सत्यमेव जयते

REPORT OF THE COMPTROLLER AND AUDITOR GENERAL OF INDIA

on

PREPAREDNESS AND RESPONSE TO FLOODS IN KERALA

लोकहितार्थ सत्यनिष्ठा
Dedicated to Truth in Public Interest

सत्यमेव जयते
GOVERNMENT OF KERALA

Government of Kerala

Report No. 6 of the year 2021

Presented to the Legislature on 11 November 2021

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PREFACE

This Report of the Comptroller and Auditor General of India for the year ended 31 March 2019 has been prepared for submission to the Governor of the State of Kerala under Article 151(2) of the Constitution of India.

This Report contains the results of the Performance Audit on 'Preparedness and response to floods in Kerala' covering the period 2014-19.

The audit has been conducted in conformity with the Auditing Standards issued by the Comptroller and Auditor General of India.

Audit wishes to acknowledge the cooperation received from Departments of Revenue and Disaster Management, Power and Water Resources at each stage of the audit process.

EXECUTIVE SUMMARY

Out of the total area of the State, 14.52 *per cent* is estimated to be prone to floods. As per India Meteorological Department data, Kerala received 2346.60 mm of rainfall from 01 June 2018 to 19 August 2018 which was about 42 *per cent* above the normal. Rainfall in the State was 164 *per cent* above normal in the period 01-19 August 2018. The devastating floods in Kerala during August 2018 severely affected 13 of the 14 districts in the State resulting in huge loss of life and property.

With a view to assess the preparedness and response of Government of Kerala (GoK) to minimise the magnitude of losses due to floods, a Performance Audit of 'Preparedness and response to floods in Kerala' was conducted. The major findings of the Performance Audit are given below.

Planning and Capacity Building

The Kerala State Water Policy 2008 was not updated in accordance with the National Water Policy and lacked provision for flood control and flood management in the State.

(Paragraph 2.1)

Provisions in the Kerala State Water Policy 2008 requiring the preparation of a State Level Master Plan for water resources development, formulation of Master Plans for the major rivers of the State and constitution of a State Level Authority for coordinating all water related activities at the river basin level were not complied with.

(Paragraph 2.2)

Flood plains of the State are yet to be demarcated and flood plain zoning legislation remains to be enacted.

(Paragraph 2.3)

No large-scale flood hazard map is available in the State; State's Disaster Management Plan includes flood susceptibility map not conforming to Central Water Commission (CWC) criteria for flood prone area. According to GoK, responsibility to provide the large-scale map is that of the Ministry of Water Resources, CWC, etc.

(Paragraph 2.4)

The Civil Defence Training Institute building at Thrissur, which was to cater to the dedicated purpose of a full-time residential training institute for civil defence, has not served the intended purpose even after the passage of five years.

(Paragraph 2.5.1)

Subsequent to signing of MOU of Aapda Mitra scheme in November 2016, procedural delay at various individual stages resulted in distribution of emergency responder kits in December 2019, one year after completion (October 2018) of training of the first batch of Aapda Mitra volunteers. Disaster response skills acquired by the volunteers could not be used for the benefit of the local community despite severe flood having affected the State in August 2019.

(Paragraph 2.5.3)

Flood forecasting and reservoir operation

Only six rain gauges against the requirement of 32 gauges (as per existing BIS norms) are available for rainfall estimation in Periyar basin by IMD.

(Paragraph 3.1)

Despite 275 flood forecasting stations having been set up by CWC across the country by the year 2017, no flood forecasting stations had been set up by the CWC in the State. GoK had not furnished to the CWC list of reservoirs/ cities and towns requiring setting up of inflow forecasting stations/ level forecasting stations. However, the Government had resolved to develop a full-fledged inflow forecasting and flood early warning system under National Hydrology Project

(Paragraph 3.3)

A project for obtaining real time data on rainfall, streamflow etc. failed to deliver reliable data on real time basis even after a lapse of five years.

(Paragraph 3.4)

Though the Disaster Management Plan 2016 envisaged State Emergency Operations Centre to be equipped with a full-fledged state-of-the-art IT and Communication network with an intelligent Decision Support System (DSS) capable of prediction and early warning of major hydro-meteorological hazards and support for emergency operation, even two years after the targeted date of completion of April 2019, the system cannot be relied upon to predict and give early warning of major hydro-meteorological hazards since its effective functioning is dependent on the receipt of externally sourced real time data which is yet to be made available.

(Paragraph 3.5.1)

Communication infrastructure was non-functional in some areas including dam sites and Government offices during or subsequent to the 2018 floods.

(Paragraph 3.5.2)

Contribution of the spills from Idamalayar and Idukki dams together, to the flows at Neeleswaram gauge station during the days 14 to 18 August 2018 was 46.43 *per cent*, 36.12 *per cent*, 29.54 *per cent*, 23.34 *per cent* and 16.99 *per cent* respectively. Contribution of spills from Mullaperiyar to the inflows at Idukki during August 15-18 ranged between 27.93 and 36.62 *per cent*.

There was no rule curve in place for the guidance of dam operators at Idamalayar reservoir at the time of the 2018 floods. Rule curve for Idukki reservoir framed in 1983 were not reviewed until after the floods of 2018.

Though reservoir operations at Idukki during 14 to 18 August 2018 resulted in lower spill of 467.51 MCM compared to 558.19 MCM (indicated through simulation studies) which would have resulted had the Rule Curve (of 1983) been followed strictly, outflows still exceeded inflows on one day (17 August 2018) in respect of Idukki reservoir and on two days (16 and 17 August 2018) in respect of Idamalayar reservoir.

(Paragraph 3.6)

Though Reservoir Operation Guidelines require capacity surveys of reservoirs to be undertaken at least once in five years, no capacity surveys or sedimentation studies were conducted in any of the KSEBL reservoirs between 2011 and August 2019 (when Audit was undertaken). However, seven sedimentation studies were carried out in 2020.

Sedimentation assessments of major reservoirs Idukki, Idamalayar, Kakki and Sholayar were last conducted in 2004, 2011, 1999 and 2003 respectively. In respect of Banasurasagar dam, commissioned during 2005, sedimentation study is yet to be conducted. KSEBL informed that in the backdrop of the 2018 floods, sedimentation study for Idukki, Idamalayar, Kakki, Banasurasagar and Sholayar reservoirs has been included in Dam Rehabilitation and Improvement Project-II.

In respect of reservoirs under the control of the Water Resources Department, though siltation studies had revealed significant levels of siltation in Aruvikkara reservoir (43 *per cent*), Mangalam reservoir (21.98 *per cent*), Peppara reservoir (21.70 *per cent*), desiltation activities were yet to take off other than in Mangalam reservoir which commenced in December 2020.

(Paragraph 3.7)

Impact of change in Land Use and Land Cover

The Land Use Land Cover analysis for the entire Periyar basin including the test-checked districts of Idukki and Ernakulam revealed an increase in the built-up area by nearly 450 *per cent* during 1985-2015 and decrease in water bodies by nearly 17 *per cent*. During 2005-2015, the built-up area increased by nearly 139 *per cent*. Had the same rainfall and spills of 2018 occurred with 1985 land use conditions, the flood depth at Neeleswaram gauge station would have reduced from 12.32 m to 10.03 m and the flood inundated area would have reduced from 520.04 sq. km to 414.76 sq. km.

(Paragraph 4.1)

Continuing presence of encroachments on Cheruthoni river bed obstructed the free flow of the river resulting in damages during the 2018 floods.

(Paragraph 4.2)

Despite passage of 20 years since the commissioning of the airport and instances of severe flooding in the area, the Irrigation/ Revenue and Disaster Management wings/ LSGIs concerned/ CIAL have not been able to ensure a well-maintained diversion canal adequate to carry the Chengalthodu waters (in the event of heavy flooding) into the Periyar river to sustain the overall hydrology of the area and ward off the potential risks of riverine flooding to the resident population.

(Paragraph 4.3)

Lower than targetted dredging to deepen and widen the leading channel of Thottapally spillway coupled with the presence of over 500 trees planted inside the spillway mouth resulted in reduction of spillway capacity, contributing to the flood situation in Alappuzha in August 2018.

(Paragraph 4.4)

Financial management and survey

Though 7124 works of immediate repair and restoration of damages in 2018 flood were approved for execution under State Disaster Response Fund, 18 *per cent* of the works were yet to be completed even after a lapse of two years and eight months (April 2021). The Government informed that the pending works were expected to be completed by May 2021.

(Paragraph 5.2)

CHAPTER I
INTRODUCTION

1 INTRODUCTION

The National Centre for Earth Science Studies (NCESS) estimates[1] that 14.52 *per cent* of the total area of Kerala is prone to floods. Floods are the most common of natural hazards that affect people, infrastructure and natural environment in Kerala. Incidence of floods in the State is becoming more frequent and severe. While high intensity rainfall causes flooding during monsoons in the State, increase in flood plain occupancy and reclamation of water bodies and wetlands over the years have contributed to increasing flood damages. Hence, flood management needs to be accorded high priority in the disaster management profile of the State. The mitigation of damages caused by floods is dependent upon a combination of pre-flood preparedness, operational flood management and post flood review.

Government of Kerala (GoK), in line with the Disaster Management Act, 2005 enacted the Kerala State Disaster Management Rules, 2007 and promulgated the Kerala State Disaster Management Policy, 2010 for holistic disaster management in the State. The Kerala State Disaster Management Authority (KSDMA) under the Revenue and Disaster Management Department was constituted (2007) to lay down guidelines to be followed by the various departments of GoK in the formulation of their development plans and projects such that integrated measures could be taken for prevention of disasters and provide necessary technical assistance for disaster management.

A Performance Audit on 'Preparedness and response to floods in Kerala' covering the period 2014-19 was conducted to assess whether planning and implementation of flood management measures were effective with focus on the floods in 2018.

1.1. Organisational set-up for flood control

The Kerala State Disaster Management Authority (KSDMA)[2] is assisted in the execution of its functions by the State Executive Committee (SEC) which was constituted (2007) by the GoK with the Chief Secretary to the Government as the Chairperson. The Head of the Department of Revenue and Disaster Management, who is the Convenor of SEC and Head of the Department of KSDMA, acts as the State Relief Commissioner.

District Disaster Management Authorities (DDMA) have been constituted in all 14 districts to act as the planning, coordinating and implementing bodies for disaster management and to mobilise resources of all relevant departments at their level. As per Kerala State Disaster Management Plan approved in 2016, the Water Resources Department is the nodal department for

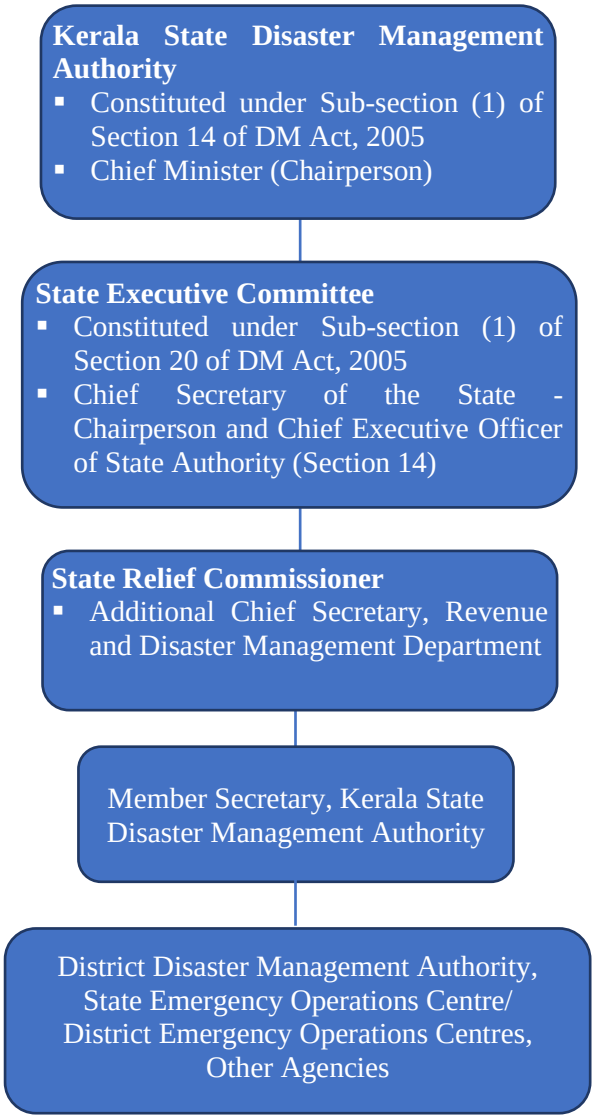
[1] Estimated in 2010 on the basis of multi hazard zonation maps prepared by NCESS

[2] with the Chief Minister of the State as the ex-officio Chairperson and nine members including the Minister of Home and Vigilance, Minister for Agriculture and Principal Secretary, Revenue and Disaster Management Department forming part of the Authority

