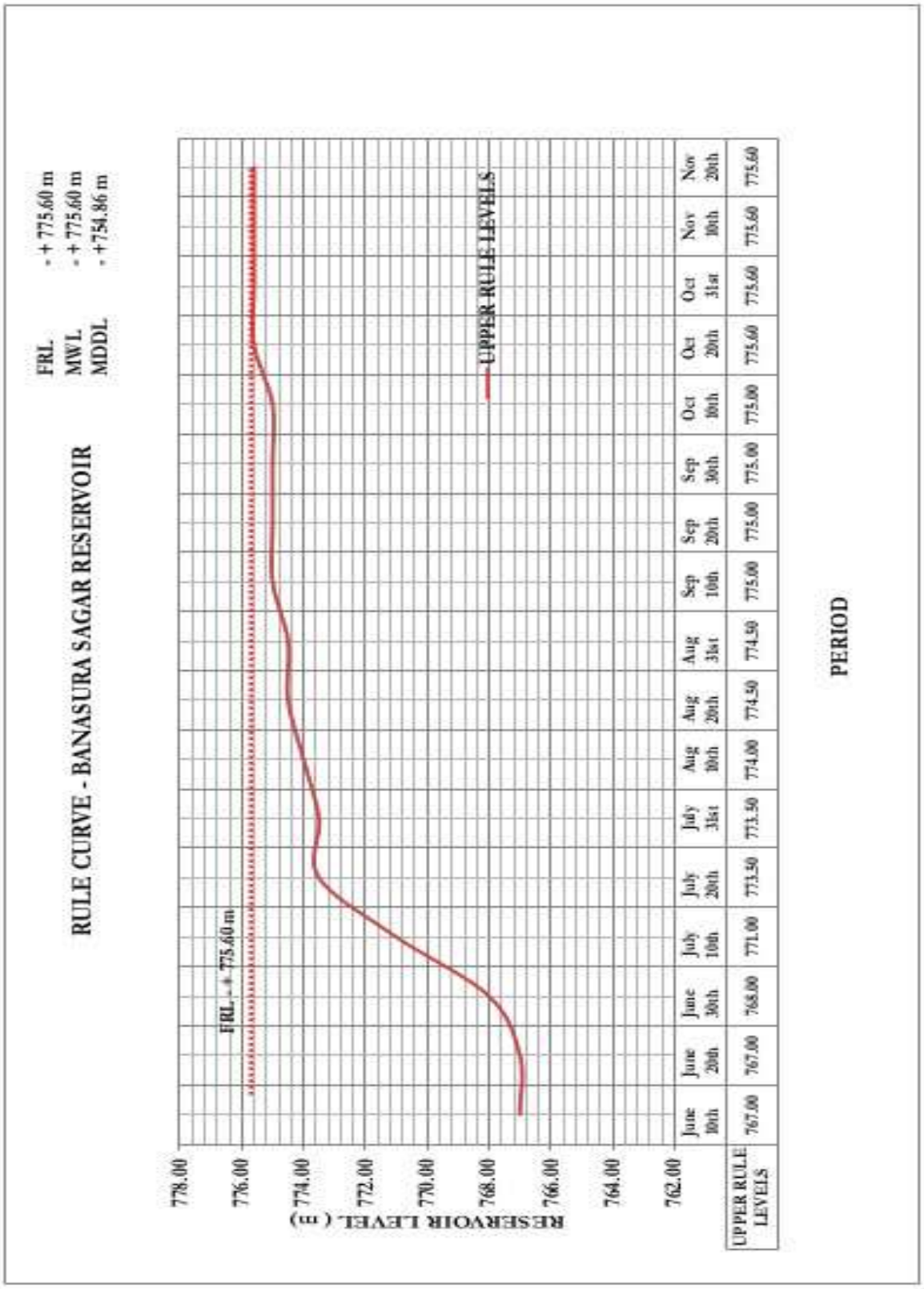


**Fig 2.24 Rule Curve**

### 2.4.4 Safety Aspects

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

### 2.4.5 Flood Release Procedure

The flood water is released through spillway gates based on the operation manual of gates and flood routing studies. There are four spillway gates. The sequence of operation of spillway gates is Gate no. 3,2,4,1. During the recession part of the inflow hydrograph, it may be necessary to close the crest gates in order to maintain the reservoir level at the rule curve elevation. In such a case, the closure of the gates should be done in the reverse order; the gate opened last being closed first, the entire operation being such that the difference between the adjacent gate openings never exceeds 0.3m.


**Fig 2.25 Spillway Radial Gates**

## 2.4.6 Reservoir Capacities

**Fig 2.26 Kuttiyadi Augmentation Reservoir**

The Gross storage of the reservoir 209.18 Million Cubic Meters and the Live Storage is 185.43 Million Cubic Meters at FRL of +775.60 m.

## 2.4.7 Inflow forecasting

The project was conceived based on the rainfall details from 1960-61 to 1974-75 and runoff details from 1960-61 to 1980-81 and working tables arrived. Average annual rainfall of the project is 6247mm and the average run off is 310 $Mm^3$.

Based on the recent flood, a flood forecasting method is proposed to be implemented. The gross storage of Kuttiyadi Augmentation Scheme at FRL+775.60 m is 209.18 $Mm^3$. The design flood of the scheme is 1275 $m^3/s$. The reservoir was fully impounded in 2006 and data is available from the year of impounding. During years of heavy monsoon incessant rains in the catchment area are likely to cause flood in the river. The floods may lead to problems like people getting displaced from their homes, huge damage to crops and other assets. The floods can have disastrous impact on the environment also. Adequate measures are required to be taken up in advance to control and regulate the flow of water in the river.

The following measures are essential for effective management of floods during monsoon.

1) Nomination of liaising officers for respective reservoirs.
2) Sharing of Sub-basin wise directory of concerned officers responsible for flood management.
3) Exchange of data regarding rainfall, releases from dams, reservoir water levels.
4) Reservoir operation schedules.

During monsoon, daily water releases from the Dams/Barrages at 8 hrs.& 16 hrs.in normal situation and hourly data exchange during heavy floods is necessary.

**Flood communication system**: The widely time tested communication to reach every corner of the flood affected zones have been radio and television and private media for the people to move to safer places by themselves in an emergency. Communication is very important in such occasions. These days due to revolution in the telecommunication system, networks of mobile phones are widely available. Mobile numbers of all officers and staff working in Dam operations wing, downstream dams in Karnataka, Revenue authorities, Local administration and District Disaster Management will be listed and made available to all. A satellite phone is provided at the dam site.

## 2.4.8Methodology of Flood Regulation

### 2.4.8.1 Inflow Computation

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

The rate of increase or decrease in storage can be determined from the observed rate of increase or decrease in reservoir level and the elevation capacity tables.

## 2.4.9 Summary of Flood Regulation Procedure

The flood regulation procedures at Kuttiyadi Augmentation Scheme can be summarized in the following 5 steps:

1. Observe the reservoir level at 1 hour interval.
2. Determine the total outflow occurring at all outlets
3. Estimate the inflow
4. Determine the gate opening of spillway dam as the case maybe.
5. Open the required number of gates of spillway dam to the extent required to maintain constant reservoir level ie. release is equal to the inflow.

## 2.4.10 Emergency Operation

The Emergency operation will be carried out following the Emergency Action Pan (EAP). The Emergency conditions are outlined in Chapter 4 under clause 4.2.1 on Immediate Maintenance. The EAP together with this Manual will be present at site at all times.

### 2.4.10.1 Emergency Action Plan

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

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

detailed EAP document of Kuttiyadi Augmentation Dams. Summary of Alert Conditions during Emergency are given in **Annexure** 8.

## 2.5 Diversion Tunnel

The diversion tunnel to Kuttiyadi reservoir is 4.763 km long. The tunnel is intended for diverting the water stored in the Banasurasagar reservoir to the Kuttiyadi reservoir for augmenting the power generation at the Kakkayam Generating stations. The gate arrangement to control the flow of water is provided at the rear end of Banasurasagar reservoir. The gate structure is provided in a control shaft.

Construction of the tunnel started on 15.07.1983. The driving of 4763 m was completed on 12.12.1986. Out of the total length of 4763 m, a length of 802 m is constructed as lined because sufficient rock cover was not available in this stretch. Over and above this, a length of 175.88 m was also lined for geological reasons.

## 2.6 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details are kept at the field office. Essential documents as per the dam safety guidelines are kept at the dam site office.

Following records of reservoir operations are being maintained:

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

# Chapter 3
# Project Inspection

An effective inspection program is essential to identify problems and to keep a dam in a good and healthy condition. Inspection details and suggestions are kept at field office and reports send to higher offices. The current practice of Inspection of dams envisages the Deputy Chief Engineer in presence of Executive Engineer at site to carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC. The Chief Engineer will review the inspection report and submit to CWC. The Executive Engineer at Site will conduct quarterly inspections and will prepare health reports as per KDSA. The format followed as per CWC is now revised during January 2018 and new guidelines issued vide Doc No. CDSO_GUD_DS_07_ v1.0, CWC 2018 for Safety Inspection of Dams. Now since the health reports are to be uploaded in DHARMA, the inspection reports are prepared in the new format incorporated in DHARMA. Detailed description on project inspections is available in the Guideline for Safety Inspection of dams. However an overview of the various types of inspections to be carried out is given below. Note that for uploading Inspection Data into DHARMA, the Inspection Instructions & Forms given in the above mentioned Guideline for Safety Inspection of Dams must be used. This Chapter provides guidance on carrying out other inspections.

## 3.1 Types of inspections

Four different types of dam safety inspections are available for being carried out in Dams. These include, but not limited, to the following:

1. Comprehensive evaluation inspections
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 dam and State DSO regulations etc.