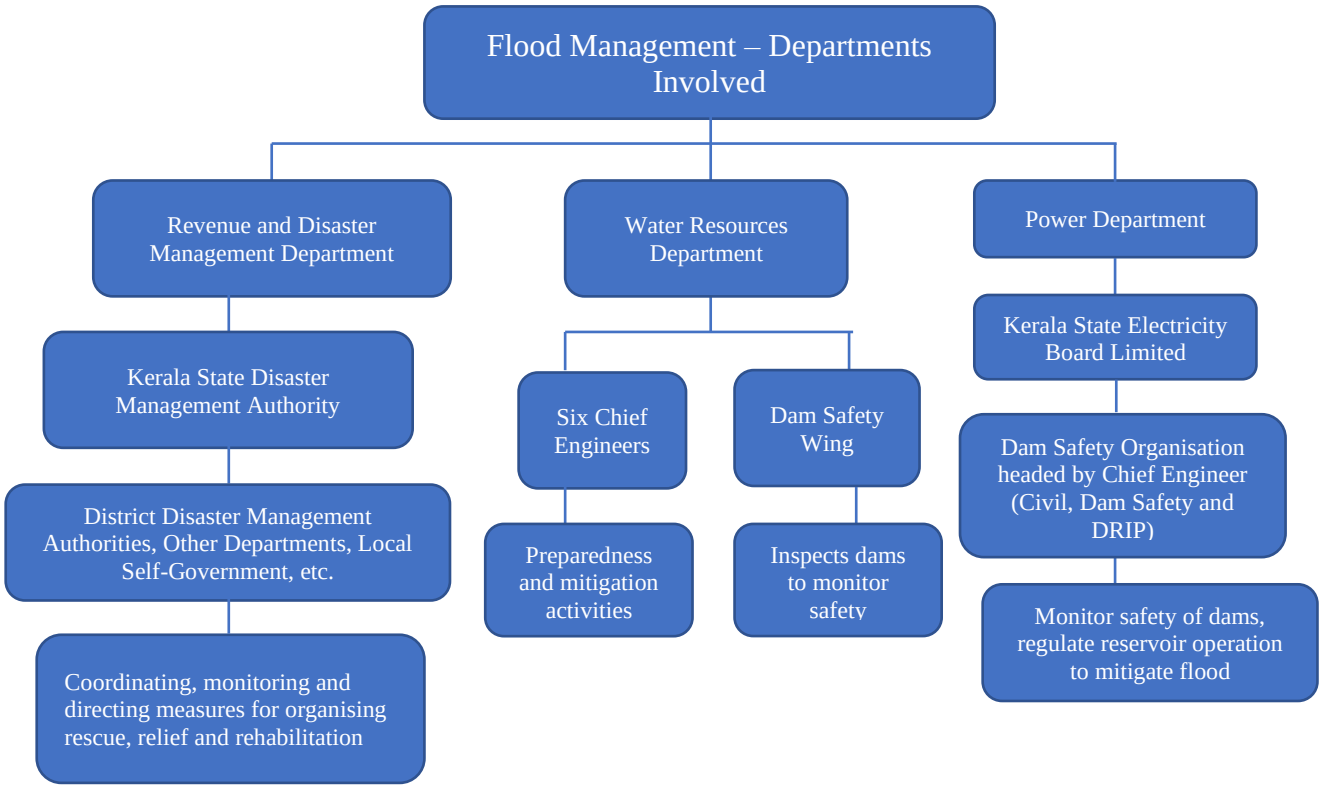
preparedness, and the Revenue and Disaster Management Department, for response and recovery in times of flood.

Emergency Operations Centres at the State (SEOC) and district level (DEOC) function under KSDMA and DDMAs respectively, for prompt assessment and relay of information to facilitate quick response and effective decision making. The Departments of Water Resources and Power, through their subordinate wings/ officers, implement structural and non-structural measures for disaster risk reduction to effectively manage flood scenarios in the State. The organograms presented below depict the organisational set up of disaster management in the State.

Institutional set up for disaster management



Institutional set up for disaster management (contd.)



1.2. Audit Objectives

The Performance Audit was conducted with a view to assess whether

- planning for flood management was comprehensive and effective;
- implementation of measures for management and control of floods was effective;
- preparedness and response to the floods in 2018 was adequate and timely.

1.3. Audit Criteria

Audit observations were benchmarked against the criteria derived from the following documents:

- The Disaster Management Act 2005
- NDMA Guidelines on Management of Floods 2008
- Kerala State Disaster Management Rules 2007
- State Disaster Management Policy 2010
- National Disaster Management Plan 2016

- State Disaster Management Plan 2016
- National Water Policy 2002, 2012
- Central/ State Government Orders, Circulars, Codes, Manuals and Guidelines of KSDMA, other implementing agencies etc.

1.4. Audit scope and methodology

Audit adopted a two-stage sampling methodology for selection of four out of 14 districts (25 *per cent*) for test check. While Idukki district was judgmentally selected due to the maximum concentration of large dams, the remaining three districts of Alappuzha, Ernakulam and Thrissur were selected through risk-based sampling. Eight[3] Taluk Offices in these four districts (two per district) which were worst hit during 2018 floods were also selected for detailed scrutiny. The detailed list of institutions covered by Audit is given in **Appendix 1.1**.

The Performance Audit covering the period 2014-19 was conducted between May 2019 and February 2020 by scrutiny of relevant records of the Revenue and Disaster Management Department and the Water Resources Department in Government Secretariat and the various agencies[4] connected with the management of floods at State/ District/ Taluk/ Village level including the Kerala State Disaster Management Authority, SEOC, Institute of Land and Disaster Management (ILDM), India Meteorological Department (IMD), Kerala State Electricity Board Limited etc. An Entry Conference was held on 18 June 2019 with the Principal Secretary, Revenue and Disaster Management Department, Secretary, Water Resources Department (who was also the Secretary, Power Department) and heads of audited institutions, including the Chairman, Kerala State Electricity Board Limited wherein the scope, objectives, criteria, and methodology of audit including selection of districts for test check were discussed.

On conclusion of audit, Exit Conferences were held with the various Departments mentioned in the Report through video conferencing on different dates as per the Government's request and in the wake of COVID pandemic, during which the audit findings and recommendations of audit were discussed in detail. Additional remarks offered by the Government with respect to the audit findings have been considered in the finalisation of the Report. Exit Conferences with Principal Secretary, Revenue and Disaster Management Department along with the Commissioner, Disaster Management and Member Secretary, KSDMA was held on 18 January 2021, with Secretary, Power Department along with Chairman, Kerala State Electricity Board Limited on

[3] Alappuzha district: Kuttanad and Chengannur; Ernakulam district: Aluva and Paravur; Thrissur district: Chalakkudy and Thalappilly; Idukki district: Idukki and Devikulam Taluk Offices

[4] Office of the Chief Engineer, Irrigation department, Dam safety offices, KSEBL/ Irrigation division offices of test-checked dams, offices of Disaster Management Authorities and Emergency Operations Centres in selected districts and Disaster Management sections in taluks.

23 January 2021 and with Additional Chief Secretary, Water Resources Department on 02 February 2021[5].

Audit methodology included scrutiny of records in selected offices, joint field visits with department officers to dam sites, river basins, flood prone areas, flood management structures etc. Audit also conducted a survey of 800 persons affected by flood in the test-checked districts. Audit engaged the Indian Institute of Science (IISc), Bangalore as Consultant to study the Kerala floods of August 2018 from a hydrological perspective. The study area was the Periyar river basin, which covers an area of 5159.71 square kilometres. The Government has communicated its concern over the fact that a simulation study by the Consultant IISc Bangalore has been relied upon for auditing a crisis management period, *viz.* the floods of August 2018. Audit's response is that the simulation studies by technical experts, though undertaken *ex post facto*, are reliable as a constructive tool, even for a crisis management situation. In this instance, the exercise has been useful in re-creating the hydrological scenario of the 2018 floods for the purpose of examining whether reservoir operations could have been handled differently with the then available set of data and thus facilitate better preparedness to handle similar challenging situations, that may arise in the future.

1.5. Acknowledgement

Audit acknowledges the cooperation extended by the Department of Revenue and Disaster Management, Department of Water Resources and Department of Power, Government of Kerala in the conduct of the Performance Audit. The co-operation extended by officials of Central Water Commission, India Meteorological Department, Kerala State Electricity Board Limited (KSEBL), Kerala State Disaster Management Authority, Irrigation Design and Research Board, Dam Safety Organisation, Kottayam, Kerala State Remote Sensing and Environment Centre and District Disaster Management Authorities in Alappuzha, Thrissur, Ernakulum and Idukki is gratefully acknowledged. Audit records its appreciation for the efforts of Prof. P. Pradeep Mujumdar and his team from IISc, Bangalore in submitting a Report on the 2018 Kerala floods. Audit has relied, *inter alia*, upon the Consultant's study for observations relating to Reservoir Operations and impact of Land Use and Land Cover change, included in this Report.

[5] Discussion was held with the Executive Director, Cochin International Airport Limited on 29 January 2021.

CHAPTER II
PLANNING AND CAPACITY BUILDING

2 PLANNING AND CAPACITY BUILDING

The Disaster Management Act (DM Act) enacted by Parliament in 2005 envisages a continuous and integrated process of planning, coordinating and implementing measures for disaster management. The Act stipulated that a State Authority shall be vested with the responsibility for laying down policies and plans for disaster management in a State. In Kerala, at the district level, District Disaster Management Authorities were also constituted in September 2008 following the constitution of the State Disaster Management Authority. The KSDMA assisted by the State Executive Committee, is responsible for measures to be taken for mitigation, capacity building and preparedness by the various departments and to issue such guidelines as may be necessary.

Planning

2.1. Inadequate provision for flood management in the State Water Policy

The Government of India formulated a National Water Policy (NWP) in 1987 which was revised in 2002 and subsequently in 2012. The NWP envisaged and included provisions relating to the management of flood. The NWP 2002 envisaged that States would formulate a Master Plan for flood control and management for each flood prone basin, and provide for adequate flood-cushion in water storage projects as well as strict regulation of settlements and economic activity in the flood plain zones to minimise the loss of life and property on account of floods. The NWP 2012 required operating procedures for reservoirs to be evolved and implemented in such a manner so as to have flood cushion and to reduce trapping of sediment during flood season. It also mentions that encroachments and diversion of water bodies must not be allowed and restoration must be promoted to the extent feasible. NWP 2012 envisages the drafting of State Water Policy (SWP) in accordance with NWP keeping in mind the basic concerns and principles as also a unified national perspective.

Audit observed that as against the NWP, the Kerala SWP, as formulated by the Water Resources Department (July 2008) did not consider the aspect of management of floods in the State. The provisions in the Water Policy of GoI which placed emphasis on preparedness for flood, modernisation of flood forecasting using real time data acquisition system linked to forecasting model[6], evolving and implementing operating procedures for reservoirs in order to have flood cushion, increasing preparedness for sudden and unexpected floods were not included in the Water Policy formulated by GoK. During the course of the Performance Audit, Audit came across issues[7] such as

[6] Paragraphs 17.2, 17.3, 17.4 and 17.5 of the NWP 2002
[7] Paragraphs 2.3, 3.3 and 3.7 and **Appendix 2.1** of this Report

the absence of legislation to demarcate flood plains, encroachment of water bodies, absence of flood forecasting stations, inadequate desiltation activities etc. Non-inclusion of elements of flood control measures in the State Water Policy was indicative of the relative low priority given to flood management issues possibly because Kerala was not considered a flood prone State until recent years.

The Department of Water Resources replied (November 2020 and April 2021) that though the SWP 2008 does not explicitly provide for flood management/ forecasting, the Department had given emphasis to flood preparedness/ forecasting in the past and 131 rain gauges, 54 river gauge stations and nine fully automatic climatic stations had become operational prior to the floods of 2018. In order to equip the State to contain disasters of similar magnitude as that which took place owing to the unprecedented heavy rainfall, after the 2018 floods, the Government resolved to develop a full-fledged inflow forecasting and flood early warning system under the National Hydrology Project in all river basins with real time monitoring through tipping bucket rain gauge (99 nos.), radar level sensor (56 nos.) and automatic weather stations (13 nos.). Orders have been issued to develop a single authoritative platform Kerala Water Resources Information System for all water resources related information. The Department stated that these facts indicate that the Government had a functional mechanism with respect to flood forecasting and was quick to formulate measures for real time flood forecasting in the wake of the after effects of 2018 floods. The reply also indicated that a drafting Committee was constituted in November 2017 for formulating a revised SWP, which was reconstituted in January 2021 and the Committee submitted a revised draft of the amended SWP on 05 April 2021. Revised State Water Policy containing the provisions for flood management based on State specific requirements would be promulgated when the new Government comes to power.

The response of the Department confirms the inadequacy of provisions relating to flood management in SWP as depicted in the audit paragraph.

Recommendation 2.1: Government of Kerala may consider revision of the State Water Policy to include aspects relating to flood management, in line with the National Water Policy and after considering the specific requirements of the State.

2.2. Non-preparation of State level Master Plan for water resources development and management

The State Water Policy (SWP) 2008 considered the micro watershed as the basic unit and the river basin as an integrated unit of micro-watersheds. It envisaged preparation of a State level Master Plan for water resources development and management by compiling the status and action plans in each micro watershed, sub-basins and river basins in a hierarchical form. Additionally, Master Plans for the major rivers of the State were to be prepared which would form the basis of any river-based project. A State Level

River Authority was also to be constituted for coordinating all water related activities at the river basin level. A GoI report of the National Commission on Flood had observed as early as in March 1980 that the practice of undertaking flood schemes on *ad hoc* basis was unscientific and recognised an urgent need for preparing basin-wise Master Plans which would indicate priority of schemes for implementation.

Audit noted that a State Level River Management Authority was yet to be constituted. Non-constitution of the same meant absence of an institutional mechanism for ensuring co-ordination between different implementing agencies and for monitoring prioritisation of works undertaken. The canal work in Cochin International Airport Limited (refer Paragraph 4.3 of this Report) is an example of a case where the State Level River Management Authority could have monitored the prioritisation of the works to be undertaken to prevent inundation of the airport and areas in the vicinity during the floods of 2018.

Audit further observed that during 2014-19, the Irrigation Department of GoK expended ₹178.99 crore for flood control/ mitigation works in the State including 273 works at a cost of ₹55.17 crore in the test-checked districts of Thrissur, Idukki, Ernakulam and Alappuzha. Works were also executed under the River Management Fund, Atal Mission for Rejuvenation and Urban Transformation (AMRUT) scheme, Kuttanad Development Scheme and Project Management works. These works were taken up at different locations, based on the requests from local people, people's representatives and local bodies without being linked to a comprehensive plan for the management of floods. In the test-checked districts, Audit noticed that no survey or investigation was conducted to identify the flood prone/ vulnerable areas for prioritising the works to be undertaken.

Audit was informed (March 2020) that the Master Plan of only one river[8] *viz.* Chaliyar besides two[9] of the five tributaries of the Bharathapuzha River had been completed. Thus, Master Plans of 42 out of 44 rivers are yet to be prepared though envisaged in the State Water Policy. Non-availability of Master Plans for the major rivers of the State implies scope for inclusion of flood control works on *ad hoc* basis.

GoK stated (March 2020) that micro watershed plans containing details of traditional water bodies such as ponds, lakes, streams and springs were prepared at Grama and Block Panchayat level under 'Haritha Kerala Mission'. However, the fact remains that a State level Master Plan for water resources development and management as envisaged in the SWP is yet to be prepared.

During the Exit conference (February 2021), Additional Chief Secretary, Water Resources Department stated that a draft bill had been finalised for constitution of River Basin Conservation and Management Authority. The Department also informed (April 2021) that when the model code of conduct

[8] Out of 44 major rivers in Kerala
[9] Gayatripuzha and Thoothapuzha

is lifted, the bill is expected to be passed as an ordinance. As per the State Water Policy 2008, preparation of State level Master Plan for water resources development and management is to be a combined effort of various stakeholder departments and the formulation of the same is progressing under the authority of Town and Country Planning Department. With respect to the preparation of master plans for major rivers in the State, priority will be given to those rivers that are prone to flood and passing through densely populated areas *viz.* Periyar, Chalakkudy, Pamba, Meenachil, Muvattupuzha, Karamana, Bharathapuzha and Chaliyar rivers.

Recommendation 2.2: Government may ensure compliance with the provisions of the Kerala State Water Policy such as formulation of a State level Master Plan for water resources development and management, formulation of Master Plans for the major rivers besides constituting a State Level Authority to coordinate all water related activities at the river basin level.

2.3. Non-enactment of legislation to identify and demarcate Flood Plains in the State

Flood plain zoning is a concept central to flood plain management. This concept recognises the fact that the flood plain of a river is essentially its domain and any intrusion into or developmental activity therein must recognise the river's 'right of way'[10]. Flood plain zoning measures aim at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones, so that whenever floods actually occur, the damage can be minimised, if not avoided. A model draft bill for flood plain zoning legislation was circulated by the Union Government in 1975 to all the States. The proposed legislation envisaged creation of a Flood Zoning Authority, survey of flood plains and prohibition or restriction in the use of these lands. The National Disaster Management Authority's (NDMA) guideline on 'management of floods' also has a section on enforcement and regulation related to flood plain zoning.

The State of Kerala has not enacted flood plain zoning legislation and the flood plains of the State have not been identified and demarcated. Had the exercise of identification and demarcation of the flood plains been undertaken, the same could have been used by GoK in their activities on flood control.

The Department of Water Resources replied (November 2020) that the State of Kerala had informed (2013) the Ministry of Water Resources and Ganga Rejuvenation about the practical difficulties and limitations of enacting the flood plain zoning legislation in Kerala. It added that the topography of Kerala was unique when compared with the States that had implemented the legislation.

[10] Source: Planning Commission, GoI, Report of Working Group on Flood Management and region-specific issues for XII Plan (2011).

However, Audit observes that while there may be challenges in implementing such a legislation as envisaged for flood plain zoning, it should not become an absolute deterrent to even initiate a process of identification of the flood plain zones for the 44 major rivers as well as the level of urbanisation and development activities. As per the NDMA Guidelines also, flood plain zoning is necessary to minimise damage in the case of floods by rivers. According to Kerala State Disaster Management Plan, 2016, flood plains are flood prone and hazardous if developmental activities in them exceed an acceptable level. It further states that reclamation and settlement in flood plain areas is a major cause of flood damage in the State. Further, during the course of audit, 913 encroachments of water bodies were noticed in the selected districts as detailed in **Appendix 2.1**. Legislation to identify and demarcate flood plain zones of the State would enable the Government to take proactive measures in controlling potential encroachment activities in the flood plains.

The Department replied (April 2021) that in India, only three States namely Manipur, Rajasthan and Uttarakhand had enacted the legislation as of December 2016. Kerala had never been considered as a major flood prone State till the flood of 2018 unlike the States located in Indo Gangetic plain. The States located on the banks of Ganges, Yamuna and Brahmaputra basins are yet to enact the Flood Plain Zoning Bill. Flood plain zoning needs institutional support and interdepartmental coordination. Though Kerala has an undulating topography and a high population density, Government recognises it is a vital tool in preventing flood. Feasibility study on enacting the Flood Plain Zoning Bill in the State would be conducted when the new Government comes to power.

Audit noticed that the need to prevent encroachments along rivers and flood plains was again emphasised in the draft River Regulation Zone notification, 2016, under the Environment (Protection) Act, 1986 which was circulated to the States by the Ministry of Environment, Forests, and Climate change (MoEFCC). The notification proposes to declare river stretches and flood plain zones as river conservation zones and to regulate or prohibit developmental activities in these zones. Further, though the Coastal Regulation Zone Notification of January 2011 (as amended in 2019) envisages that coastal land from High Tide Line upto 50 m[11] on the landward side along rivers subject to tidal influence fall under the coastal regulation zone and would be regulated as per the provisions of the Act, this would not suffice to check encroachments, as flood plains of only some rivers/stretches of rivers in some districts are covered under the CR Zones.

Flood plains and river beds are some of the natural features that allow absorption of heavy rainfall or a river's overflow and facilitate mitigation of adverse effects, hence permitting uncontrolled constructions and encroachments, particularly in an era of climate change could be extremely short-sighted. Recognising the river's right to expand and contract over seasons is vital. Notwithstanding the practical difficulties in implementing

[11] 100 m upto 17 January 2019

flood plain zoning legislation/ regulation in a densely populated State like Kerala, the Government needs to ensure through active stakeholder engagement that this gap in the regulatory framework is not allowed to persist.

Recommendation 2.3: Government of Kerala may initiate action for a legislation/regulation on flood plain zoning, as well as constitute an Authority to identify and demarcate flood plain zones of the State and to prohibit or restrict the use of these lands.

2.4. Flood Hazard Map not conforming to criteria

Flood Hazard Mapping is a vital component to facilitate the identification of areas at risk of flooding and also helps to prioritise mitigation and response efforts[12].

An Expert Committee constituted by GoI[13] for scientific assessment of flood prone areas in India defined (June 2013) flood prone areas as such areas affected by floods which have a return period of 10 years *viz.* probability of its recurrence and emphasised that the return period of flood would be one of the important criteria for classification of flood prone areas. Flood prone areas were to be initially categorised as Severe, Moderate and Normal. Methodology for identifying these areas as such were also detailed by the Expert Committee. The Expert Committee recommended that each State should set up a Regional Committee which, among other things, would be responsible for delineating flood prone areas of the State based on methodology finalised by it. The State was bound to follow the procedures laid down by the Expert Committee. In line with GoI recommendations, GoK constituted[14] (October 2014) a Regional Committee to identify, demarcate and classify the flood prone areas in Kerala.

GoK formulated a Kerala State Disaster Management Plan approved by the SEC and KSDMA (September 2016) which was intended to be an ever-evolving document formulated under the Disaster Management Act 2005. Audit noticed that the map adopted by GoK and incorporated in the Kerala State Disaster Management Plan 2016 was prepared (2010) by the National Centre for Earth Science Studies (NCESS)[15] in 1:50,000 scale using satellite images. Though Central Water Commission (CWC) in June 2013 had fixed the return period of flood as the criteria for identifying flood prone areas, GoK continues to rely upon a flood prone area map prepared in 2010 which does not adhere to the criteria fixed by CWC for earmarking an area as flood prone.

The inadequacy of the maps adopted in the DM Plan was evident from the reply of NCESS to Audit (July 2019) that large scale maps would be required for application at the local level. The need for integrating field mapping, high resolution satellite images and Digital Elevation Models for generation of database for local level application was also emphasised by NCESS.

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12 Source: Flood Hazard Atlas of Odisha prepared by National Remote Sensing Centre, GoI
13 Ministry of Water Resources, Central Water Commission
14 Additional Chief Secretary, Water Resources Department as Chairman, Chief Engineer, CWC Coimbatore as Member Secretary, Secretary, KSDMA as member and two other members
15 NCESS – formerly known as Centre for Earth Science Studies

Thus, flood susceptibility map of NCESS as adopted by GoK in its Disaster Management Plan needs to be revisited in order to make it useful for local level applicability.

Audit observed that the Regional Committee[16] constituted (October 2014) to identify, demarcate and classify the flood prone areas in Kerala by July 2015 met only twice during 2014-19 and could not achieve its stated objective.

GoK in its response stated that

- the flood susceptibility map was prepared by the State in 2010 when the Expert Committee's recommended methodology was not available. It is not meant to be a substitute for the large scale Flood Hazard map required to be prepared (in accordance with the methodology prescribed by the Expert Committee) and provided by the Ministry of Water Resources, National Remote Sensing Centre, Survey of India and Central Water Commission as notified in the Disaster Management Plan of 2016 and the National Disaster Management Guidelines-Management of Floods 2008, which when obtained, would be incorporated in the State Disaster Management Plan.
- The Department said that CWC informed (May 2020) that there was not much progress in the matter of large-scale flood mapping due to non-availability of high-resolution digital elevation models for the States. Thus, the delay in identification, demarcation and classification of flood prone areas cannot be attributed to the State Government.
- In the Exit Conference (18 January 2021) Member Secretary, KSDMA stated that the NCESS map adopted in the State DM Plan 2016 had an accuracy of 70 *per cent* which was sufficient for all planning purposes.

The reply of the Government confirms the audit observation that the State is yet to have a large-scale flood hazard map satisfying the criteria, even though the flood hazard map is a vital component for identification of risk prone areas and to prioritise response efforts. Though seven years have elapsed since the methodology was prescribed for preparation of flood prone map, the State is still dependent on the 2010 map.

Audit observed that United Nations Development Programme in its Post Disaster Needs Assessment document[17] (released after the Kerala floods of 2018) referring to the available map notes that the same has been prepared at a scale of 1:50,000 while indicating that this has resulted in awareness among

[16] Based on the recommendations of Expert Committee for Scientific Assessment of Flood Prone Areas in India, Government of Kerala constituted (October 2014) a Regional Committee with Additional Chief Secretary, Water Resources Department as Chairman to identify, demarcate and classify the flood prone areas in Kerala.

[17] Commissioned by the Kerala Government, the Kerala PDNA was undertaken jointly by experts from the line Ministries and the United Nations.

the citizens about hazards and environmental conservation, these maps should ideally be prepared at a scale of 1:10,000 or 1:5000 if they are to be useful for planning and policy making. Accordingly, the contention raised in the Exit Conference that this map is sufficient for planning is not acceptable because the map does not meet the criteria set by CWC and also since NCESS, which created this map had informed Audit that the map is insufficient.

Recommendation 2.4: Government of Kerala may take steps to ensure availability of large scale flood hazard maps conforming to CWC criteria which would facilitate planning, policy making and prioritisation of flood mitigation activities by identifying flood risk areas.

Capacity Building in Disaster Management

2.5. Implementation of Civil Defence in the State

The Disaster Management Act envisages requisite institutional mechanisms to promote general education, awareness and community training in regard to forms of disasters to which different parts of the State are vulnerable and the measures that may be taken by such community to prevent the disaster, mitigate and respond to such disaster. In order to create a mechanism for efficient and effective response to any natural or manmade emergency, a sizable trained volunteer force of emergency responders at the grassroots level needs to be made available as standby in all vulnerable urban/ rural areas[18]. Accordingly, amendment was enacted (2009) to the definition of "civil defence" contained in the Civil Defence Act, 1968 so as to bring within its scope the measures which may be taken for the purpose of disaster management during, at, before, or after any disaster. Since the community was invariably the first responder to any disaster, adequate awareness and preparedness of the community to respond to any such emergency/ disaster would be very crucial in mitigating the damage and suffering.

In Kerala, the post of Director of Fire Force was redesignated (October 1980) as the Commandant General (Home Guards, Civil Defence and Fire Services). However, Civil Defence was officially formed in the State under the Fire and Rescue Services Department only on 30 August 2019. Consequently, the implementation of three schemes launched by GoI during 2009-2016 to strengthen civil defence in the State *viz*., 'Revamping of Civil Defence', 'Mainstreaming Civil Defence in Disaster Risk Reduction' and the 'Aapda Mitra' scheme suffered setbacks. An amount of ₹4.43 crore was released by GoI during the period towards implementation of these schemes, which could not also be effectively utilised. Audit noticed that due to non-formation of Civil Defence in the State, little headway was made in implementing these schemes meant to ensure the availability of an active volunteer-based

[18] Suggestions of K. M. Singh (Member NDMA) Committee to integrate Civil Defence in Disaster Management framework, endorsed by Home Minister's Civil Defence Advisory Committee in April 2008

emergency force for disaster mitigation. The following three paragraphs highlight the issues observed by Audit.

2.5.1. Unfruitful expenditure of ₹1.54 crore on construction of Civil Defence Training Institute

Figure 2.1: Civil Defence Training Institute Building
29 October 2019, CDTI, Viyyur, Thrissur District
Photo taken by Audit party, attested by Director, Fire and Rescue Services Academy

Audit observed that under the scheme 'Revamping of Civil Defence' launched by GoI in July 2009, ₹154.20 lakh out of ₹195 lakh received from GoI was expended on construction of a Civil Defence Training Institute (CDTI) at Viyyur in Thrissur district. Joint field verification (October 2019) revealed that though the building, completed in 2014, was envisaged to function as a State level residential training institute for civil defence under the Fire and Rescue Services Department (F&RSD), it was being utilised as a camping place for members of the National Disaster Response Force (NDRF), with the classrooms and dormitory converted as barracks. Audit observed that the building which was in possession of Revenue Department till April 2018, was handed over to F&RSD on the pre-condition that the NDRF battalion was to be accommodated in the building until a new own building was identified. Joint verification (October 2019) revealed that possession of only a small room had in fact been transferred to the Director of CDTI, which was used for office functioning, with the rest of the building continuing to be occupied by NDRF. The residential training centre to impart training to civil defence volunteers has not become functional despite passage of over five years. Had the State rolled out Civil Defence, selected the volunteers and trained them in a timely manner, the CDTI building could have catered to the envisaged objective.