Typical inspection elements and the detail of the safety inspections are provided below. More detailed descriptions are given in the "Guideline for Safety Inspection of

Dams" (CWC 2018). A comprehensive health checklist for recording the status of each item being inspected and the overall condition of the equipment along with any consequential risks on the health of the dam is also to be maintained.

## 3.2 Comprehensive Evaluation Inspections

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

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

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

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

### 3.2.1 Details to be provided to DSRP before inspection.

The report of the latest DSRP inspection conducted at Kuttiyadi Augmentation Scheme is included as **Annexure 4**.

**General information and Scope of the Project**

General information of the project, Salient features, and issues related to dam, Emergency preparedness, Details of key personnel, Hydrology Original and reviewed, Geology, Special problems if any at site and their treatment, Drawings, Reservoir operation and regulation plan are to be handed over in detail.

**Basic data and Issues related to safety of dam**

The basic data and salient features are elaborated in **Chapter 2**.

**Problems if any during construction**

Special problems and treatments done if any are to be brought to the notice of DSRP.

**Drawings**

Drawings of dams and appurtenant structures etc. are available at the field office for reference.

**Seismicity**

Seismic zone of the scheme area at the time of design was II and the revised seismic zone is now III of the seismic zone map of India. The maximum intensity to be expected at the Dam site has ranged from 5 to 7on M.M. Scale. The Dam is required to be safe using the appropriate seismic coefficients in the BIS code and as approved by NCSDP. Historical significant earthquake events in the near vicinity are as under.

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

**Construction History**

Construction history is briefed in **Chapter 1**.

**Geological Report**

Geological report of the dam site is given in **Annexure 5.**

**First filling of the Reservoir**

Kuttiyadi Augmentation Scheme was dedicated to nation on 16.12.2005. Since land acquisition above FRL was not completed, the reservoir was only impounded up to +772.00 m for the utilization of the project, instead of the FRL at +775.60 m at that time and the reservoir was fully impounded in 2006.

**Field Inspection- Observation & recommendation regarding Remedial Measures**

Based on the field inspection, remedial measures recommended by the DSRP are to be undertaken.

## 3.3 Scheduled Inspections

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

The purpose of scheduled inspections is to keep the dam and its appurtenant structures in good operating condition and to maintain a safe structure. As such, these inspections and timely maintenance will minimize long-term costs and will extend the life of the dam. Scheduled inspections are performed more frequently than comprehensive evaluation inspections to detect at an early stage any development that may be detrimental to the dam. These inspections involve assessing operational capability as well as structural stability and detection of any problem and to correct them before the conditions worsen. The field examinations should be made by the personnel assigned responsibility for monitoring the safety of the dam. If the dam or appurtenant works have instrumentation, the individual responsible for monitoring should analyze measurements as they are received

and include an evaluation of that data. Dam Inspection Report or an inspection brief should be prepared following the field visit (Dam Inspection Report is recommended).

Scheduled inspections include the following components as a minimum:

- Review of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required
- Visual inspection of the dam and its appurtenant works
- Preparation of a report or inspection brief, with relevant documentation and photographs.

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

Detailed checklists are required to ensure the health of the dam and to ensure that it continues to operate in satisfactory and safe condition. The proforma to be used for inspection should be the one enclosed in the Doc. No. CDSO.GUD.DS07 v 1.0, CWC 2018 on the Guide lines for Safety Inspection of Dams **(Annexure 3)**.

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

## 3.4 Special (Unscheduled) Inspections

Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections are not regularly

scheduled activities, but are usually made before or immediately after the dam or appurtenant works have been subjected to unusual events or conditions, such as an unusually high flood or a significant earthquake. These inspections are to be carried out by teams to be constituted by State DSO after an initial assessment based on informal inspection carried out by project personnel reveal dam safety related concerns like cracking in the dam, damages, erosion/ scour, undermining/ piping/ sink holes/ liquefaction or any such undesirable feature. A special inspection may also be performed during an emergency, such as an impending dam breach, to evaluate specific areas or concerns. They are also made when the ongoing surveillance program identifies a condition or a trend that appears to warrant a special evaluation. Special inspections should focus on those dam components that are affected by the unusual event and should include at least three elements:

1) Review of relevant files or data
2) Visual inspection
3) Report preparation.

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

## 3.5 Informal Inspections

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

Operators, maintenance crews, or other staff who are posted at dam site conduct informal inspections. 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 in walking over the dam, 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 occasion

presents itself, or they may cover the entire dam and its appurtenant structures. 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 etc.

# Chapter 4

# Project Maintenance

A good maintenance program is required to protect a dam against deterioration, to prolong its life and 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 and litigation.

## 4.1 Maintenance Plan

A basic maintenance schedule for the various monitoring components based on frequent inspections, priority, and interval is attached as **Annexure 6**. This shows the tasks to be performed and how frequently that is to be inspected/observed and repaired.

## 4.2 Maintenance Priorities

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

### 4.2.1 Immediate Maintenance

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

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

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

### 4.2.2 Preventive Maintenance

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

#### 4.2.2.1 Condition Based Maintenance

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

- Remove all vegetation and bushes from the dam and restoring any eroded areas.
- Repair of defective gates, valves, and other hydro-mechanical equipment.
- Repair any concrete or metal components that have deteriorated.
- Repair any damages on spillway glacis, piers, energy dissipaters, training/divide walls, downstream areas etc.
- Cleaning of the choked drainage holes in the dam body/ foundations in dams.
- Repair any damages on upstream and downstream areas.
- Controlling any heavy seepage in the foundation/ inspection galleries in Concrete dam from drainage holes.
- Repairs of any cracks/cavities/joints in dams/structures.

  However many of these works will require the services of experienced engineers/expert panels.

#### 4.2.2.2 Routine Maintenance

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

- Observation of any springs or seepage areas, comparing quantity and quality (clarity) with prior observations.
- Monitoring of downstream development which could have an impact on the dam and its hazard category.
- Maintenance of Electrical and Hydro-Mechanic equipment and systems eg. Servicing of spillway gates, hoisting arrangements, and gates/hoist of outlet works and standby generator.

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

## 4.3 Maintenance items

The O&M Manual includes detailed instructions and schedules for performing periodic maintenance works at the site. This includes maintenance of the dam, the appurtenant works, and the reservoir areas. Methodology / Specifications for carrying out maintenance works of general & recurring nature should be included in the Manual. Dam repairs are scheduled based on severity of the problem, available resources, and weather conditions. For example, if a severe settlement problem (more than envisaged in designs) or cracking is detected on the crest of the dam, it should have a high priority since further degradation could lead to dam breaching. The causes of all major issues / problems should be identified and evaluated by experienced engineers/ Expert Panels so that appropriate remedial measures can be finalized. Correcting minor rill erosion on the downstream slope could be assigned a low priority since it is not a dam safety concern. This type of repair will also be weather dependent, since grass can only be planted during specific times of the year, and the embankment should be dry so that more damage is not inflicted to the embankment slopes.

### 4.3.1 Earthwork

The surfaces of an earthen dam may deteriorate due to several reasons. For example, wave action may cut into the upstream slope, vehicles may cause ruts in the crest or slopes,

trails left by livestock can result in erosion, or runoff waters may leave erosion gullies on the downstream slope. Other special problems, such as shrinkage cracks or rodent damage, may also occur. Damage of this nature must be repaired constantly.

The maintenance procedures described here are effective in repairing minor earthwork problems. However, this section is not intended to be a technical guide, and the methods discussed should not be used to solve serious problems. Conditions such as embankment slides, structural cracking, and sinkholes threaten the immediate safety of a dam and require immediate repair under the directions of experienced engineers/Expert panels.

The material selected for repairing embankments should be free from vegetation, organic materials, trash, and large rocks.

If flow-resistant portions of an embankment are being repaired, materials that are high in clay or silt content should be used. If the area is to be free draining or highly permeable (such as pervious shell of an embankment dam) the material should have a higher percentage of sand and gravel. It is usually satisfactory to replace or repair damaged areas with soils like those originally in place.

An important soil property affecting compaction is moisture content. Soils that are too dry or too wet do not compact well. One may test repair material by squeezing it into a tight ball. If the sample keeps its shape without cracking and falling apart (which means it is too dry), and without depositing excess water onto the hand (which means it is too wet), the moisture content is near the proper level.

Before placement of earth, the repair area needs to be prepared by removing all inappropriate material. All vegetation, such as bushes, roots, and tree stumps, along with any large rocks or trash need to be removed. Also, unsuitable earth, such as organic or loose soils, should be removed, so that the work surface consists of exposed, firm, clean embankment material.

Following clean up, shape and dress the affected area so that the new fill can be compacted to the level specified in the technical specifications. Also it should properly key with the existing fill. Further trim the slopes and roughen the surfaces by scarifying or plowing to improve the bond between the new and existing fill and to provide a good base to compact against.

Place soils in loose layers up to 20 centimeters thick and compact manually or mechanically to form a dense mass free from large rock or organic material. Keep soil moisture in the proper range. The fill should be watered and mixed to the proper wetness and allowed to dry if too wet.

Erosion is one of the most common maintenance problems at embankment structures. Erosion is a natural process and its continuous forces will eventually wear down almost any surface or structure. Periodic and prompt maintenance is essential to prevent continuous deterioration and possible failure.

Turfing, free from weeds and bushes, is an effective means of preventing erosion.

Rills and gullies should be filled with suitable soil, compacted, and then seeded for growing the turfing. Erosion in large gullies can be slowed by stacking bales of hay or straw across the gully until permanent repairs can be made.