Figure 2.2: CDTI being used as barracks for NDRF battalion and materials being stored in lobby
29 October 2019, CDTI, Viyyur, Thrissur District
Photo taken by Audit party, attested by Director, Fire and Rescue Services Academy

Audit had previously pointed out[19] the non-functioning of CDTI due to delay in creation of posts and purchase of equipment, to which GoK replied (November 2016) that the responsibility to activate CDTI has been entrusted to KSDMA. The reply offered by GoK in November 2020 was that the temporary pre-positioning of NDRF team in the building facilitated judicious utilisation of an otherwise idling building. It was also stated that there was adequate facility in the Fire and Rescue Services Academy to provide captive training to Civil Defence Volunteers and in-service men. The reply is contrary to facts as it was the responsibility of KSDMA to activate CDTI building so as to cater to the dedicated purpose of a full-time residential training institute for civil defence, which remains unrealised. Further, DG, F&RS stated (December 2020) that as a variety of training schedules[20] were being conducted in Fire and Rescue Services Academy, it was essential to allot maximum space for the residential training of civil defence volunteers at CDTI. On pointing this out in Exit Conference (January 2021), GoK stated that though allocations were made for construction of CDTI and DG, F&RS designated as Director General (Civil Defence), Civil Defence was not notified in the State until 2019. For this reason, even if a building was constructed there, no training would have happened and the scenario of State's flood response would not have changed. The reply reveals the low priority given to the formation of Civil Defence and for equipping the volunteers as emergency responders in crisis situations. Despite designating Director of Fire Force as the Head of Civil Defence as early as in October 1980, the State was left without any civil defence volunteers for the past 38 years.

During the Exit Conference, Audit was informed that, now that a separate piece of land has been allotted to NDRF for constructing their own building and Civil Defence has been formed, NDRF would move out soon. In view of the idling of existing infrastructure provided for training in the past years and construction of new building not having commenced yet, the possibility of NDRF moving out and the entire building of CDTI being utilised for Civil Defence related trainings in the near future remains doubtful.

2.5.2. Mainstreaming Civil Defence in Disaster Risk Reduction

Government of India scheme 'Mainstreaming Civil Defence in Disaster Risk Reduction' for strengthening the Civil Defence setup in the Most Vulnerable Districts/ Multi Hazard Districts envisaged creating a response system based on minimum permanent staff backed by skilled volunteers. Six[21] districts in Kerala were classified (2014) as 'Most Vulnerable'. Ministry of Home Affairs released (November 2014) ₹225.52 lakh as first instalment of grant-in-aid to the State for the financial year 2014-15. This included ₹198.52 lakh for the six most vulnerable districts and ₹27 lakh to the CDTI envisaged under the scheme 'Revamping of Civil Defence'. Audit observed that the entire ₹225.52

[19] Paragraph 4.4.6.1 of the Audit Report of Comptroller and Auditor General of India for the year ended March 2016, currently under consideration of PAC.
[20] Station officer course, Driver Mechanic course, Fireman course etc.
[21] Ernakulam, Kannur, Kottayam, Kozhikode, Thiruvananthapuram and Wayanad

lakh received in November 2014 was retained by the Finance Department until March 2017, when it was provided in the budget as Supplementary demand for grants, as proposed by the Revenue Department. As the Director General of Civil Defence did not receive the money, the scheme could not be implemented and the amount was resumed by GoK in June 2017 without any further disbursement. Thus, GoI assistance of ₹225.52 lakh for strengthening of Civil Defence set up in the State could not be utilised for the envisaged purpose. GoK replied that a request has been made (November 2020) to Home Department to revalidate the amount for implementation of the scheme by F&RSD.

2.5.3. Slow pace of implementation of Aapda Mitra Scheme

National Disaster Management Authority (NDMA) approved 'Aapda Mitra', a 100 *per cent* Centrally Sponsored Scheme, with focus on training 6000 community volunteers in disaster response in the 30 most flood prone districts (200 volunteers per district) in India. This was to bestow them with skills needed to respond to the immediate needs of their community and undertake basic relief and rescue tasks during emergency situations such as floods, flash floods and urban flooding. In Kerala, Kottayam district was selected for implementation of the scheme. Consequent upon signing (November 2016) of MOU of two-year validity with KSDMA, NDMA released ₹22.70 lakh[22] to GoK in February 2017.

Audit observed that while more than half of the beneficiary States[23] had completed the selection of volunteers and were about to commence training for volunteers in 2017 itself, KSDMA forwarded the list of selected volunteers from Kottayam district to NDMA only in February 2018. Verification of records at F&RSD and KSDMA showed that though the allotted funds were resumed in February 2018, GoK released the amount subsequently to KSDMA in June 2018 and KSDMA arranged training to 200 enlisted volunteers from Kottayam from October 2018 to March 2019. Thus, the services of the envisaged trained team of community volunteers were not available during the floods of August 2018.

Audit further observed that the emergency responder kits[24] to the trained volunteers were distributed by KSDMA only in December 2019, one year after the completion of training of the first batch of volunteers. Purchase of emergency stockpile[25] was still under process (May 2020).

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22 50 *per cent* of the sanctioned amount

23 Andhra Pradesh, Delhi, Gujarat, Himachal Pradesh, Karnataka, Manipur, Meghalaya, Nagaland, Punjab, Tamil Nadu, Tripura, Bihar, Uttarakhand and West Bengal as per the information provided by NDMA in March 2021.

24 Kits comprising Life Jacket, Solar Torch, Safety gloves, Nylon rope, Pocket knife, First Aid Kit, Rain coat, Water bottle etc.

25 Stockpile consisting of Personal Floatation device, Torch, Safety Gloves, Rope, Lifebuoy, Oars, Paddles, Anchors, Bailer, OB Motor, Fire Extinguisher, Emergency Spotlight, Stretcher, Tool Kit, Walkie-talkie, first aid kits, GPS sets etc.

The Department of Revenue and Disaster Management replied (November 2020) that

- While the project was launched in November 2016, the modalities for implementation were briefed in the National Technical Committee meeting on 01 April 2017 following which the first meeting of the State Project Steering Committee was held on 31 August 2017 in which public notice for the scheme was handed over to DDMA Kottayam for circulation. The scheme was formally inaugurated on 13 October 2017.
- Owing to adverse ways and means position, the first instalment of ₹22.70 lakh allotted to KSDMA vide GO dated 14 March 2018 was not released and after allotment in 2018-19, the amount was finally credited to KSDMA account in June 2018, after which alone activities such as printing of training modules, training of volunteers etc. could be taken up.
- Fire and Rescue Services Academy was approved as the training Academy by NDMA on 08 June 2018.
- The catastrophic floods of August 2018 rendered the entire operational machinery out of gear and KSDMA being in the vanguard of the Disaster Management activities could not provide attention to other matters.
- The second instalment of ₹22.70 lakh was allotted vide GO dated 21 December 2019. Despite the delay in receipt of funds, KSDMA managed to supply the emergency responder kits in December 2019 itself.
- GeM portal through which emergency responder kits were purchased had many glitches and required frequent communication with GeM portal managers for rectification. Samples of each item had to be purchased first to get assurance of quality and this took time.
- KSDMA has organised various programmes to ensure continued participation of volunteers in the mission 'towards safe state'. Exposure and orientation programme (29 January 2019), training on Civil Defence (10 December 2019), annual refresher training for volunteers (09 to 12 July 2019), meeting with Unit Coordinators (13 November 2019) were conducted.
- The State is considered by NDMA as a model State in the implementation of Aapda Mitra scheme. NDMA decided to conduct the national review meeting in Kerala in 2020 to demonstrate the achievements of Aapda Mitra in Kottayam district.
- Further, Government of India has extended (July 2020) the project till 31 December 2020 as most States could not complete the programme owing to local implementation difficulties.

- Training by Fire and Rescue Services Academy commenced on 22 October 2018 after the floods of 2018 (meant for 200 volunteers in batches of 25) on specific dates. Many volunteers dropped out citing personal and livelihood reasons, captive nature and length of training etc. Aapda Mitra being a voluntary capacity building programme, there is no legal provision to demand work from volunteers who render work voluntarily based on request.
- The programme was successful in Kerala as owing to the pragmatic approach of NDMA, KSDMA and the DDMA, they were able to impart a spirit of voluntarism in the participants.

During the Exit Conference, it was added that the scheme deadline has been extended to March 2021.

Audit noticed that subsequent to signing of MoU of Aapda Mitra Scheme in November 2016, procedural delay at various individual stages[26] resulted in distribution of emergency responder kits in December 2019, one year after completion (October 2018) of training of the first batch of Aapda Mitra volunteers. Thus, the disaster response skills acquired by the volunteers were yet to be supplemented with vital equipment for basic relief and rescue and coordinated under the Aapda Mitra scheme for the benefit of the local community, despite another severe flood having affected the State in August 2019. The justification of Government that the extension of the project (July 2020) till 31 December 2020 (and subsequently till 31 March 2021) by GoI due to the fact that most States could not complete the programme owing to local implementation difficulties is not acceptable as a reason for justifying the slow pace in Kerala which has a higher degree of disaster risks as compared to the rest of the country (Paragraph 1.2 of Kerala State Disaster Management Plan 2016) and more so when there was only one selected district (Kottayam) as part of the programme. Further, it was seen that the list forwarded to KSDMA was taken directly from the Community Rescue Volunteer Scheme list in Kottayam by the DDMA. Being readily available, this could have been forwarded much earlier than February 2018 to NDMA, had the level of preparedness been higher.

Though it was stated that the F&RS Academy was approved by NDMA as the training Academy in June 2018 only, as pointed out in Paragraph 2.5.1 of this report, the State had a Civil Defence Training Institute right from 2014, which if utilised as a dedicated training institute, could have catered to the training needs of Aapda Mitra too. Further, DG (F&RS), had earlier requested (November 2017) Revenue and Disaster Management Department to handover the CDTI building and premises urgently for conducting trainings of Aapda Mitra/ Community Rescue Volunteer Scheme.

[26] First meeting of the State Project Steering Committee took place five months after the National Technical Committee meeting, hence request for list of volunteers was sent only in August 2017 by KSDMA, list forwarded by DDMA Kottayam received by KSDMA in November 2017 was forwarded to NDMA only in February 2018, release of funds by GoK in June 2018 and of second instalment by December 2019.

Though the reply mentioned (November 2020) that the State has been considered by NDMA as a model State in the implementation of Aapda Mitra scheme and that NDMA even decided to conduct the national review meeting in Kerala in 2020 to demonstrate the achievements in Kottayam district, Audit noted that the document forwarded in support of the 'national review' meeting in fact pertained to a 'regional assessment' workshop and the contention of Kerala being a model State in Aapda Mitra was not supported by documents.

Recommendation 2.5: The State may initiate action to operationalise the Civil Defence Training Institute for the fulfilment of the intended objective of training and equipping sufficient number of Civil Defence volunteers. Civil Defence needs to be strengthened in the State through ensuring a) adequacy of communication facilities and trained volunteers including availability of licensed HAM radio operators, and b) availability of emergency responder kits to enable timely and effective rescue operation during emergency/ disaster situations.

2.6. Revamping of Kerala Fire and Rescue Services Academy

The Director General (Fire and Rescue Services) (DG) requested Government of Kerala (August 2016) to allot ₹98.25 lakh[27] from the savings of the 13th Finance Commission grant-in-aid for revamping F&RS Academy at Viyyur, Thrissur. The proposal included procurement of vital equipment for rescue operation during flood such as Self-Contained Underwater Breathing Apparatus (SCUBA) Set (₹26 lakh), Breathing Air Compressor (₹ six lakh) etc. Accordingly, GoK accorded Administrative sanction (September 2016) for the proposal and the funds were credited by KSDMA to the treasury account of DG (F&RS) in March 2017.

Audit observed from scrutiny of records at the F&RSD that the funds remained idle with F&RSD until March 2018, when these were resumed by GoK. Further examination revealed that though tenders were invited (May-June 2018) by F&RSD for the purchase of requisite items in 2018-19, these had to be cancelled (August 2018) as the funds were already revoked by GoK. Nevertheless, even without obtaining Utilisation Certificates from F&RSD, KSDMA recorded the entire amount resumed by GoK as expenditure for the year 2016-17.

Joint physical verification conducted by Audit along with Assistant Director, F&RS Academy (October 2019) revealed severe shortage of equipment, vehicles and infrastructural facilities **(Appendix 2.2)** in the Academy. With the sparse facilities available in the F&RS Academy, Audit observed that the 3173 trainees who enrolled in Academy during the audit period (2014-19) could not get the benefit of quality training in simulated environment to equip them both mentally and physically for quick response during a crisis situation.

[27] The amount was from fund provided by 13th FC during the period 2010-11 to 2014-15 of which ₹103.97 lakh remained unutilised with KSDMA. The remaining amount of ₹5.72 lakh in the fund balance of KSDMA was approved by GoK (March 2017) to be utilised for making the SEOC Green Energy Compliant.

GoK replied (November 2020) that KSDMA had to book the amount as outgo of funds since the amount allotted and released by Government under the supplementary grant was in turn released to F&RSD and the same has subsequently been resumed by Government. The efforts made by the department to procure items in 2018-19 fell through because the Government did not release the resumed funds mainly due to the adverse ways and means position arising from the floods of 2018. GoK also referred to the audit contention that had the purchases been effected the material could have been utilised for training purposes as hypothetical. The reply is not justifiable as KSDMA should have monitored more closely the utilisation of funds released by it. GoK informed in the Exit conference (January 2021) that the proposal to re-credit the funds to F&RSD and revalidate it for the purposes for which allotted or return the funds to KSDMA for capacity building has been rejected (July 2020) by the State Executive Committee.

Audit notes that the shortage of equipment at the Academy was also accompanied by shortages in Fire and Rescue stations and hence needs immediate attention as Fire and Rescue Services Department, established in 1962 is the dedicated force under Government of Kerala equipped for rescue services during disasters. In exercise of the powers vested in the Disaster Management Act 2005, KSDMA proposes the annual fund requirements to Government of Kerala for Disaster Management. Analysis of records relating to formulation of Annual plans of KSDMA from 2016-17 onwards showed that though regular provision of funds to F&RSD was made in the annual plan proposals of KSDMA and ₹25 crore allotted earlier[28] for the purchase of modern rescue equipment, the equipment in the test-checked fire stations was not adequate to meet the unprecedented flood situation in 2018. The fire station at Chengannur, for instance, one of the worst hit areas during 2018 flood did not possess Rubber Dinghy boats, speed fibre boats or scuba sets. Rubber dinghy boats from Tamil Nadu and Odisha had to be depended upon. No high beam lights were available for night rescue operations. Communication devices such as HAM radios were not seen utilised effectively in test-checked districts.

Audit observed that urgent attention needs to be given to reviewing availability of equipment in possession of the Academy and fire stations across the State.

Recommendation 2.6: Priority needs to be given to review the adequacy of equipment, vehicles and infrastructural facilities in the Fire and Rescue Services Academy as well as in Fire and Rescue stations so that the GoK's dedicated force for rescue services may be adequately equipped to handle any flood or other disaster situation.

[28] between 2009-10 and 2012-13

2.7. Non-functioning of Virtual Cadre for Disaster Management

The Kerala State Disaster Management Plan (KSDMP) approved (September 2016) by Government of Kerala with its focus on disaster risk reduction in the State, envisaged formation of a Virtual Cadre for Disaster Management. The Virtual Cadre would principally be 15 selected individuals (one from each district and one at the State level) from each department, with at least 20 years or more of service left. The members of this Virtual Cadre would be the departmental nodal officers responsible for liaising and coordinating with KSDMA and DDMAs in disaster management. It was envisaged that the disaster-specific nodal departments through Virtual Cadre would also work in tandem with the State Emergency Operations Centre (SEOC) and District Emergency Operations Centres (DEOC) for ensuring coordinated response to disastrous events.

Departments were to intimate to KSDMA, the names of members nominated to the Virtual Cadre. State Government was to issue an Executive order under Section 16[29] of the DM Act, 2005 formalising[30] the Virtual Cadre once the selection list was approved by the State Executive Committee (SEC). Audit observed the following;

- Consequent upon the formulation of KSDMP in September 2016, GoK issued (November 2017 and February 2018[31]) orders instructing Heads of 26 Departments to furnish details of officials to be included in the Virtual cadre to KSDMA before 31 December 2017. Eight[32] Departments forwarded (between November 2017 and May 2018) the lists of officials to be included in the Virtual Cadre of disaster management. The information furnished by five[33] out of the eight Departments was not in consonance with the criteria stipulated in the Government order with reference to educational qualification, date of entry in service and years of service left. Though the data were returned to the departments seeking rectification, no further response was obtained from the departments.
- KSDMA did not take up with SEC, the matter of approval of the selection lists of the three remaining departments. Consequently, GoK did not issue executive orders under Section 16 of Disaster Management Act, 2005 for formalising the Virtual Cadre.

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29 The State Government shall provide the State Authority with such officers, consultants and employees, as it considers necessary, for carrying out the functions of the State Authority

30 Paragraph 5.3 of State Disaster Management Plan

31 Order was issued for including one more Department.

32 i) Commissionerate of Land Revenue, ii) Public Works Buildings, iii) Directorate of Panchayat, iv) Directorate of Health Services, v) Directorate of Mining and Geology, vi) Directorate of Ground Water Department, vii) Directorate of Soil Survey and Soil Conservation and viii) CE Irrigation and Administration

33 i) Directorate of Panchayat, ii) Directorate of Health Services, iii) Directorate of Mining and Geology, iv) Directorate of Soil Survey and Soil Conservation and v) CE Irrigation and Administration

Government cited (November 2020) insufficient allotment of funds and difficulty in enrolment to a voluntary and non-remunerative service as hurdles in implementation of the scheme and stated that 96 officers from eight departments have been initially provided training and inducted and that more personnel are expected to be inducted subject to availability of funds and willingness of officers.

To the specific question of why lists of officials of the three Departments mentioned above were not presented to SEC and Executive orders issued formalising the cadre, Member Secretary KSDMA replied in the Exit Conference (January 2021) that a prudent examination was required before finalising the cadre.

Audit is of the view that considering the envisaged role of the Virtual Cadre in disaster risk reduction through effective liaising and coordination with KSDMA/ DDMAs and SEOC/ DEOCs, it is imperative that the State gives attention to operationalise effectively the Virtual Cadre across all the departments at the earliest. Since the State Government was to issue an Executive order under Section 16 of the DM Act, 2005 formalising the Virtual Cadre once the selection list was approved by the State Executive Committee, non-approval of a selection list would in effect be reflective of the relative low priority being given to implementation of this item in the State's Disaster Management Plan. Since the Kerala State Disaster Management Authority currently functions with only 27[34] full time employees, the role that could be potentially played by an active Virtual Cadre during disasters cannot be underestimated.

Recommendation 2.7: Virtual Cadre needs to be formalised and strengthened in the State so that the disaster-specific nodal departments could work in tandem with the State/ District Emergency Operations Centres through the cadre, for ensuring coordinated response to disastrous events.

[34] Position as in March 2019

August 10, 2018
Cheruthoni Dam, Idukki District

CHAPTER III
FLOOD FORECASTING AND RESERVOIR OPERATION

3 FLOOD FORECASTING AND RESERVOIR OPERATION

Flood Management includes planned engineering measures (structural and non-structural) aimed not only at controlling the flood, but also providing optimum utilisation of stored surplus water during lean seasons. Structural measures include multipurpose reservoirs and retarding structures for storage of flood waters, channel improvements to increase flood carrying capacity of the river, embankments for keeping the water away from flood prone areas, improvements in drainage system etc. which have the effect of restricting the movement of flood water into flood plains. Non-structural measures such as flood forecasting and warning, soil conservation, flood proofing, flood plain zoning etc. largely depend upon how accurately the estimation of future stage or flow of incoming flood and its time sequence at selected points along the river, could be predicted[35].

The devastating floods in Kerala during August 2018 severely affected 13 of the 14 districts in the State resulting in huge loss of life and property. Kerala received 2,346.60 mm rainfall between 01 June and 19 August 2018, which was about 42 *per cent* higher than the normal rainfall of 1,649.50 mm during the same period[36]. Further, the rainfall over Kerala during June, July and August 01 - 19, 2018 was 15 *per cent*, 18 *per cent* and 164 *per cent* respectively above normal (CWC, 2018). As the Performance audit included examining technical aspects which required expert support, Indian Institute of Science (IISc) Bangalore was engaged as Consultant to study the Kerala floods of August 2018, from a hydrological perspective. The focus of the study was the Periyar river basin which covers an area of 5,159.71 square kilometres. The following paragraphs are the findings of Audit including those based on the study undertaken through IISc, Bangalore.

3.1. Adequacy of rain gauges in Periyar basin

Rain gauges[37] are instruments used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over an area in a predefined period of time. Measurement of rainfall at several critical locations in the basin is extremely important because of the high spatial variability of rainfall. The accuracy of rainfall estimation over a region with significant spatial variability in rainfall is dependent on distribution of rain gauges in the region. Rain gauge density[38], therefore, plays an important role in quantifying the rainfall amount over a region.

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35 Manual on Flood Forecasting, CWC, 1989
36 CWC Report, 2018
37 Rain gauges are also known as udometers, pluviometers, or ombrometers.
38 Rain gauge density is defined as the ratio of the area of the catchment to the number of rain gauges there.

An examination of the existing density of IMD rain gauges[39] in the Periyar basin with respect to norms stipulated by the Bureau of Indian Standards[40] was carried out by IISc, to assess the adequacy of rain gauges in the basin. **Figure 3.1** shows the locations of the existing rain gauges and flow gauges in the basin.

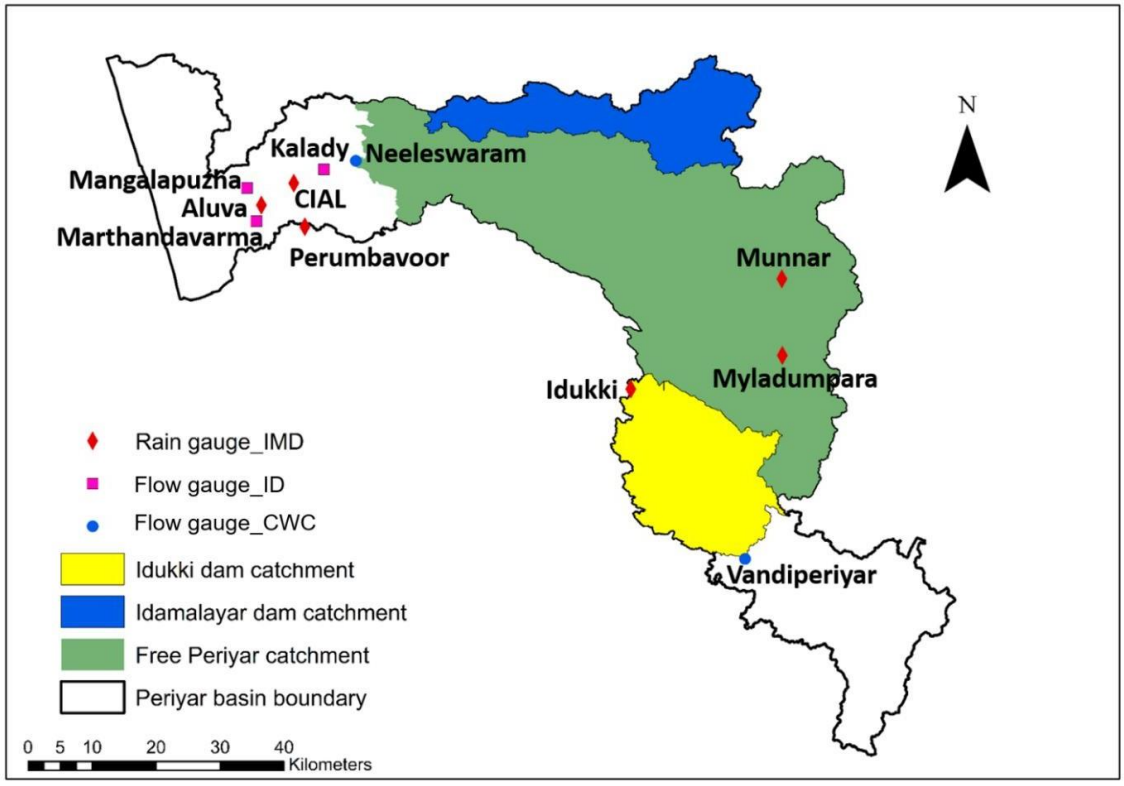

Figure 3.1: Locations of existing rain gauges and flow gauges in the Periyar basin (2019)

(Source: IMD, CWC and Irrigation Department)

The rain gauge density as recommended by BIS code (IS 4987:1994) is given in **Table 3.1**.

Table 3.1: Recommended minimum rain gauge density

Region type	Rain gauge density (sq. km per gauge)
Plains	500
Regions with average elevation of 1000 m above MSL	250-400
Hilly areas with heavy rainfall	150

(Source: BIS Code, IS 4987:1994)

Periyar basin is characterised largely as a hilly terrain upto Neeleswaram and receives heavy rainfall. Therefore, according to the IS 4987:1994 one rain gauge per 150 sq. km is required in the basin, up to Neeleswaram (Region type III), whereas, the area downstream of Neeleswaram lies in the Region type I

[39] IS 5225:1992 provides that the Director General of Meteorology, New Delhi has been designated the sole authority for ensuring the correct rainfall registration in India.

[40] IS 4987:1994 Recommendations for establishing network of rain gauge stations.

(Plains) and therefore requires one rain gauge per 500 sq. km. The Periyar basin is divided into a number of sub-catchments. The details of additional rain gauges needed in the catchments are given in **Table 3.2**.

Table 3.2: Number of IMD rain gauges in place and additional numbers required

Catchment	Area (sq.km)	Density of rain gauge required (sq.km/gauge)	Minimum number of rain gauges required	Existing number of IMD rain gauges	Additional numbers required
Start of the basin boundary till Vandiperiyar	737.61	150	5	0	5
Idukki	569.55	150	4	1	3
Idamalayar	469.49	150	4	0	4
Free Periyar (downstream of Idukki and Idamalayar till Neeleswaram)	2367.22	150	16	2	14
Downstream of Neeleswaram	1015.83	500	3	3	0
Total	**5159.71**		**32**	**6**	**26**

(Source: Kerala Floods 2018, Report of IISc, Bangalore, July 2020)

It is therefore evident that against the recommended minimum requirement of 32 rain gauges in the Periyar basin, only six rain gauges were in place. Audit observes that the shortfall of 26 rain gauges in the basin resulted in lack of real time data on spatially distributed rainfall which could have an adverse impact on flood forecasting and alleviation measures.

Additional Chief Secretary, Water Resources Department, GoK, stated (November 2020) that the Irrigation Department maintains 10 meteorological stations with rain gauges in Periyar basin. Audit was also informed that installation of 18 Tipping Bucket Rain Gauges was in progress and Government intends to develop a full-fledged inflow forecasting and flood early warning system National Hydrology Project (NHP).