Paths due to pedestrian, livestock, or vehicular traffic (two and four-wheeled) are a problem on many embankments. If a path has become established, vegetation will not provide adequate protection and more durable cover will be required unless traffic is eliminated. Stones may be used effectively to cover such footpaths.

In addition, steps can be provided/ constructed at regular intervals along the length of the dam for going from downstream toe to the dam top. All vehicular traffic, except for maintenance, should be restricted from the dam.

Erosion is also common at the point where an embankment and the concrete walls of a spillway or other structure meet. Poor compaction adjacent to such walls during

construction and later settlement can result in an area along the wall that is lower than the grade of the embankment.

Runoff, therefore, often concentrates along these structures, resulting in erosion. People also often walk along these walls, wearing down the vegetative cover. Workable solution include re-grading the area so that it slopes away from the wall, adding more resistant surface protection, or constructing steps.

### 4.3.2 Upstream riprap

The upstream face is protected against wave erosion. Rip-rap is provided for the purpose with filter layers below.

Nonetheless, erosion can still occur in existing riprap. Water running down the slope under the riprap can erode the finer filter materials under the riprap and soils leaving voids and loss of grade. Wave run up will also undermine the filter layer especially along the full reservoir level and over time wash out finer material. This can be checked through observance of linear embankment settlement. Sections of riprap that have slumped downward are often signs of this kind of erosion.

When erosion occurs on the upstream slope of a dam, repairs should be made as soon as possible. (Refer IS: 8237- Code of practice for protection of Slopes for Reservoir Embankments).

**Fig 4.1 Upstream rip rap**

### 4.3.3 Controlling vegetation

Keep the entire dam clear of unwanted vegetation such as bushes or trees. Excessive growth may cause several problems:

- It can obscure the surface of an embankment and not allow proper inspection of the dam.
- Large trees can be uprooted by high wind or erosion and leave large voids that can lead to breaching of the dam.
- Some root systems can decay and rot, creating passageways for water, leading to piping erosion.
- Growing root systems can lift concrete slabs or structures.
- Rodent habitats can develop undetected.

All bushes/trees should be as far as possible removed by roots. The resulting holes should be filled with well compacted earth. It would be desirable to remove the plants/vegetation at their early stage to prevent their growing into big tree/bushes. In cases where trees and bushes cannot be removed, the root systems should be treated with herbicide (properly selected and applied) to retard further growth. Concerned Government

Agencies should be consulted for selection of appropriate herbicides & their use for control of vegetation on dam structures.

Further, it is desirable that there are no trees or bushes within 500 m of the toe drain on the downstream side of the dam.

### 4.3.4 Controlling animal damage

Livestock should not be allowed to graze on an embankment surface. Livestock are not allowed to graze on the embankment section of the dam. When soil is wet, livestock can damage vegetation and disrupt the uniformity of the surface. Moreover, livestock tend to walk in established paths and thus can promote erosion. Such paths should be re-graded and seeded, and the livestock permanently fenced out of the area.

The burrows and tunnels of burrowing animals (beaver, muskrat, groundhogs and others) should be filled by mud packing. The method involves placing vent pipe in a vertical position over the entrance of the den. Making sure that the pipe connection to the den does not leak, the mud-pack mixture is poured into the pipe until the burrow and pipe are filled with the soil-water mixture. The pipe is removed and more dry earth is tamped into the entrance. The mud pack is generally made by adding water to 90% earth & 10% cement mixture until a slurry or thin cement consistency is attained. For bigger holes, bentonite coated stones can also be used. All entrances should be plugged with well compacted earth & vegetation reestablished. Dens should be eliminated without delay. Different repair measures are necessary if a dam has been damaged by extensive small rodent tunnelling or large rodent activity. Excavate the area around the entrance and then backfill it with impervious material. This plugs the passage entrance so that water is prevented from saturating the dam‘s interior.

### 4.3.5 Controlling ants and termites (white ants)

Ants and termites if left undisturbed can build mounds that can become quite large. Frequent mowing can induce the colonies to migrate to neighbouring, undisturbed areas. Use only pesticides labelled as suitable for the location you want to treat. Make every effort to avoid contaminating water with pesticide.

### 4.3.6 Controlling damage from vehicular traffic

Vehicles, except for maintenance, should be restricted on the dam top and kept out by fences or barricades. Any ruts should be repaired as soon as possible. In the case of existing dams having permission for movement of nearby villagers, heavy traffic movement may be avoided. If possible, separate connectivity may be explored for such cases. In the case of barrages and dams having provisions for roads of National/State Highways etc., all efforts should be made to restrict the speed of vehicles. Regular maintenance of bridges and roads shall be mandatory.

### 4.3.7 Masonry/ concrete dams and spillways

Various issues/problems that may need maintenance /repairs in Concrete/Masonry dams & Spillways may include but are not limited to:

- Cracking in concrete (potential causes are alkali – aggregate reaction, thermal stresses because of heat of hydration or temperature variations, foundation problems).
- Damages on spillway glacis, spillway piers, training/divide walls, energy dissipaters, downstream areas (probable causes are cavitations, abrasion, unsymmetrical flows, unfavourable downstream conditions)
- Vegetation growth in unattended Auxiliary spillways, spill channel, approach channel etc.
- Seepage in Galleries and on d/s face of the dam.
- Cleaning and removal of leached deposits from choked drainage holes in the dam body/foundations.
- Repair to upstream face of masonry dams in case the pointing is damaged, leading to increased seepage.
- To ensure proper access & lighting in galleries.
- To ensure that the dam is behaving as designed based on instrumentation programs.
- Periodic maintenance should be performed of all concrete surfaces to repair deteriorated areas. Repair deteriorated concrete at the earliest; it is most easily repaired in its initial stages. Deterioration can accelerate and, if left unattended, can result in serious problems or dam failure. (For remedial measures of problems of special nature advice of experienced engineers/ Panel of Experts needs to be obtained)

### 4.3.8 Outlet works

Outlet conduits should be inspected thoroughly once a year. Circular conduits that are one and a half meter or more in diameter can be entered and visually inspected. Common problems are improper alignment (sagging), separation and displacement at joints, cracks, leaks, surface wear, loss of protective coatings, corrosion, and blockage. Problems with conduits occur most often at the joints. Further collars at joints used to also lead to inadequate compaction. Hence, special attention should be given to them during the inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause leakage of water into the embankment during pressure flow. The outlet should be checked for signs of water seeping along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

Listed below are common concerns regarding repairs to outlet works:

- Asphalt mastic is not recommended for other than temporary repairs. Asphalt mastic used as joint filler becomes hard and brittle, is easily eroded, and as per literature survey it may provide a satisfactory seal for only about five years. Mastic should not be used if the conduit is expected to flow under pressure.
- The instructions on the label should be followed when using thermosetting plastics (epoxy). Most of these products must be applied to a clean and dry surface to set up an effective bond. However cementations materials are to be preferred in view of their UV resistance & longer life.
- Material used as joint filler should be impervious to water and should be flexible throughout the range of expected air and water temperatures.
- The internal surfaces of the conduit should be made as smooth as possible when repairs are made so that high-velocity flow will not damage the repair material.
- Minor cracks in concrete are not considered a dangerous problem. Repair is not necessary unless the cracks widen or leak.

The general practice now is not to go in for pre-cast concrete/MS pipe conduits with collars but to construct RCC conduits at site without any collars and joints. PVC water stops are provided at joints and the exterior collars but to construct RCC conduits at site

without any collars and joints. PVC water stops are provided at joints and the exterior faces of the conduits are given a slope to enable better contact at the interface with earth.

### 4.3.9 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 or reduce their discharging capacity. The head losses through clogged trash racks also increase.

Maintenance of trash racks includes periodic inspections for rusted and broken sections and repairs are made as needed. Trash racks should be checked during and after floods to ensure that they are functioning properly and to remove accumulated debris.

### 4.3.10 Spillway Radial Gates & Hoisting Equipment

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

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

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

i) The gate slot and bottom platform/sill beam should be cleaned periodically. Scales formed over the embedded parts should be removed. Second-stage

concrete should be checked for any development of cracks / leakages and repairs should be attended to immediately.

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

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

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

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

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

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

viii) 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.

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

x) All nuts and bolts shall be tightened.

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

**a) Rubber Seals:**

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

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

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

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

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

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

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

**c) Gate structures:**

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

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

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

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

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

**d) Embedded Parts:**

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

ii) The guide roller pins shall be lubricated.

**e) General Maintenance:**

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

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

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

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

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

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

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

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

viii) Wire ropes should be properly lubricated.

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

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

xi) Flexible couplings should be adjusted if required.

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

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

xiv) The list of essential spare parts to be kept available should be reviewed and updated periodically. The condition of spares should be checked periodically and protective coating given for use.

### 4.3.10.1 Maintenance of Electrically operated fixed hoists

**i) General Instructions:**

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

**ii) Inspection and Maintenance**

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

i. Entrance to all hoist platforms shall be kept locked. All keys shall remain with the shift supervisor.
ii. A cursory daily inspection shall be made of hoist and gate to ensure that there is no unusual happening.
iii. Clean all hoisting equipment and hoist platform.
iv. Check oil level in gearboxes and replenish as and when required with oil of proper grade.
v. Apply grease of suitable grade by grease gun.
vi. Lubricate all bearings, bushings, pins, linkages etc.
vii. Check all the fuses on the power lines.
viii. All bolts and nuts on gear boxes, hoist drum and shaft couplings should be checked for tightness.
ix. Check the supply voltage.
x. Drain sample gear oil from each of the gear boxes. If excessive foreign particles or sludge is found, the gear box shall be drained, flushed and filled with new oil.
xi. All the geared couplings shall be greased.
xii. Raise and lower the gate by hoist motor and check for smooth, and trouble free operation of gate without excessive vibration.
xiii. Observe current drawn by motor at the time of lifting and check if it is more than normal. If so, stop the hoist and investigate the cause and rectify.
xiv. Check the condition of painting of various components and remove rust wherever noticed and repaint the portion after proper cleaning as per painting schedule.

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

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

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

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

xviii. Check the overload relays for proper functioning.

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

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

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

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

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

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

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

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

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

### 4.3.10.2 Maintenance of Electrical components of Fixed Rope Drum Hoists:

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

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

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

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

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

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

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

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

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

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

xi) Do not lubricate the contacts.

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

xii) Examine earth connections and motor leads.

xiii) Examine motor windings for overheating

xiv) Examine control equipment

xv) Examine starting equipment for burnt contacts

xvi) Check and tighten all nuts and bolts

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

xviii) Lubricate the bearings

xix) Overhaul the controllers

xx) Inspect and clean circuit breakers

xxi) Wipe brush holders and check bedding of brushes.

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

xxiii) Check the insulation resistance of the motor between any terminal and the frame. If the measured resistance is less than the prescribed value, then steps shall be taken to dry- out the motors either by passing a low voltage current through the windings or by placing the stator and rotor only in a warm dry place for a day or so.

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

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

xxv) Over haul the motor, if required.

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

xxvii) Check resistance or earth connections.

xxviii)Check air gap.

**b) Solenoid Operated Brakes**

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

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

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

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

v) Examine all electrical leads and connections.

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

vii) The pins should be tightened.

### 4.3.10.3 Lifting beam and gantry for outlet works

**a) Lifting beam**

Lifting beam shall be used for both raising & lowering of Emergency gate with the use of Gantry. Lifting Beam shall mainly comprise of two number structural steel channels or fabricated channels with back to back connection to make it a single fabricated structural frame.

Two side guide rollers/shoes shall be provided on each side of the lifting beam. The depth of lifting beam/frame should be sufficient to accommodate to rollers on each side located at sufficient distance from one another to enable proper guided movement. The depth of lifting beam shall not be less than one tenth of the length/span of the lifting beam

or 500 mm whichever is more. Lifting beam hook mechanism shall provide for automatic engagement and release of the equipment to be handled manually by movement of the hook block. The two hooks shall be mechanically linked together for simultaneous operation. All rotating parts of the lifting beam shall be provided with corrosion resistant steel pins and aluminium bronze bushing/roller bearings. All nuts, bolts and washers and retaining devices for pins shall be of corrosion resistant steel.

Following issues need to be considered and attended during maintenance;

i) Bush bearing of lifting attachment and various pulleys etc. should be properly lubricated.

ii) Whenever it is felt that friction in the bearing has increased, these should be taken out for cleaning and lubrication and should be refitted properly. These should be replaced, if found beyond repair.

**b) Gantry**

The major component parts of the gantry comprise of the following: Frame ladders and railings, wire rope, rope drum, gears and pinions, reduction gear box, shafts for gears and pinions, sheaves and pulleys, bearings, flexible couplings, lifting hook and block, sockets for wire ropes, gear box covers, keys & key ways, counter weight, wrenches and tools, electrical equipment, electric motor, master control equipment, cables and cable reel, wiring ,limit switches, miscellaneous components etc.

Following aspects need to be considered and attended to during maintenance;

- The insulation resistance of motor winding. In case it is found to have dropped below a prescribed value, the motor should be dried prior to putting back in service. If weak insulation becomes a regular feature, the winding should be given a good coat of insulating varnish after the motor has been dried.
- Checking of all the electrical connections.
- Lubrication of each part of crane
- Removal of any loose/foreign material along the rail track
- Actuating tests of limit switches
- Actuating tests of brakes.

- All fuses in the control panel should be checked and if necessary it should be replaced.
- Necessary terminal connections of motors, brakes etc. is to be checked.
- Overload relay should be checked.
- Visual inspection of wire ropes for any snapped loose wire and its proper lubrication.
- Checking of rope clamps on the drum and tightening of bolts if required.
- Gearbox assembly should not have any leakage of oil.
- Unusual noise/vibration if any should be checked and rectified before operation.

### 4.3.10.4 Surface preparation and painting of HM works

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

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

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

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

- Machine finished or similar surface

- Surfaces which will be in contact with concrete
- Stainless steel overlay surfaces.
- Surfaces in sliding or rolling contact
- Galvanized surfaces, brass and bronze surfaces.
- Aluminium alloy surfaces

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

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

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

a) Embedded parts

- The prescribed primer shall be applied as soon as the surface preparation is complete and prior to the development of surface rusting and within the specified time prescribed by Indian Standards or the Paint Manufacturer. In case there is lapse of considerable time beyond the prescribed time limit, the surfaces shall be again cleaned prior to priming.
- Two coats of zinc rich primer with epoxy resin shall be applied to all embedded parts surfaces which are not in contact with concrete and shall remain exposed to atmosphere or submerged in water to obtain a dry film thickness of 75 microns.
- This shall be followed by three coats at an interval of 24hours of coal-tar blend epoxy resin so as to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall not be less than 300 microns.

b) Gates

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

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

v) Hoist and supporting structure

a) Structural component

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

b) Machinery:

Except machined surfaces all surfaces of machinery including gearing, housing, shafting, bearing pedestals etc., shall be given: Primer coats: One coat of zinc phosphate primer paint to give minimum film thickness of 50 microns. Motors and other bought out items shall be painted if necessary. Finished coats: The finished paint shall consists of three coats of aluminum paint confirming to IS: 2339 – 1963 or synthetic enamel paint confirming to IS: 2932 – 1977 to give a dry film thickness of 25±5 microns per coat to obtain a total minimum dry film thickness of 125 microns.

c) Machined surfaces

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

vi) Application of paint

Mix the contents thoroughly as directed by paint manufacturer before and during use. Painting at shop can be done by any of the three methods namely Brush/roller, Conventional spray, Airless spray etc. The paint can be made to suit the adopted method. But once the gate and equipment is in erected position the general method adopted is only brush / roller. In case of spray lot of precautions are to be taken. For More details: Refer IS: 14177 Part (II) – 1971.

Appendix A – Brushing of paint

Appendix B – Spraying of paint

Appendix C – Spray painting defects: Causes and remedies.

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

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

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

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

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

a) Wire brushing, Scraping, and chipping. Sand papering or cleaning with steel wool or abrasive paper
b) Power tool cleaning
c) Flame cleaning
d) Sand blasting or shot blasting and
e) Chemical rust removal.

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

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

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

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

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

**a)** General

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

c) Inspection of surfaces prior to painting - Inspection methods will depend on whether it is to be painted for the first time or is to be repainted.

**b)** New Works (not previously painted).

The following shall be decided by inspection:

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

**c)** Old Work (which requires repainting)

The following shall be decided by inspection:

- Whether the entire existing paint requires removal; and/or
- Whether repainting without paint removal would be adequate.

### 4.3.11 Electrical system

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

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

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

### 4.3.12 Maintenance of Metal Components of Gates

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

### 4.3.13 Access Roads

For a dam to be operated and maintained, there must be a safe means of access to it at all times. Access road surfaces must be maintained to allow safe passage of automobiles and any required equipment for servicing the dam in any weather conditions. Routine observations of any cut and fill slopes along the sides of the road should be made. If unstable conditions develop assistance of experienced Engineers/Expert Panels should be

obtained and remedial measures initiated. Drains are required to be provided and maintained along roads to remove surface and subsurface drainage. This will prolong the life of the road and help reduce deterioration from rutting. Road surfacing should be repaired or replaced as necessary to maintain the required traffic loadings. In most cases, specialized contractors will be required to perform this maintenance.

### 4.3.14 General Cleaning

As already suggested, for proper operation of spillways, sluiceways, approach channels, inlet and outlet structures, stilling basin / energy dissipation arrangements, discharge conduit, dam slopes, trash racks, debris control devices etc., regular and thorough cleaning and removal of debris is necessary. Cleaning is especially important after large floods, which tend to send more debris into the reservoir. The dam top road and the gallery are to be cleaned regularly.

## 4.4 Materials and Establishment Requirements during Monsoon

Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked in adequate quantities for emergency situations that may arise. At Dam, round the clock patrol is to be carried out during monsoon period. At the same time the man power requirements during monsoon period are to be enhanced. An Organisation Structure of the Control Unit is given in **Chapter 1**.

The materials normally required to be stocked in sufficient quantity are:-

- 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 the Dam should essentially include but not be limited to the following items:

i) Establishment Cost of Regular Staff – Salaries and allowances, Bonus, Medical Reimbursement, LTC, Leave Encashment, Pension benefits etc. (As applicable)

ii) Establishment Cost of Work charged – Salaries and allowances, Bonus, Medical Reimbursement, LTC, Leave Encashment, Pension benefits, TA and DA etc. ( As applicable)

iii) Establishment Cost of Daily Wage Staff – Salaries and allowances, TA and DA etc. ( As applicable)

iv) Office Expenses – Rent for Office, Telephone/Mobile/ any other Telecommunication bills, Electricity bills, Water bills, Office stationery Day to day office requirements

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

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

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

viii) Works-Painting, oiling, greasing, overhauling of HM equipment's, Repair/replacement of gates seals & wire ropes, POL for pumps & generator sets, Electricity charges and maintenance of Electric systems of dam site, specific requirements for all Civil, H.M & Electrical maintenance works, Vegetation removal, maintenance/cleaning of drains in dam, maintenance of lift/elevators in dam (as applicable), maintenance of access roads & basic facilities, provision for flood contingency works during monsoon, unforeseen events/items (about 10% of the cost of works) etc.