Though agencies like KSEBL, Irrigation Department etc. maintain rain gauges in Periyar basin, IMD informed (February 2021) Audit that only data generated by those gauge stations conforming to IMD standards (measured at 0830 hours IST daily and reported to IMD) is utilised by IMD. Since data from Irrigation Department gauges were not utilised by IMD, they were not considered while assessing the adequacy of rain gauges in Periyar basin. However, as the already installed/ proposed to be installed rain gauges under the NHP could also be useful for increasing the accuracy of rainfall estimation by IMD, the Irrigation Department may examine the feasibility of sharing of data with the IMD for the purpose by ensuring that the gauges conform to IMD specifications. This needs to be prioritised as irregular distribution of rain gauges could create an information gap in time and space, ultimately hindering decision-making.

The Government further replied (April 2021) that the equipment for installing 18 Tipping Bucket Rain Gauges in Periyar basin under National Hydrology Project have IMD specifications and therefore, the data generated by TBRGs of Irrigation Department could be used by the IMD. Nine of these have

already been installed and the remaining nine TBRGs will be installed, commissioned and made fully operational by 31 May 2021.

Recommendation 3.1: Adequacy of the number of rain gauges capable of generating real time data in order to ensure accuracy of rainfall estimation may be ensured. System of sharing data from rain gauges with IMD must be put in place at the earliest.

3.2. Adequacy of flow gauge density in Periyar Basin

Flow gauge[41] density helps to determine the minimum network of flow gauges required to avoid serious deficiencies in developing and managing water resources[42]. Adequate flow gauge density is especially important in flood prone regions to provide useful information on flow depth/ discharge to help in operational decisions.

Audit observed that against the requirement of three flow gauges in the 5,159.71 sq.km. Periyar basin as per World Meteorological Organisation 2008 norms (one flow gauge per 1,875 sq.km. hilly terrain), five flow gauges were installed in the Periyar basin by CWC and the Irrigation Department, of which three gauges at Kalady, Mangalapuzha and Marthandavarma are maintained by the Irrigation Department and the other two gauges at Neeleswaram and Vandiperiyar are maintained by the CWC. Thus, the existing number of flow gauges in the basin as a whole, was adequate. However, there was shortfall of one flow gauge in the free Periyar catchment, comprising of 2,367.22 sq.km of hilly terrain. Thus, in addition to the Neeleswaram flow gauge, an additional flow gauge needs to be located just upstream of Bhoothathankettu barrage[43], which is a major control point in the basin, receiving flows from a large free catchment (contributed by Perinjankutty, Pooyamkutty and Muthirapuzha tributaries and overflows/ spills from Idukki, Lower Periyar and Idamalayar dams).

Additional Chief Secretary, Water Resources Department, GoK replied (November 2020 and April 2021) that in addition to the three gauges in the Periyar basin, it is proposed to install three[44] Radar Level Sensors (RLS) under NHP. Once it is fully operational, it is expected that heavy flow from upper catchment of Bhoothathankettu could be measured and observed on real time basis. Chief Engineer, Irrigation Design and Research Board (IDRB) has assured that the RLS, which will provide real time data in every 15 minutes, will be commissioned and made fully operational by 31 May 2021.

3.3. Flood Forecasting Stations not set up in the State

The activity of flood forecasting includes level forecasting and inflow forecasting. Level forecasts are issued once the water level in a river touches a

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41 Flow gauge is a device that measures flow rate of a liquid, gas or steam. It could be measuring, for instance, the velocity of fluid over a known area.

42 Source: World Meteorological Organisation (WMO), 2008.

43 IISc Report on Kerala Floods by P P Mujumdar et al.

44 at Bhoothathankettu, Malayattoor and Neriyamangalam

pre-defined warning level (usually one meter below the danger level but dependent on threat perception of the particular location). The level forecasts help user agencies in deciding mitigating measures like evacuation of people and shifting people and their movable properties to safer locations. Inflow forecasting is used by various dam authorities in optimum operation of reservoirs for safe passage of flood downstream as well as to ensure adequate storage in the reservoirs for meeting demand during non-monsoon period.

Audit noticed that CWC requested (November 2011) Government of Kerala to provide the list of reservoirs which required inflow forecasting stations and list of cities/ towns for flood forecasting purpose. CWC confirmed (August 2019) to Audit that GoK did not furnish the details and hence, no Flood Forecasting Stations (FFS) were set up by the CWC in the State. This was despite 275 flood forecasting stations having been set up by CWC across the country by the year 2017.

The Department of Water Resources (WRD) replied (November 2020) that the Irrigation Department had to address specific technical matters such as the technology of flood forecasting proposed to be used, usability of the system in steep, flashy rivers in Kerala. The viability of an effective forecasting system suitable for peculiar terrain of Kerala was discussed with CWC officials on several occasions.

Audit however noticed that subsequent to floods of 2018, three level forecasting stations and two inflow forecasting stations were installed (2019) by CWC in the State indicating the suitability of the FFS in the State.

The Department informed (April 2021) that the list of flood prone cities/ towns requiring flood forecasting stations and also the list of reservoirs, which need inflow forecasting has been forwarded on 17 April 2021. Government is on course to develop a full-fledged inflow forecasting and a flood early warning system under National Hydrology Project operational in all river basins in Kerala for real time monitoring by installing 99 Tipping bucket Rain Gauges, 56 Radar Level Sensors and 13 Automatic Weather Stations. Equipment including data loggers have been procured and 33 TBRGs, one RLS and seven AWS installed and the remaining would be installed by 31 May 2021.

The failure of GoK to provide list of reservoirs and cities/towns to CWC resulted in non-installation of FFS in the State and resultant deprival of data which State could have utilised for flood forecasting purpose.

3.4. Non-completion of a project intended for obtaining data required for flood management

The project Modernisation of Hydrology Information System implemented by Irrigation Department, GoK involved supply, installation and commissioning of Real Time Data Acquisition System (RTDAS) capable of delivering real time data on rainfall, streamflow etc. and assuring data retrieval for a specific period without interruption. The objective of RTDAS was to provide reliable

hydrological information required for flood/ drought management, water availability and quality management, streamflow forecasting, integrated operations of reservoirs etc.

Based on competitive tender, the work was awarded (April 2014) to the lowest bidder[45] for ₹1.34 crore with time of completion (TOC) as three months (July 2014). The TOC was initially extended up to 25 October 2014 based on the supplier's request. Citing delay in installation of server (to be done by Irrigation Department), it was extended upto 30 September 2016. No further extension of time was provided and ₹30.19 lakh being the cost of 14 Radar Level Sensors (RLS) was paid to the firm in June 2016.

Audit observed that though all the equipment were installed, many of them were not functional (status as of August 2020) as detailed in **Table 3.3**.

Table 3.3: Status of Real Time Data Acquisition System

Sl. No.	Item of work	Quantity	Unit rate	Total quoted amount	Status of execution (as of August 2020)
1	Supply, installation, testing and commissioning of Tipping Bucket Rain Gauges (TBRG) with data collection platform consisting of data logger	8	79,080	6,32,640	Data from one TBRG was not being received in the central server.
2	Supply, installation, testing and commissioning of Automatic Weather Stations (AWS) with data collection platform consisting of data logger	19	2,65,300	50,40,700	Data from nine AWS was not being received in the central server.
3	Supply, installation, testing and commissioning of Radar Level Sensors (RLS) in river gauging stations with data collection platform consisting of data logger	18	2,75,100	49,51,800	Data from five RLSs was not being received in the central server.
4	Installation and commissioning of ground station consisting of telemetry GSM/GPRS transmission system and software to evaluate streams of data	1	2,25,000	2,25,000	Commissioned in June 2019
Total (less discount offered two *per cent*)				1,06,33,137	
AMC for five years after two years' warranty period				27,64,200	
Grand total				**1,33,97,337**[46]	

(Source: Data furnished by the Irrigation Department)

The Department had also noticed errors in data received from certain equipment and had intimated Audit that the process of verifying the reliability of data by comparing it with manual data was underway. Audit noticed that though more than five years have elapsed, the objective of obtaining real time hydrological data useful for improving flood management capabilities remained unachieved.

Government replied (November 2020 and April 2021) that even though instruments with IMD calibration and certification were installed, the instruments failed to deliver reliable data on real time basis. Most of the data could not be retrieved through data logger and showed variations when compared with manual reading. Despite Irrigation Department's constant follow-up, the firm did not attend to the same. Notice to the firm was issued on 16 April 2021 for termination of contract and the concerned Chief Engineer

[45] M/s. Astra Microwave Products Ltd, Hyderabad

[46] The firm had quoted 11.82 and 54.16 *per cent* less than the estimated amount for equipment and AMC respectively.

has been directed to take steps to blacklist the firm for breach of agreement conditions.

3.5. Inadequacies of State Emergency Operations Centre

3.5.1. Non-availability of data required for the functioning of Decision Support System established in State Emergency Operations Centre

The State Emergency Operations Centre (SEOC) is the research and technology laboratory of KSDMA and is the State nodal office for the collection, compilation and analysis of data received from all Government departments and institutions on a no-cost basis. DM Plan 2016 envisaged SEOC to be equipped with a full-fledged state-of-the-art IT and Communication network with an intelligent Decision Support System (DSS) capable of prediction and early warning of major hydro-meteorological hazards and support for emergency operation.

The work of setting up an Information Technology and Communication System (IT & CS) in SEOC which includes DSS was awarded (April 2016) to Keltron, a State Public Sector Undertaking with the targeted date for completion of work fixed as April 2019. The estimated cost of the project was ₹5.96 crore to be met from the 13th Finance Commission grant. The work was to be completed in three phases. While the first phase involving IT set up, base configuration etc. was completed in January 2017, the second phase which involved development of Decision Support System, Standard Operating Procedure etc. was completed in October 2017. The third phase *viz.*, scaling to the new SEOC building and continued handholding remains to be completed (March 2020). KSDMA stated that 85 *per cent* of the project was completed and payment of ₹4.54 crore made to Keltron till date (October 2019). The target date for completion was extended up to 31 March 2020 at the request of Keltron.

According to the Flood Management Organisation of Central Water Commission, flood forecasting requires hydro-meteorological data on real time basis at least hourly or sub-hourly for the parameters of rainfall and water level. According to the pre-development solution design document prepared by M/s. Element Blue[47] for KSDMA, 10 sets of real time data which includes rainfall, temperature, humidity etc. were to be provided by KSDMA.

KSDMA stated (March 2020) that though the DSS was capable of ingesting multiple real time data, KSDMA was unable to enable this part since no real time data was provided by IMD, CWC or Geological Survey of India. Audit examination of records to ascertain reasons for dearth of real time data necessary to make the DSS fully operational, revealed the following.

[47] M/s. Element Blue prepared the solution design document which describes the system requirement, operating environment, system and sub system architecture, files and database design, input formats, output lay-outs detailed designs.

- None of the 69 manual rain gauges utilised by the Indian Meteorological Department (IMD) generate real time data. Real time data is obtained only from the seven functional Automatic Weather Stations and 10 Automatic Rain Gauges of IMD.
- The 22 rain gauges installed by KSEBL also do not generate real time data.
- Out of the 39 river gauges operated by Central Water Commission, only one generated real time data. However, Audit observed that KSDMA had no access to this data, though CWC was sharing data from this telemetric station with the Karnataka State Disaster Monitoring Centre.
- Audit noticed that the DSS was to function on the basis of 10 available data sources which included, *inter alia*, weather data source (rainfall, temperature, humidity etc.), satellite images and derivatives, water data (reservoir water level, river flow data etc.), seismic data etc. However, Audit observed that historical data available with KSDMA was limited to rainfall, temperature, humidity and dry bulb temperature (provided by IMD).
- The Flood Hazard Susceptibility map prepared by NCESS in 2010 has been configured in the DSS despite it not possessing the necessary characteristics of such a map, as pointed out in Paragraph 2.4 of this Report. Since the DSS looks up in this map for the nearest rainfall scenario and identifies the nearest probability scenario from the look up library and uses it for identifying critical assets[48] and areas needing external assistance[49], the inadequacies of the map would impair the capabilities of the DSS.

Audit noticed that before commencement of the IT and CS project, the State IT department had raised doubts (June 2014) about the availability of data and cost involved in collection of data. KSDMA clarified (July 2014) that weather data (near real time to daily), seismic data (near real time), reservoir data (daily digital from KSEBL) and historical data from IMD and Irrigation Department (stream flow) were available with KSDMA. Being the nodal agency for collection, compilation and analysis of data, it was incumbent upon SEOC to ensure availability of required data for prediction and early warning of major hydro-meteorological hazards and intelligent support for emergency operation. However, as per details furnished to Audit, data presently available with SEOC was limited. The absence of real time/ historical data and an adequate flood hazard map would impair the functioning of the DSS.

Department of Revenue and Disaster Management in its reply dated (December 2020) stated the following points;

[48] critical assets such as schools, hospitals, shelters etc.
[49] Source: Pre-development solution design document.

- Establishing warning systems and providing disaster alerts are the functions of notified Central agencies under the Disaster Management Act 2005/ NDM Plan and not of KSEOC.
- Decision Support System of KSDMA is not for analysing raw data and generating alerts. KSDMA's function is confined to crisis management in accordance with the magnitude of an event as projected by the notified agencies.
- KSDMA referred to GOs dated 18 October 2019 and 06 May 2020 as examples of KSEOC's efforts for ensuring real time data. Since 2017, it has been engaging with IMD (which has statutory responsibilities laid down in NDM Plan) for sourcing real time data.
- CWC has only one real time monitoring station in the State. It is the responsibility of CWC to have increased the number after assessing the hazard potential. Kerala was never identified nationally as a priority State for implementation of flood monitoring systems. Detailed demands of KSDMA for improving flood forecasting was placed before CWC (March 2017) and the Rajya Sabha Committee on Petitions (30 May to 02 June 2017).
- One of the fundamental requirements of real time operations is the availability of accurate river flow forecasts. The dilemma of prudent inflow forecasting is reflected in the counter affidavit of Government of India in WP (C) 2996 of 2018 where CWC has admitted the limited scope of riverine flood forecasting systems in Kerala. The technology and science are not developed as yet to implement a pragmatic and usable forecasting system in Kerala's flashy rivers. Until these technical bottlenecks are resolved, it is not possible to determine the feasibility and usability of inflow forecasting and flood forecasting in the rivers of Kerala. Hence, Audit observation that KSDMA/ KSEOC should have such data was contested.
- DSS of KSDMA is a management decision making tool and not meant for such analysis.
- KSDMA possesses data of satellite images, various derivatives such as slope, aspect, NDVI, Seismic Catalogue etc. as well as reservoir data, together with over 60 geospatial data. KSEOC utilised the available data for providing risk maps to districts[50] for enabling crisis management. Maps of immediate threat zones due to any opening of shutters of Cheruthoni dam of Idukki reservoir overlaid with satellite images were provided to DEOCs of Idukki, Thrissur and Ernakulam on 28 July 2018 based on the inundation history of 2013 and rapid assessment of available satellite images.