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

| SL. NO. | BUDGET ITEM | PREVIOUS YEAR COST (Rs) | CURRENT YEAR BUDGET (YR _____) (Rs) | REMARKS |
|---|---|---|---|---|
| **A. ESTABLISHMENT** | | | | |
| 1 | SALARY OF REGULAR STAFF INCLUDING ALL OTHER BENEFITS | | | |
| 2 | TRAVEL EXPENSES | | | |
| 3 | OFFICE EXPENSES | | | |
| 4 | MOTOR VEHICLE EXPENSES | | | |
| 5 | MAINTENANCE OF OFFICE & COLONY COMPLEX | | | |
| | SUB-TOTAL - A | | | |
| **B. WORKS** | | | | |
| **1** | **CIVIL WORKS** | | | |
| 1.1 | CONCRETE / MASONRY DAM | | | |
| 1.2 | SLUICES IN CONCRETE / MASONRY DAMS | | | |
| 1.3 | APPROACH / INSPECTION ROADS WITHIN DAM AREA | | | |
| **2** | **HYDRO-MECHANICAL** | | | |
| 2.1 | SPILLWAY GATES & HOISTS | | | |
| 2.2 | SLUICES IN CONCRETE / MASONRY DAMS – SERVICE / EMERGENCY GATES & HOISTS | | | |
| **3** | **ELECTRICAL** | | | |
| 3.1 | ELECTRICAL FITTINGS, MOTORS, CONTROLS FOR ALL GATE HOISTS | | | |
| 3.2 | POWER SUPPLY LINES | | | |
| 3.3 | ELECTRICAL FITTINGS ON DAM TOP, DAM GALLERIES, ETC | | | |
| 3.4 | STANDBY POWER / DIESEL GENERATOR | | | |
| 3.5 | REMOTE CONTROL/CCTV | | | |
| **4** | **INSTRUMENTATION** | | | |
| **5** | **MISCELLANEOUS WORKS** | | | |
| **6** | **SALARY OF WORK- CHARGED STAFF INCLUDING ALL BENEFITS** | | | |

| | | | | |
|---|---|---|---|---|
| 7 | **MATERIALS TO BE STORED BEFORE MONSOON** | | | |
| | **SUB-TOTAL - B** | | | |
| 8 | **CONTINGENCY (10%) ON SUB-TOTAL OF A & B** | | | |
| 9 | **TOOLS & PLANTS** | | | |
| | **SUB-TOTAL- C** | | | |
| 10 | **TOTAL ANNUAL COST** | | | |

**Table 4.1 Summary Table for Annual O & M Budget**

## 4.6 Maintenance Records

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

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

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

# Chapter 5
# Instrumentation and Monitoring

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

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

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

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

- weather and precipitation data
- stress and strains

## 5.1A Instrument Types and Usage in Kuttiyadi Spillway Dam

The instruments installed in Spillway Dam are appended below.

| LIST OF INSTRUMENTS INSTALLED IN SPILLWAY DAM | | | |
|---|---|---|---|
| **Sl. No.** | **Name of Instruments** | **Total No. installed Functioning** | **Location** |
| 1 | Pressure Gauge | 3 | Gallery |
| 2 | V notch | 1 | Gallery |

**Table 5.1 Instrumentation present status in Spillway Dam**

### 5.1.1A Parameters monitored

#### 5.1.1.1A Uplift Pressure

Pressure gauges are installed in the gallery for measuring uplift pressure**.** Readings are taken monthly

#### 5.1.1.2A Water Level

Water level gauge is provided in the spillway dam. Daily water levels are taken. During monsoon, three hourly readings and during spill, hourly readings are taken and recorded.

#### 5.1.1.3A Seepage Flow

Seepage is measured with V notch installed in the gallery. Readings are taken monthly.

**Seepage assessment**

In Spillway Dam, seepage is measured using V-notch fitted in the gallery. Seepage details for the years 2017 and 2018 are tabulated below.

| Date | Reservoir level in m | V-notch reading in cm | Discharge in lit/sec |
|---|---|---|---|
| 04-01-2017 | 770.5 | 6.0 | 0.644 |
| 07-02-2017 | 768.15 | 3.0 | 0.114 |
| 01-03-2017 | 766.8 | 3.0 | 0.114 |
| 06-04-2017 | 762.75 | 2.5 | 0.072 |
| 03-05-2017 | 769.2 | 2.5 | 0.072 |
| 08-06-2017 | 755.75 | Nil | Nil |
| 10-07-2017 | 761.8 | Nil | Nil |
| 18-08-2017 | 769 | 3.0 | 0.114 |
| 27-09-2017 | 774.85 | 3.0 | 0.114 |
| 31-10-2017 | 772.5 | 2.0 | 0.041 |
| 30-11-2017 | 770.8 | 3.0 | 0.114 |
| 06-01-2018 | 768.4 | 4.0 | 0.234 |
| 20-02-2018 | 766.2 | 3.0 | 0.114 |
| 06-03-2018 | 764.75 | 2.0 | 0.041 |
| 01-08-2018 | 775.6 | 2.0 | 0.041 |
| 07-11-2018 | 769 | 4.0 | 0.234 |
| 04-12-2018 | 768.1 | 1.7 | 0.028 |

**Table 5.2 Seepage Details**

**Uplift pressure assessment**

In Spillway Dam, uplift pressure is measured using 3 pressure gauges installed in the gallery. Pressure gauge readings for the years 2017 and 2018 are tabulated below.

| Date | Reservoir level in m | Pressure gauge reading in kg/cm$^2$ | | | Discharge in lit/sec | | |
|---|---|---|---|---|---|---|---|
| | | F/D-1 | F/D-2 | F/D-3 | F/D-1 | F/D-2 | F/D-3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 04-01-2017 | 770.5 | Nil | 0.40 | 1.70 | Nil | Nil | 0.230 |
| 07-02-2017 | 768.15 | Nil | 0.30 | 1.50 | Nil | Nil | 0.383 |
| 01-03-2017 | 766.8 | Nil | 0.30 | 1.50 | Nil | Nil | 0.260 |
| 06-04-2017 | 762.75 | Nil | 0.25 | 1.10 | Nil | Nil | 0.270 |
| 03-05-2017 | 769.2 | Nil | 0.20 | 0.50 | Nil | Nil | 0.280 |
| 08-06-2017 | 755.75 | Nil | Nil | 0.10 | Nil | Nil | 0.013 |
| 10-07-2017 | 761.8 | Nil | Nil | Nil | Nil | Nil | Nil |
| 18-08-2017 | 769 | Nil | 0.30 | 1.40 | Nil | Nil | 0.430 |
| 27-09-2017 | 774.85 | Nil | 0.48 | 2.00 | Nil | 0.05 | 0.350 |
| 31-10-2017 | 772.5 | Nil | 0.40 | 1.80 | Nil | 0.06 | 0.213 |
| 30-11-2017 | 770.8 | Nil | 0.37 | 1.60 | Nil | 0.06 | 0.380 |
| 06-01-2018 | 768.4 | Nil | 1.50 | 2.10 | Nil | 0.053 | 0.410 |
| 20-02-2018 | 766.2 | Nil | 1.40 | 1.20 | Nil | 0.5 | 13.400 |
| 06-03-2018 | 764.75 | Nil | 0.70 | 0.10 | Nil | Nil | 0.232 |
| 01-08-2018 | 775.6 | Nil | 0.52 | 0.18 | Nil | 0.053 | 0.543 |
| 07-11-2018 | 769 | Nil | 1.50 | 2.20 | Nil | 10.5 | 1.150 |
| 04-12-2018 | 768.1 | Nil | 1.50 | 1.80 | Nil | 1.96 | 1.660 |

**Table 5.3 Pressure Gauge Readings**

## 5.1B Instrument Types and Usage in Banasurasagar Main Dam

The instruments installed in the Main Dam (Embankment Dam) are appended below.

| LIST OF INSTRUMENTS INSTALLED IN MAIN DAM | | | |
|---|---|---|---|
| **Sl. No.** | **Name of Instruments** | **Total No. installed** | **Location** |
| 1 | Piezometer | 10 | 1No at Ch. 30 m,<br>4Nos at Ch.120 m,<br>1No at Ch.200 m,<br>3Nos at Ch. 300 m<br>1No at Ch.500 m. |

| | | | |
|---|---|---|---|
| 2 | V notch | 1 | Toe drain |
| 3 | Settlement Blocks | 20 | At Ch. 90 m, 180 m, 320 m & 500 m in D/S Rock Toe, D/S Lower Bay, D/S Upper Bay, Top of Dam & U/S above FRL |
| 2 | Relief Well | 4 | Ch. 120 m, 140 m, 160 m and 410 m |

**Table 5.4 Instrumentation present status in Main Dam**

## 5.1.1B Parameters monitored

### 5.1.1.1B Pore Pressure

Piezometers are installed for measuring pore pressure. Measurements are taken weekly.

### 5.1.1.2B Seepage Flow

Seepage is measured with V notch. Measurements are taken weekly.

### 5.1.1.3B Settlement

Settlement blocks are installed to observe settlement. Reduced levels are taken Six monthly / yearly.

**Pore Pressure assessment**

In Main dam, for measuring pore pressure, 10 piezometers are installed. Recent piezometer readings are tabulated below in **Table 5.5**.

| **KUTTIYADI AUGMENTATION SCHEME - BANASURASAGAR DAM** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PIEZOMETER READING in m** | | | | | | | | | | | |
| **Date** | **1/1** | **2/1** | **2/2** | **2/3** | **2/4** | **3/1** | **4/1** | **4/2** | **4/3** | **5/1** | **Reservoir water level in m** |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 03-05-16 | | 23.80 | 17.82 | 26.72 | | | 25.10 | 29.42 | | 26.44 | 759.20 |
| 12-05-16 | | 23.78 | 17.86 | 26.68 | | | 25.12 | 22.40 | | 26.46 | 758.25 |
| 20-05-16 | | 23.85 | 17.85 | 26.79 | | | 25.17 | 22.60 | | 26.41 | 757.30 |
| 31-05-16 | | 23.85 | 17.80 | 26.80 | | | 25.15 | 22.45 | | 26.30 | 756.30 |
| 09-06-16 | | 23.75 | 17.76 | 26.60 | | | 25.10 | 22.15 | | 26.20 | 755.90 |
| 16-06-16 | | 23.74 | 17.72 | 26.55 | | | 24.90 | 22.00 | | 26.20 | 755.85 |
| 25-06-16 | | 23.80 | 17.75 | 26.45 | | | 24.85 | 21.90 | | 26.15 | 756.10 |
| 01-07-16 | 24.25 | 23.80 | 17.20 | 26.28 | | | 24.50 | 20.80 | | 25.70 | 759.00 |
| 08-07-16 | 24.30 | 23.85 | 17.25 | 27.30 | | | 24.55 | 20.78 | | 25.75 | 761.10 |
| 16-07-16 | 24.35 | 23.89 | 17.22 | 26.33 | | | 24.50 | 20.75 | | 25.73 | 763.70 |
| 22-07-16 | 24.85 | 23.82 | 18.40 | 26.47 | | | 24.10 | 20.60 | | 25.68 | 764.30 |
| 28-07-16 | 24.48 | 23.73 | 18.34 | 26.40 | | | 24.90 | 19.90 | | 25.39 | 765.35 |
| 06-08-16 | 23.75 | 23.45 | 18.28 | 26.20 | | | 23.47 | 19.45 | | 25.50 | 766.60 |
| 12-08-16 | 23.37 | 23.15 | 18.18 | 26.05 | | | 23.18 | 19.15 | | 25.15 | 767.55 |
| 20-08-16 | 22.77 | 22.45 | 18.20 | 26.30 | | | 22.67 | 18.90 | | 24.45 | 769.35 |
| 27-08-16 | 21.18 | 21.64 | 18.35 | 26.44 | | | 22.05 | 18.44 | | 24.05 | 770.20 |
| 01-09-16 | 19.44 | 20.82 | 18.42 | 26.68 | | | 21.74 | 18.32 | | 23.47 | 770.70 |
| 08-09-16 | 18.91 | 20.55 | 18.22 | 26.43 | | | 21.40 | 18.00 | | 23.05 | 771.15 |
| 19-09-16 | 18.54 | 20.60 | 18.00 | 26.34 | | | 20.92 | 17.70 | | 22.70 | 771.95 |
| 28-09-16 | 18.20 | 19.95 | 17.60 | 26.37 | | | 20.60 | 17.70 | | 22.20 | 772.05 |
| 04-10-16 | 18.05 | 19.75 | 18.17 | 26.38 | | | 19.75 | 17.51 | | 22.07 | 772.50 |
| 13-10-16 | 17.90 | 19.62 | 17.88 | 26.40 | | | 19.95 | 17.47 | | 21.74 | 772.70 |
| 18-10-16 | 17.78 | 19.36 | 17.63 | 26.40 | | | 20.08 | 17.42 | | 21.59 | 772.85 |
| 28-10-16 | 17.72 | 19.20 | 17.60 | 26.32 | | | 20.07 | 17.42 | | 21.68 | 772.35 |
| 03-11-16 | 17.88 | 19.30 | 17.62 | 26.35 | | | 20.15 | 17.41 | | 21.74 | 772.25 |
| 15-11-16 | 17.84 | 19.31 | 17.65 | 26.36 | | | 19.85 | 17.42 | | 21.93 | 772.30 |
| 22-11-16 | 17.85 | 19.30 | 17.68 | 26.37 | | | 20.00 | 17.35 | | 21.90 | 772.10 |
| 30-11-16 | 18.30 | 19.30 | 17.76 | 26.35 | | | 20.30 | 17.67 | | 22.09 | 771.35 |
| 08-12-16 | 18.42 | 19.40 | 17.45 | 26.42 | | | 20.47 | 17.70 | | 22.15 | 771.00 |
| 19-12-16 | 18.64 | 19.70 | 17.80 | 26.48 | | | 20.52 | 17.71 | | 22.47 | 771.00 |
| 26-12-16 | 18.70 | 19.67 | 17.72 | 26.43 | | | 20.44 | 17.74 | | 22.57 | 771.05 |
| 03-01-17 | 18.85 | 19.69 | 17.77 | 26.40 | | | 20.10 | 17.78 | | 22.54 | 770.60 |
| 09-01-17 | 19.25 | 19.80 | 17.77 | 26.44 | | | 20.86 | 17.98 | | 22.71 | 770.00 |
| 17-01-17 | 19.58 | 20.00 | 17.67 | 26.48 | | | 21.12 | 17.95 | | 22.90 | 769.75 |
| 24-01-17 | 19.70 | 20.26 | 17.85 | 26.47 | | | 21.15 | 17.83 | | 22.90 | 769.60 |
| 31-01-17 | 20.08 | 20.27 | 17.92 | 26.42 | | | 21.24 | 18.20 | | 23.04 | 768.90 |
| 13-02-17 | 21.19 | 20.70 | 17.94 | 26.47 | | | 21.59 | 18.62 | | 23.37 | 767.80 |
| 20-02-17 | 21.48 | 20.82 | 17.97 | 26.49 | | | 21.79 | 18.64 | | 23.57 | 767.75 |
| 27-02-17 | 21.82 | 21.00 | 18.50 | 26.53 | | | 21.95 | 18.90 | | 23.59 | 767.00 |
| 08-03-17 | 22.54 | 21.25 | 18.74 | 26.60 | | | 22.08 | 19.17 | | 23.94 | 766.00 |
| 14-03-17 | 22.98 | 21.43 | 18.75 | 26.62 | | | 22.43 | 19.38 | | 24.17 | 765.25 |
| 21-03-17 | 23.42 | 21.63 | 18.79 | 26.65 | | | 22.63 | 19.66 | | 24.40 | 764.55 |
| 27-03-17 | 23.84 | 21.86 | 18.23 | 26.63 | | | 22.83 | 19.73 | | 24.55 | 763.90 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 05-04-17 | 24.58 | 22.25 | 18.22 | 26.53 | | | 23.12 | 20.26 | | 24.70 | 762.90 |
| 12-04-17 | | 22.37 | 18.34 | 26.55 | | | 23.27 | 20.32 | | 24.92 | 762.00 |
| 18-04-17 | | 22.57 | 18.42 | 26.58 | | | 23.46 | 20.55 | | 25.08 | 761.20 |
| 25-04-17 | | 22.86 | 18.44 | 26.62 | | | 23.66 | 20.97 | | 25.33 | 760.25 |
| 05-05-17 | | 23.30 | 18.45 | 26.43 | | | 24.08 | 21.39 | | 25.45 | 758.95 |
| 11-05-17 | | 23.36 | 18.55 | 26.62 | | | 24.29 | 21.59 | | 25.65 | 758.30 |
| 19-05-17 | | 23.74 | 18.85 | 26.70 | | | 24.58 | 21.77 | | 25.79 | 757.20 |
| 29-05-17 | | 23.87 | 18.59 | 26.70 | | | 24.75 | 22.07 | | 26.10 | 755.80 |
| 06-06-17 | | 23.92 | 18.64 | 26.75 | | | 24.80 | 22.10 | | 26.17 | 755.75 |
| 15-06-17 | | 23.78 | 18.81 | 26.68 | | | 24.62 | 21.80 | | 25.87 | 757.00 |
| 23-06-17 | | 23.78 | 18.76 | 26.61 | | | 24.60 | 21.68 | | 25.83 | 757.50 |
| 30-06-17 | | 23.80 | 18.71 | 26.55 | | | 24.51 | 21.65 | | 25.80 | 760.10 |
| 06-07-17 | | 23.78 | 18.67 | 26.60 | | | 23.80 | 21.47 | | 25.75 | 761.30 |
| 15-07-17 | 24.60 | 23.47 | 18.45 | 26.44 | | | 23.38 | 21.19 | | 25.46 | 762.70 |
| 21-07-17 | 23.90 | 23.35 | 18.48 | 26.40 | | | 23.14 | 20.87 | | 25.02 | 764.95 |