[50] by email with maps dated 28.07.2018 from KSEOC to DEOC

- The Flood Susceptibility Map of Kerala is accurate enough for all practical purposes and can be used for DM preparedness till such time as CWC is able to provide large scale flood prone area maps.
- KSDMA was in receipt of daily rainfall data from IMD. Seismic data was available real time during the period from KSEB- KSDMA joint project. Reservoir data of KSEBL reservoirs was available in digital format from KSEBL as well as historic data from IMD, Irrigation department and Ground Water department. Inadequacy of real time monitoring systems of Central agencies is a reason for KSEOC developing a system with futuristic data management possibility.

Audit observes that the DM Plan 2016 envisaged SEOC to be equipped with a full-fledged state-of-the-art IT and Communication network with an intelligent Decision Support System (DSS) capable of prediction and early warning of major hydro-meteorological hazards and support for emergency operation. Even two years after the targeted date of completion of April 2019, the system cannot be relied upon to predict and give early warning of major hydro-meteorological hazards since its effective functioning is dependent on the receipt of externally sourced real time data which is yet to be made available. The IT department of GoK had even before commencement of the project raised doubts about the availability of data for functioning of the DSS. The reply of GoK is silent about how DSS is to be optimally used by KSDMA in the absence of required data and how the State proposes to meet the pressing need of an effective early warning system. The inadequacies of Flood Prone Area Map of the State and the lack of GoK response to the request of CWC to install Flood Forecasting Station have also been discussed in Paragraphs 2.4 and 3.3 of this Report. Prudent project implementation would require the consideration of the likelihood of essential inputs being available in time, for effective functioning of the system and fulfilment of what is stated in the State's Disaster Management Plan.

Recommendation 3.2: Keeping in view the criticality of flood management projects and in order to ensure their successful and time-bound implementation, Government may ensure that projects for procurement/ installation of systems meant for flood management such as information systems, decision support system etc.,

(i) are entered into only after fulfilment of a pre-determined common list of prerequisites as well as consideration of aspects such as a) the likelihood of timely availability of input data from all sources including external sources, b) whether Government would be in a position to meet its commitments such as installations of servers without delay, previous experience of bidders etc. and

(ii) are covered by a stringent monitoring mechanism with clearly defined responsibilities and accountability.

3.5.2. Maintenance of Communication Infrastructure

The Disaster Management Act, 2005[51] envisages that the State Executive Committee would ensure that communication systems are in order. Recognising that communication systems were the first to be affected in the event of a calamity, the Handbook on Disaster Management issued by KSDMA therefore required all Emergency Operations Centres (EOC)[52] to have built-in redundancy of different layers of communication networks for ensuring effective communication system even during the most adverse circumstances. Keeping communication system in order even during the most adverse circumstances would be one of the main functions of the EOC.

Tahsildars of Idukki and Chalakudy Taluks informed Audit that there was total failure of communication infrastructure in their respective areas during the floods of 2018. Assistant Engineer (AE) in charge of Poringalkuthu dam in Thrissur informed Audit that communication infrastructure in the dam had failed on 16 August 2018 and could be restored only after one week. Similarly, AE of Lower Sholayar dam (Thrissur District) informed Audit that a landslide had occurred during the 2018 floods obstructing the road to dam office and no reliable and uninterrupted communication facility was available in the dam site. The official at the dam site had depended on the mobile network of Tamil Nadu which was available at some distance from the dam. Officials of both the dams intimated Audit that failure of communication network had created difficulty in contacting higher authorities for help and directions.

Audit, therefore examined the status of implementation of various projects/ schemes meant for ensuring failsafe communication in the State as availability of reliable communication systems would be integral to flood preparedness.

The Revenue and Disaster Management Department informed (November 2020) that uninterrupted communication systems[53] required in SEOC and DEOC to combat disaster as laid down in the Orange Book include dedicated mobile phone, optical fibre internet, hotline, landphone, Fax, VSAT module, Satellite phones, police wireless, Whatsapp groups, Facebook, Twitter, dedicated email, HAM radio and YouTube channel. The healthy mix of civilian and official communication systems through several media reduces significantly chances of communication failure. When one system fails, another would be used and none of them is an always-on system. It acknowledged that GSM, telephonic and internet communication was temporarily disrupted in parts of Idukki due to power failure and optical fibre

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51 Section 22(2)(p) of the Disaster Management Act 2005

52 Recognising the need for such a State-level dedicated facility for disaster management, the Government of Kerala (GoK) has established the State Emergency Operations Centre (SEOC). The SEOC is envisaged to cater to varying levels of disasters with a state-of-the-art Decision Support System (DSS), integrated with a multichannel communication network. It has advanced redundant satellite-based communication network (National Disaster Management Services Project) and multi-channel terrestrial communications systems including VHF, GSM, 4G, 3G and broadband internet connectivity. (Paragraph 1 and 2 of the EOCESFP 2015, renamed in 2019 as Orange Book of Disaster Management).

53 According to the reply of Government there are 16 types of communication systems, however, the reply as well as the Orange Book lists only 14 types of communication system.

disconnection and the Cell-sites on Wheels (CoWs) deployed provided the required connectivity. Deployment of communication systems at dam sites was taken care of, adequately by dam owners and management of dams was not a function of KSDMA.

Audit observes that the Disaster Management Act 2005 does not exclude communication systems at dam sites from the purview of the SEC or KSDMA.

The deficiencies in maintenance of effective communication systems, as noticed during the course of audit, are detailed below.

3.5.2.1. National Disaster Management Services

The National Disaster Management Services (NDMS), a project implemented by National Disaster Management Authority, envisaged to provide to States, failsafe communication infrastructure[54] and technical support[55]. Thus, VSAT[56] phones were installed by BSNL at the SEOC at Thiruvananthapuram and DEOCs at Idukki, Ernakulam and Wayanad during March and April 2016 respectively. Satellite phones were also provided to these districts after the floods of 2018 for providing additional redundancy in communication. Government of Kerala also nominated (March 2016) the Member Secretary, KSDMA as the nodal officer for the Project.

Audit examined the status of the VSAT communication system/ satellite phones in the test-checked districts and noted that the system was not completely dependable as seen from the following;

- Audit was informed (October 2019) by the Additional District Magistrate, Idukki that VSAT connection was not working regularly and that voice of the speaker was not audible. The connection was not working from 15 August 2018 and that only after issuing many reminders to SEOC was it repaired in December 2019.

  It is significant that VSAT was not functional in Idukki during the floods of 2018, when terrestrial and mobile communication network in the district had failed. Further, the system in Idukki district became functional after over a year.

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[54] NDMS is a grant-in-aid in kind project to establish a satellite-based communication network in all States. In Kerala, the project is implemented in creating satellite-based communication linkages between SEOC and DEOCs of Idukki, Ernakulam and Wayanad. The instrumentation includes VSAT Connectivity, Satellite Phones and HF Radio sets. The satellite-based network was to provide additional redundancy in communication. The project was implemented by SEOC vide GO (Rt) No. 2203/2016/DMD dated 30 March 2016. MoU was entered between the NDMA and Government of Kerala on 05 May 2016 for the implementation of the project with duration of 24 months (EOCESFP 2015, renamed in 2019 as Orange book of Disaster Management). Paragraph 4 of the revised scheme proposal for NDMS pilot project for satellite-based communication network refers to failsafe communication infrastructure.

[55] Source: Paragraph 4 of revised scheme proposal for NDMS pilot project for satellite-based communication network.

[56] Very small aperture terminal

- VSAT at DEOC, Ernakulam remained non-functional for about 45 days during January-November 2019. VSAT at DEOC, Wayanad was non-functional in October-November 2019 as per SEOC, Thiruvananthapuram records.
- Audit observed that even in SEOC which commenced operation in its new premises at Thiruvananthapuram from January 2019, VSAT was re-installed only in November 2019. SEOC could not utilise this communication tool for about 10 months. NDMA also informed SEOC (November 2019) that daily testing of VSAT sites at SEOC, Thiruvananthapuram and DEOC, Idukki indicated either faulty or non-responsive systems and required that these VSAT sites be made functional.
- Audit noticed that though satellite phones had been made available at DEOCs and dams, they would not function indoors and were unreliable during overcast conditions. The inability of Satellite phones to function during adverse weather conditions affects its effectiveness as a means of communication during disaster.
- Joint check conducted by Audit along with departmental officers at DDMA Idukki (25 October 2019) revealed that the satellite phone was non-functional. ADM Idukki cited expiry of validity period of satellite phone connection as a reason for non-functioning of satellite phones.

The Department responded (December 2020) that NDMS is not a fail proof communication system but an alternate communication system along with the other systems provided by KSDMA. Performance of NDMS depends on BSNL for bandwidth and hardware maintenance, ISRO for satellite health, KSEBL for power, weather systems for cloud cover and failure of any of these can result in the system becoming non-functional. Inadequacy of bandwidth was reported to NDMA in December 2016. Ensuring connectivity through ISRO bandwidth was BSNL's responsibility. KSDMA informed BSNL and NDMA in September 2016 that the system was agreed to be commissioned only after imparting necessary training to its engineers and ensuring seamless functioning. Initial handing over of systems occurred only on 05 October 2018 and final handing over on 01 and 02 February 2019 after training of DEOC and SEOC staff at BSNL. The department stated that Audit was commenting on a non-commissioned system. Since handing over, the system was augmented further and is maintained meticulously. It added that all complaints other than power related, could only be reported to the toll-free number of BSNL. The logbook of VSAT at SEOC indicated that calls were made to DEOC, Idukki on 10 August 2018, 30 August 2018, 14 September 2018 and 19 November 2018. The log also indicated that the system did work prior to and during the flood and the voice of the speaker was clear. As regards the relocation of VSAT to the new SEOC premises after a gap of one year, the department stated that KSDMA took all possible steps to operationalise the VSAT terminal through frequent requests to BSNL and intervention of

NDMA. Satellite phones were delivered on 17 August 2018. As it is with any satellite signals, reflectivity interference could affect signals temporarily in cloudy conditions and high solar insolation. Possibility of purchasing antenna to enable indoor use of the device is being explored with BSNL. The non-functioning of satellite phone during physical verification was attributed to the lack of support from the service provider who got it functional on 22 November 2019 after detailed proposal for recharge was received from him on 13 November 2019. The reply added that during the short durations when satellite phones were non-functional, there were other communication systems to supplement the failsafe communication.

Audit observes that the department's response corroborates the audit observations as the NDMS system (VSAT and satellite phone) with all its limitations did not provide assurance of being a fully dependable communication system. The observations of Audit regarding the non-functioning of VSAT and satellites phones are based on the remarks provided by end users, i.e., ADM (Disaster Management), Idukki, engineers in dam sites and officials at DEOC. Audit observed that no entries were made in the VSAT log maintained by DEOC, Idukki after 26 March 2018. Further, the reply of Government that functioning of Satellite phone is temporarily affected during cloudy conditions and high solar insolation, is supportive of the audit finding. As regards the Department's contention that commissioning of VSAT had not taken place by the time of the 2018 floods, the fact remains that the system was being relied upon by the end-users from March/ April 2016 and the department itself lists and recognises VSAT module among the effective communication systems followed in KSDMA. As part of its normal time functions, the SEOC was to ensure proper functioning of multi-channel alternate communication systems.[57]

3.5.2.2. Non-functional Very High Frequency Radio communication system

The Department of Revenue and Disaster Management established[58] a network of 379 Very High Frequency (VHF) Radios[59] in the State (2010) for enforcing effective early warning system with an outlay of ₹2.65 crore. VHF radio network of KSDMA is a wireless communication technology similar to that used by the Police Department. The advantages of VHF communication over other forms of communication includes its ability to function in severe weather conditions as the equipment is shock and dust proof, resistant to humidity and able to work with a 12-volt battery.

[57] Paragraph 4.1 of EOCESFP 2015, renamed in 2019 as Orange Book of Disaster Management
[58] with the financial assistance of UNDP and the Tsunami Rehabilitation Programme
[59] State level - 5, Revenue Divisional Office - 2, District level - 14, Taluks - 63 and vulnerable Village - 295.

A survey conducted by Audit in 2013 for inclusion in the Report of CAG[60], had revealed that 82 *per cent* of the equipment were non-functional, due to improper installation, non-execution of repair works and absence of technically skilled personnel. The letter of Director, Institute of Land and Disaster Management (ILDM) (January 2018) addressed to Additional Chief Secretary, Revenue and Disaster Management, GoK also indicates that VHF network was inactive since its installation. Audit observed that an amount of ₹35 lakh (November 2013) was provided to ILDM for engaging technical staff to revamp[61] the VHF equipment at Collectorate and Taluk level and subsequently 130 equipment were repaired. However, the revamping activities were abandoned in November 2016 due to lack of further Government sanction. A revamping proposal of ₹1.28 crore submitted to GoK by ILDM (January 2018) is yet to receive approval (December 2019). VHF equipment which was installed incurring an expenditure of ₹2.65 crore to ensure hassle free communication was not functional during the floods of 2018 in any of the test-checked District Collectorates and Taluks. Deputy Collector (DM) Idukki stated (December 2019) that they were dependent on the VHF maintained by Police for communication during the floods of 2018. Taluks and villages which are involved in ground level relief and rescue works during disaster have to depend mainly on land phones, email, CUG mobile network and a fully functional VHF would be a step towards strengthening the communication network at the ground level.