| 27-07-17 | 23.10 | 23.35 | 18.50 | 26.40 | | | 22.96 | 20.16 | | 24.95 | 766.00 |
| 01-08-17 | 22.70 | 23.30 | 18.75 | 26.43 | | | 22.62 | 19.28 | | 24.43 | 766.40 |
| 08-08-17 | 22.46 | 23.18 | 18.55 | 26.41 | | | 22.43 | 19.15 | | | 767.75 |
| 16-08-17 | 21.79 | 22.90 | 18.48 | 26.40 | | | 22.17 | 18.90 | | 24.10 | 768.90 |
| 23-08-17 | 21.05 | 22.45 | 18.23 | 26.19 | | | 21.85 | 18.55 | | 23.95 | 770.15 |
| 31-08-17 | 19.41 | 21.94 | 18.12 | 26.18 | | | 21.20 | 17.83 | | 23.45 | 772.20 |
| 07-09-17 | 18.10 | 20.94 | 17.93 | 26.24 | | | 20.76 | 17.60 | | 22.76 | 772.80 |
| 14-09-17 | 17.92 | 20.14 | 17.68 | 26.17 | | | 20.55 | 17.42 | | 22.05 | 773.00 |
| 22-09-17 | 17.60 | 19.77 | 17.56 | 26.15 | | | 20.48 | 17.26 | | 21.62 | 774.30 |
| 28-09-17 | 16.90 | 18.92 | 17.60 | 26.18 | | | 19.81 | 17.12 | | 21.20 | 774.30 |
| 04-10-17 | 17.05 | 18.73 | 17.56 | 26.17 | | | 19.67 | 17.02 | | 21.70 | 774.00 |
| 11-10-17 | 17.80 | 18.40 | 17.42 | 26.21 | | | 19.55 | 17.05 | | 21.00 | 773.60 |
| 20-10-17 | 17.27 | 18.45 | 17.48 | 26.20 | | | 19.55 | 17.15 | | 21.25 | 773.05 |
| 26-10-17 | 13.30 | 18.61 | 17.46 | 26.22 | | | 19.15 | 17.20 | | 21.30 | 772.90 |
| 01-11-17 | 17.39 | 18.62 | 17.42 | 26.21 | | | 19.00 | 17.25 | | 21.50 | 772.40 |
| 06-11-17 | 17.68 | 18.83 | 17.47 | 26.24 | | | 19.25 | 17.34 | | 21.70 | 771.90 |
| 15-11-17 | 17.74 | 18.82 | 17.55 | 26.24 | | | 19.48 | 17.40 | | 21.80 | 771.70 |
| 22-11-17 | 18.00 | 19.18 | 17.60 | 26.30 | | | 19.88 | 17.58 | | 22.76 | 771.30 |
| 27-11-17 | 18.25 | 19.17 | 17.61 | 26.31 | | | 19.88 | 17.60 | | 22.16 | 771.00 |
| 12-12-17 | 18.40 | 18.59 | 16.65 | 25.33 | | | 19.35 | 17.00 | | 22.60 | 769.70 |
| 27-12-17 | 18.47 | 18.96 | 16.82 | 25.38 | | | 19.58 | 17.07 | | 21.94 | 769.30 |
| 03-01-18 | 18.96 | 19.06 | 16.80 | 25.40 | | | 19.94 | 17.28 | | 22.10 | 768.70 |
| 11-01-18 | 18.98 | 19.25 | 16.82 | 25.40 | | | 19.98 | 17.35 | | 22.18 | 768.00 |
| 23-01-18 | 20.10 | 19.60 | 16.90 | 25.46 | | | 20.41 | 17.54 | | 22.52 | 767.90 |
| 30-01-18 | 20.12 | 19.74 | 16.97 | 25.46 | | | 20.49 | 17.65 | | 23.35 | 767.90 |
| 06-02-18 | 20.31 | 19.93 | 17.00 | 25.49 | | | 20.60 | 17.70 | | 22.67 | 767.50 |
| 12-02-18 | 20.79 | 20.40 | 17.40 | 25.47 | | | 20.82 | 17.88 | | 26.66 | 766.90 |
| 21-02-18 | 21.36 | 20.21 | 17.50 | 25.50 | | | 20.88 | 18.70 | | 22.94 | 766.05 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28-02-18 | 21.38 | 20.22 | 17.10 | 25.57 | | | 20.90 | 19.00 | | 22.94 | 765.40 |
| 22-03-18 | 23.60 | 21.00 | 17.30 | 25.45 | | | 21.81 | 19.23 | | 24.23 | 763.10 |
| 27-03-18 | 23.75 | 21.90 | 17.22 | 25.55 | | | 21.95 | | | 23.88 | 762.60 |
| 03-04-18 | 23.85 | 22.10 | 18.00 | 25.50 | | | 21.90 | 19.00 | | 23.00 | 761.90 |
| 11-04-18 | | 21.60 | 17.33 | 25.64 | | | 22.39 | | | 24.20 | 761.00 |
| 23-04-18 | | 19.95 | 17.46 | 25.64 | | | 22.75 | 20.28 | | 24.60 | 759.60 |
| 04-05-18 | | 18.90 | 17.11 | 24.60 | | | 22.50 | 19.18 | | 23.10 | 758.40 |
| 18-05-18 | | 17.10 | 16.80 | 20.10 | | | 22.10 | 19.20 | | 23.00 | 756.80 |
| 29-05-18 | | 16.00 | 16.00 | 20.00 | | | 21.18 | 19.00 | | 22.80 | 755.60 |
| 08-06-18 | 20.18 | 18.10 | 17.40 | 22.10 | | | 21.10 | 20.28 | | 24.60 | 756.40 |
| 16-06-18 | 24.85 | 19.20 | 17.18 | 23.26 | | | 20.80 | 20.87 | | 22.90 | 764.20 |
| 24-06-18 | 23.80 | 20.10 | 17.80 | 24.30 | | | 20.88 | 18.70 | | 23.20 | 766.00 |
| 06-07-18 | 18.06 | 17.10 | 15.84 | 22.00 | | | 21.20 | 18.50 | | 23.47 | 768.60 |
| 19-07-18 | 17.10 | 19.19 | 16.60 | 19.00 | | | 22.46 | 19.35 | | 24.20 | 775.60 |
| 02-08-18 | 19.40 | 19.20 | 17.80 | 24.00 | | | 20.32 | 20.72 | | 22.10 | 775.60 |
| 25-08-18 | 18.20 | 19.30 | 17.18 | 21.20 | | | 19.74 | 17.46 | | 23.26 | 774.85 |
| 08-09-18 | 24.60 | 19.93 | 17.50 | 25.41 | | | 22.16 | 18.36 | | 22.25 | 773.60 |
| 20-09-18 | 22.60 | 19.74 | 17.58 | 24.32 | | | 21.17 | 19.12 | | 23.26 | 772.70 |
| 03-10-18 | 23.65 | 20.16 | 16.13 | 24.68 | | | 20.16 | 19.46 | | 21.13 | 771.75 |
| 24-10-18 | 21.16 | 19.12 | 16.21 | 25.12 | | | 19.98 | 18.52 | | 22.16 | 770.20 |
| 10-11-18 | 18.66 | 18.90 | 16.84 | 25.40 | | | 20.18 | 17.21 | | 21.97 | 768.70 |
| 17-11-18 | 19.10 | 19.19 | 16.87 | 25.48 | | 20.32 | 17.31 | 17.32 | | 22.11 | 768.45 |
| 21-11-18 | 19.23 | 19.24 | 16.82 | 25.39 | | 5.40 | 20.35 | 17.27 | | 22.23 | 768.45 |
| 26-11-18 | 19.28 | 19.45 | 16.92 | 25.40 | | 5.26 | 20.40 | 17.29 | | 22.26 | 768.50 |
| 03-12-18 | 19.44 | 19.56 | 16.78 | 25.40 | | 5.60 | 20.60 | 17.39 | | 22.38 | 768.15 |
| 10-12-18 | 19.77 | 19.77 | 16.93 | 25.53 | | 6.05 | 20.58 | 17.63 | | 22.53 | 768.10 |
| 17-12-18 | 20.11 | 19.89 | 16.94 | 25.50 | | 6.36 | 20.78 | 17.64 | | 22.60 | 767.50 |
| 24-12-18 | 20.66 | 20.15 | 17.15 | 25.51 | | 6.60 | 20.89 | 17.80 | | 22.80 | 766.95 |
| 31-12-18 | 20.90 | 20.20 | 17.12 | 25.50 | | 7.00 | 20.91 | 17.93 | | 22.75 | 767.00 |
| 14-01-19 | 21.50 | 20.37 | 17.90 | 25.44 | | 7.58 | 21.10 | 17.89 | | 22.90 | 766.55 |
| 25-01-19 | 21.57 | 20.61 | 17.16 | 25.57 | | 8.22 | 21.3 | 18.3 | | 23.2 | 765.85 |
| 25-02-19 | 23.7 | 21.24 | 17.26 | 25.59 | | 8.56 | 21.82 | 18.93 | | 23.8 | 763.7 |
| 05-03-19 | 23.36 | 21.42 | 17.26 | 25.63 | | 8.74 | 21.97 | 19.7 | | 23.9 | 763.6 |
| 11-03-19 | 23.70 | 21.56 | 17.24 | 25.66 | | 8.95 | 22.17 | 19.20 | | 24.00 | 763.25 |

**Table 5.5 Piezometer Readings**

**Settlement observation**

In Main dam, for observing settlement, 20 settlement blocks are installed. Reduced levels taken are tabulated below in **Table 5.6**.

**KUTTYADI AUGMENTATION PROJECT -BANASURASAGAR DAM - SETTLEMENT BLOCK**

| Permanent Benchmark No | 1/1 | 2/1 | `3/1 | `4/1 | `1/2 | `2/2 | `3/2 | `4/2 | `1/3 | `2/3 | `3/3 | `4/3 | `1/4 | `2/4 | `3/4 | `4/4 | `1/5 | `2/5 | `3/5 | `4/5 | Concrete Block Near Boat Jetty | Date of Reduced Level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chainage | 90m | 180m | 320m | 500m | 90m | 180m | 320m | 500m | 90m | 180m | 320m | 500m | 90m | 180m | 320m | 500m | 90m | 180m | 320m | 500m | | |
| Position | D/S Rock Toe | | | | D/S Lower Bay | | | | D/S Upper Bay | | | | Top of Dam | | | | | U/S Above FRL | | | Near Boat Jetty | |
| Reduced Level | 746.5000 | 751.0150 | 752.2700 | 750.6850 | 759.4500 | 763.2900 | 762.3650 | 760.5500 | 773.4600 | 773.2175 | 772.7675 | 772.0050 | 778.2575 | 778.3375 | 778.2325 | 778.3100 | 778.5100 | 778.6725 | 778.4150 | 778.7525 | 778.4500 | 18.04.2009 |
| Reduced Level | 746.5000 | 751.0150 | 752.2675 | 750.6850 | 759.4450 | 763.2950 | 762.3600 | 760.5500 | 773.4550 | 773.2150 | 772.7600 | 772.0050 | 778.2575 | 778.3350 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 57.04.2010 |
| Reduced Level | 746.5000 | 751.0150 | 752.2650 | 750.6850 | 759.4450 | 763.2950 | 762.3600 | 760.5500 | 773.4500 | 773.2150 | 772.7650 | 772.0050 | 778.2575 | 778.3350 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 25.04.2011 |
| Reduced Level | 746.5000 | 751.0150 | 752.2650 | 750.6850 | 759.4450 | 763.2950 | 762.3600 | 760.5500 | 773.4550 | 773.2150 | 772.7650 | 772.0050 | 778.2575 | 778.3350 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 17.04.2012 |
| Reduced Level | 746.5000 | 751.0150 | 752.2650 | 750.6850 | 759.4450 | 763.2950 | 762.3600 | 760.5500 | 773.4550 | 773.2150 | 772.7650 | 772.0050 | 778.2575 | 778.3350 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 16.06.2012 |
| Reduced Level | 746.5000 | 751.0150 | 752.2650 | 750.6850 | 759.4450 | 763.2950 | 762.3600 | 760.5500 | 773.4550 | 773.2150 | 772.7650 | 772.0050 | 778.2575 | 778.3350 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 12.07.2012 |
| Reduced Level | 746.5000 | 751.0150 | 752.2650 | 750.6850 | 759.4450 | 763.2950 | 762.3600 | 760.5500 | 773.4550 | 773.2150 | 772.7650 | 772.0050 | 778.2575 | 778.3350 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 17.04.2013 |
| Reduced Level | 746.5000 | 751.0150 | 752.2650 | 750.6800 | 759.4400 | 763.2950 | 762.3650 | 760.5450 | 773.4500 | 773.2200 | 772.7600 | 772.0000 | 778.2600 | 778.3300 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 25.04.2014 |
| Reduced Level | 746.5000 | 751.0100 | 752.2650 | 750.6800 | 759.4400 | 763.2950 | 762.3650 | 760.5400 | 773.4500 | 773.2200 | 772.7600 | 772.0050 | 778.2600 | 778.3300 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 18.03.2015 |
| Reduced Level | 746.5000 | 751.0100 | 752.2650 | 750.6800 | 759.4400 | 763.2950 | 762.3650 | 760.5400 | 773.4500 | 773.2200 | 772.7600 | 772.0050 | 778.2600 | 778.3300 | 778.2350 | 778.3100 | 778.5100 | 778.6700 | 778.4100 | 778.7500 | 778.4500 | 22.03.2017 |

**Table 5.6 Settlement Block levels**

### 5.1.1.4 Water Quality

The quality of water including pH value is to be tested.

### 5.1.1.5 Seismic Station

There is no Seismic observatory installed in Kuttiyadi Augmentation Scheme.

### 5.1.1.6 Weather Conditions

Now the rainfall data is measured daily with 2 rain gauges, one at dam site and other at Control shaft.

## 5.2 Data Processing and Evaluation

Instrument data should be processed and evaluated according to the procedures established by the monitoring program. Accumulation of instrument data by itself does not improve dam safety or protect the public.

The monthly reports are prepared for evaluation.

### 5.2.1 Data Collection

Data collected manually should be recorded on the data sheets prepared as part of the monitoring program. Complementary data, such as air temperature, reservoir level, reservoir temperature, recent precipitation, and other information or observations that may be important in evaluating the instrumentation data should be noted on the data sheets.

Data collection for the dam is carried out on daily, fortnightly / monthly basis as the case may be.

### 5.2.2 Data Presentation

All data should be summarized in graphical form. All plots should include sufficient previous data to identify any long-term trends. Furthermore, the plots should be self explanatory.

On monthly basis or as per direction of the Design department.

### 5.2.3 Data Interpretation

Data should be reviewed for reasonableness, evidence of incorrectly functioning instruments, and transposed data. Several checks for reasonableness can be made on all data. The magnitude of data should be near the range of previous data. Data that are significantly different may be incorrect. All data will have scatter from instrument error, human error, and from changes in natural phenomena such as temperature, wind, and humidity. The true accuracy of data will not be apparent until a significant number of readings have been taken under a variety of conditions. All data will follow trends, such as decreasing with time or depth, increasing with time or depth, seasonal fluctuation, direct variation with reservoir or tail water level, direct variation with temperature, or a combination of such trends. Interpretation of data is carried out as per standard practice & on monthly / six monthly / yearly basis or as decided by design authorities for this dam.

Interpretation of data, so collected, needs to be carried out judiciously. Help of experienced personnel from the concerned field from Institutes / manufacturers / instrument suppliers could prove to be useful.

### 5.2.4 Dam Performance Evaluation

All data should be compared with expected behaviour based on the basic engineering concepts. Variations from expected behaviour may suggest development of conditions that should be evaluated. All data should be compared with design assumptions. If no unusual behaviour or evidence of problems is detected, the data should be filed for future reference. If data deviates from expected behaviour or design assumptions, action should be taken. The action to be taken depends on the nature of the problem, and should be determined on case-by-case basis. Possible actions include:

- Performing detailed visual inspection;
- Repeating measurements to confirm behaviour;
- Re-evaluating stability using new data;
- Increasing frequency of measurements;
- Installing additional instrumentation;
- Designing and constructing remedial measures;
- Operating the reservoir at a lower level; and
- Emergency lowering of the reservoir.

## 5.3 Methods of Behavior Prediction

Each dam is a unique structure and has its own special conditions of siting, design, construction and operation. Rigorous methods of prediction have been developed over the years. These methods apply the laws of physics to problems of slope stability, foundation stability and rock deformation. Modern solutions use finite element or finite difference models run on computers. Such numerical analyses are expensive and for that reason are generally used only for larger dams. Special analyses are made when investigations reveal weak materials or other anomalies.

### 5.3.1 Visual Observations

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

### 5.3.2 Monitoring Results

Analysis and observation of the instrument readings on water level, leakages, uplift and other parameters can ascertain the visually observed behavior.

# Chapter 6

# Remedial measures taken earlier

Before DRIP, maintenance activities were limited to routine greasing, oiling and patch painting of Hydro- mechanical devices, routine repair of electrical systems, gallery drainage, routine mowing, vegetation removal etc. Apart from these routine maintenance activities, no major rehabilitation was carried out before the involvement of DRIP. Under DRIP, major rehabilitation works have been carried out (with some activities still on-going during the preparation of this O & M Manual).

The rehabilitation works carried out under DRIP include

**1 Providing fencing at K.A Main Dam premises.**

The security wing of the State and Central governments has instructed to tighten the security of important hydraulic structures. Moreover, experts of the Dam Safety Review Panel on inspection of the dam site instructed to arrange security fencing in the dam premises. Hence fencing was carried out from spillway right bank to left bank of the main dam using chain link and barbed wire.

**2 Providing chipping carpet to the top of K.A Main Dam.**

The condition of the dam top road was very bad and some portions were severely damaged due to heavy rain and traffic. No maintenance work had been done for the road for the past several years. Experts of Dam Safety Review Panel on inspection of the dam, instructed to arrange the repair works urgently. Hence the repair works were carried out including filling pot holes, bitumen levelling course, providing chipping carpet etc.

**3 Providing access from right end of Spillway Dam to downstream of gallery by constructing steps.**

Experts of Dam Safety Review Panel during inspection of the dam observed that there is no proper access to the foundation gallery. Hence based on their recommendation, concrete steps were constructed from right end of spillway dam to downstream of gallery.

**4 Providing access from left end of Spillway Dam to walkway by constructing steps.**

Considering the recommendation of experts from Dam Safety Review Panel and to make an easy and convenient passage to walkway, steps were constructed from left end of spillway dam to walk way.

**5 Providing access to gallery No II of Kuttiyadi Saddle Dam by constructing a steel foot bridge**

Kuttiyadi saddle dam is a concrete dam of K A Scheme with two galleries out of which only one gallery is accessible for inspection. During the visit of DSRP team, they recommended to provide access to the second gallery. Hence a steel footbridge over power sluice block connecting the two galleries was constructed.

**6 Replacing old wire ropes of emergency gate at Control Shaft.**

The wire ropes of the emergency gate at control shaft were done in 2016.

**7 Widening of the existing concrete deck slab- Fabrication, supply and erection of steel walkway.**

As recommended by DSRP, in order to facilitate easy movement through the spillway top, the concrete deck slab is widened with steel structures. The work consisted of demolishing the RCC parapet wall on the top of the deck slab, erection of steel foot bridge, fixing 10mm thick chequered plate and handrails etc.

**8 Electrification of Main Dam and Spillway Dam**

The power supply arrangement of main dam and spillway dam was very old and heavily damaged and hence there were frequent power failures. In order to overcome the problems of power supply, electrification works were carried out at main dam and spillway dam using underground cables. The work consisted of laying new power cables, its control arrangements / switch gears, providing panel board with necessary control & safety arrangements as per standards. Peripheral lighting was also done using LED Lights.

**9 Supply and installation of High Mast light.**

As part of enhanced security measures, for effective vision of the dam premises during night, high mast lights are installed at left and right banks of main dam, near road downstream of main dam, near main gate and at left and right banks of spillway dam.

**10 Purchase of speed boat.**

The photographs showing the DRIP works are given below:

**Fig 6.1 Steps constructed**

**Fig 6.2 Fencing**

**Fig 6.3 Steel walkway at spillway**

**Fig 6.4 Electrification work**

Other non-structural measures under DRIP include preparation of inundation maps and Emergency Action Plan (EAP), review of design floods, preparation of O & M Manual, data entry to DHARMA etc.

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

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