The Revenue and Disaster Management Department responded (November 2020) that as VHF systems were meant not for day-to-day communication but for use in periods of disaster (unlike in the Police department), they are liable to frequent repairs on account of prolonged idling. VHF systems were used intermittently after the warranty period depending on the periodic repairs. The asset installed in 2008-10 being more than 10 years old had outlived its normal useful life. Any further spending on the asset would result in unfruitful expenditure, hence the decision not to sanction further expenditure and to recommend handing over to the Police department. By preventing avoidable expenditure on revamp and utilising the wireless phones of the Police personnel for flood management, the 2018 flood situation was managed well by KSDMA and the DDMAs. The department avoided expenditure on a failed and redundant system, it added.

Audit noticed that though Government had provided different types of communications, most of them were vulnerable to failure during a disaster owing to their dependence on internet or terrestrial network. The VHF of Police department had withstood the disaster of 2018 as stated in the paragraph and hence can be considered as a reliable communication network.

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[60] Report of C&AG of India on General and Social Sector, Government of Kerala for the year ended March 2013. The survey was part of Paragraph 3.9 'Unfruitful expenditure on Early Warning Systems'. The paragraph was discussed in PAC and PAC had sought additional details from Revenue and Disaster Management Department.

[61] for repairing nine out of 14 VHF supplied to Collectorates, 24 out of 64 VHF supplied to Taluks and three out of five Repeaters.

The Kerala State Disaster Management Plan, 2016 elaborates the procedure for maintaining the VHF system and ensuring that the system remains functional, it includes daily checking and sorting out any technical issues using the services of Police Telecommunication wing. Hence, the contention of Government that VHF networks were not intended for day-to-day communication purposes but for use during periods of disaster, and equipment were liable for frequent repair on account of prolonged idling, is not acceptable.

Recommendation 3.3: KSDMA may ensure that fail-safe communication infrastructure is available in vital installations such as at dam sites and that a built-in redundancy of different layers of communication capable of functioning during the most adverse circumstances exists in flood-prone locations across the State.

3.5.3. Non-functional state-of-the-art Digital Seismographs

Idukki district in Kerala hosts 17 dams including the 125-year-old Mullaperiyar dam[62]. Consequent to an earthquake of 3.8 M on Richter scale (July 2011) in the Idukki region, GoK decided to establish (August 2011) a state of the art digital system of seismographs in and around Mullaperiyar dam site for obtaining real time Seismic data as the existing equipment were analogue type and incapable of immediate analysis of data. The work was awarded to M/s. Encardio Rites Electronics Pvt. Ltd. (M/s. Encardio) for ₹3.90 crore. The new equipment was capable of providing reliable, compact and portable data. As stated earlier in this Report, the data from the seismographs would also be an input to the Decision Support System being established at the SEOC.

After setting up (March 2014) six digital seismographs and five accelerographs[63] near and around Mullaperiyar dam site[64] for the effective monitoring of seismic activities, GoK further accorded sanction (August 2016) to purchase one full spare set[65] of GURALP seismograph for ₹50.93 lakh for installation at a suitable site within the ILDM premises[66].

Audit observed that though the vendor supplied (December 2016) one full set of GURALP seismograph along with its allied items and the instruments, these were not installed and were stored in the KSDMA building. Audit further observed that the warranty period of the six digital seismographs and five accelerographs, set up in March 2014, expired in March 2017. A proposal (March 2017) of the vendor offering a three-year AMC for ₹66.32 lakh was not successfully concluded. Resultant non-maintenance of the equipment

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62 Mullaperiyar dam lies in seismic zone III, where as per the seismic zoning map of India, earthquake of intensity seven in the Richter scale could be expected.

63 An electromagnetic device used to measure acceleration forces

64 Seismographs at Vallakadavu, Meencut, Chottupara, Aladi, Kulamavu and Pamba; Accelerographs at Idukki dam and Vallakadavu observatory in Idukki District

65 Since the spares of any malfunctioning instrument are to be imported, components from the spare instrument could be used as a replacement till M/s. Encardio substitutes the spare.

66 Institute of Land and Disaster Management under Department of Revenue at Thiruvananthapuram which accommodated the SEOC till it was shifted to the new building in January 2019.

possibly led to the seismographs installed in Idukki becoming non-functional since January 2019. No seismic data is being received by the Central Receiving Station (CRS) since then. Sanction accorded by GoK in July 2018 for entering into an AMC with the vendor became infructuous as the vendor M/s. Encardio intimated KSDMA (December 2018) that they had ceased functioning as the distributor for GURALP instruments in India. After inspection of equipment, a new vendor intimated (August 2019) KSDMA that majority of the original equipment had reached its end of life and offered to replace/ repair the faulty instruments for ₹49.50 lakh before entering into an AMC. The offer was not accepted (January 2020) pending receipt of clarifications from the original vendor.

Want of proper maintenance of the seismographs and related equipment resulted in expenditure of ₹3.90 crore becoming infructuous with the State being forced to depend on data from the erstwhile analogue seismograph instead of obtaining real time seismic data. Further, non-installation of the seismograph purchased in December 2016 meant idling of equipment worth ₹50.93 lakh for the last three years in Thiruvananthapuram.

The Revenue and Disaster Management Department in its reply (December 2020) stated as follows;

- The paragraph has nothing to do with the subject matter of preparedness for floods.
- The six digital seismographs and five accelerographs set up in March 2014 were proprietary items. Any repair or AMC had to be through services of the principal/ their authorised dealers in India. Extended warranty period expired in 2017. AMC could not be concluded beyond this period since the authorised dealer ceased to function after December 2018. New vendor after inspection in August 2019 reported that majority of the items had reached their end of life.
- The equipment custodian KSEBL had utilised its internal skills to revitalise and use the system as long as the original equipment continued to work.
- The offer of the new dealer to repair the instruments for ₹49.50 lakh and then enter into AMC did not appear economical, since the equipment had already outlived their normal life.
- Audit conclusion of failure to ensure adequate maintenance resulting in infructuous expenditure was pre-conceived and irrelevant.
- The purpose of collecting seismic data is served by two digital seismographs in the State, one of IMD in Thiruvananthapuram and the second of NCESS at Peechi.
- Audit observation on non-installation of the spare seismograph was not accepted as the spare intended for replacement in the event of

failure of one of the already installed seismographs could not be considered as idling equipment.

During the Exit conference (18 January 2021), it was also informed that the seismographs were not for detection of earthquakes in the State. The responsibility of earthquake detection and monitoring is that of IMD and KSDMA is in receipt of such detections that are relevant to the State. The purpose of the KSDMA funded, KSEBL established seismic monitoring system was for confined monitoring of the selected area in Idukki and at a global scale of earthquake detection and monitoring, all the systems deployed in Idukki would only count as one system. Further, under the initiative of KSDMA, the National Centre for Seismology (NCS), New Delhi has deployed one seismograph in Idukki. Therefore, earthquake detection purpose is well served. The system was funded by KSDMA to KSEBL and KSEBL had the responsibility of deploying and maintaining the system ever since the beginning. During the active period of the system, the system worked satisfactorily.

The contention of the Government that the seismographs at Thiruvananthapuram and Peechi are sufficient could not be accepted since while initiating the project proposal by KSEBL, expert opinions from National Geophysical Research Institute (NGRI) and NCESS were obtained by KSEBL and NGRI had opined that any network around a reservoir should be located in such a way that there is minimum azimuthal gap and a station should be located in the centre of the network for assessing depth resolution of earthquakes. NCESS while underscoring the necessity of the project added that the seismic observatories of IMD and NCESS could complement the proposed network. Further, following mild tremors in Idukki area in February 2020, KSEBL conducted a meeting (March 2020) to assess the situation and it was opined that the observations from the above Seismographs are highly important for the study of seismic behaviour of Idukki region as it has link with the safety of KSEBL dams and hence action is to be taken to initiate reviving the equipment/ system. Audit clarifies that it is based on the linkage to dam safety and possibility of flooding from dam break that this audit observation has been included in this Audit Report. GoK's contention that the spare equipment cannot be considered as idling is also not acceptable as the sanction order for purchase of the spare instrument specifically stated that the spare instrument shall be mounted in the campus of Institute of Land and Disaster Management, Thiruvananthapuram and data received in the present network at the Central Receiving Station at KSDMA.

In the wake of frequent mild tremors which occurred in Idukki during February 2020, KSEBL contacted CWC for expert advice and CWC recommended to constitute an expert group with representation from a few organisations including National Centre for Seismology (NCS), New Delhi. NCS as part of their study installed (March 2020) seismic equipment in Idukki utilising their own funds and the data was streamed to its Headquarters at New Delhi. KSDMA's contention that the equipment installed by NCS is more than

sufficient cannot be accepted since the objective of the subject scheme was to extract real time seismic data which would be relayed to the State's own CRS that could be monitored at close quarters as recommended by NGRI and NCESS. Audit observes that the single seismograph set up in 2020 is not intended to be a substitute for a system of six seismographs and five accelographs in place earlier.

Further, Audit noticed that the situation which warranted the establishment of these seismographs in 2014 still exists as evident from the tremors felt in Idukki as recently as February 2020.

Recommendation 3.4: Keeping in view the role of the seismograph network in Idukki in studying seismic behaviour and their linkage to the safety of dams in the region, Government of Kerala may ensure that the network of seismographs as recommended by NGRI is put in place at the earliest and the agencies concerned receive real time seismic data from these locations.

Reservoir operation

Dams ensure a large number of potential benefits, but are also structures with potential hazards. Any uncontrolled or excessive release of huge amount of water has potential for loss of life and damage to property due to flooding. Of the 59 dams in the State, 17 dams are in Idukki district. Kerala received 2,346.60 mm rainfall between 01 June and 19 August, 2018, which was about 42 *per cent* higher than the normal rainfall.

Audit engaged the services of the Indian Institute of Science Bangalore (IISc) to study, from a hydrological perspective, the operations of reservoirs in the Periyar basin, during and immediately preceding the flood period[67]. Salient features of Mullaperiyar, Idukki, Idamalayar, Lower Periyar dams and Bhoothathankettu barrage are given in **Appendix 3.1.** While the Mullaperiyar dam is controlled by Tamil Nadu, the Idukki and Idamalayar dams are under the control of KSEBL. Lower Periyar dam is situated downstream of Idukki dam and has a very small capacity compared to the three major dams. Audit findings with regard to reservoir operations are given in succeeding paragraphs.

3.6. Assessment of impact of dam spillage on flooding in downstream areas

Audit evaluated the relative contributions of the spills from the two major dams, Idukki and Idamalayar, to the flood flow observed at Neeleswaram gauge station, based on observed data. Contribution of the spills from Mullaperiyar dam to the Idukki inflows was also examined. Data on reservoir inflows, power house (PH) discharge, spills, storage and water levels at the dams, barrage and flow gauges provided by the KSEBL, CWC and Irrigation Department was used to assess the impact of the spills on the floods.

[67] June - August 2018

Since observed flow and river level data was available at Neeleswaram gauge station, the spills from the reservoirs were compared with the observed flow at Neeleswaram to assess the impact of spills on the floods. The percentage contribution of the reservoir spills, on a daily scale, to the Neeleswaram gauge station is shown in **Table 3.4**.

Table 3.4: Contribution of daily spills from Idukki and Idamalayar dams to the observed flow at Neeleswaram gauge station

Date	Total observed spills from Idukki and Idamalayar dams (MCM)*	Flow observed at Neeleswaram (MCM)	Contribution of total spills from Idukki and Idamalayar dams to flow at Neeleswaram (*per cent*)[68]
1	**2**	**3**	**[(2) / (3)] * 100**
14-08-2018	91.06	196.13	46.43
15-08-2018	192.47	532.83	36.12
16-08-2018	234.53	793.93	29.54
17-08-2018	185.85	796.44	23.34
18-08-2018	104.11	612.75	16.99

***The spills presented for Idukki and Idamalayar dams for a day correspond to the observed flow during the 24 hours from 7AM on that day to 7AM on the next day.*

(Source: Report of IISc, Bangalore)

The contribution of the spills from Idamalayar and Idukki dams together, to the flows at Neeleswaram gauge station during the period 14 to 18 August 2018 was significant at 46.43 *per cent*, 36.12 *per cent*, 29.54 *per cent*, 23.34 *per cent* and 16.99 *per cent* respectively, though as the extreme rainfall event continued for a few days, the contribution of the spills in percentage terms is seen to have declined.

Further, as the spills from the Mullaperiyar dam pass through the Vandiperiyar gauge station and subsequently contribute to the inflows to the Idukki reservoir, the role of spills from Mullaperiyar dam in the escalation of flows at Idukki reservoir during the flood period was also examined as shown in **Table 3.5**.

Table 3.5: Contribution of spills from Mullaperiyar dam to Idukki inflows

Date	Spills from Mullaperiyar dam (MCM)	Inflows observed at Idukki dam (MCM)*	Contribution of spills from Mullaperiyar to Idukki inflows (*per cent*)
1	**2**	**3**	**[(2) / (3)] * 100**
14-08-2018	2.17	84.18	2.58
15-08-2018	46.10	165.06	27.93
16-08-2018	56.74	154.96	36.62
17-08-2018	33.87	111.70	30.32
18-08-2018	33.26	92.51	35.95

***The flow data presented for Idukki and Mullaperiyar dam correspond to the observed flow during the 24 hours from 7AM on that day to 7AM on the next day.*

(Source: Report of IISc, Bangalore)

[68] The volume of total spills from the two dams (Idukki and Idamalayar) together is added and its percentage contribution is analysed to the flows at the barrage and Neeleswaram gauge station.

As evident from the table, the operation of the Mullaperiyar dam had a negligible effect on 14 August but its contribution to the inflows at Idukki was significant during 15 to 18 August (>20 *per cent*), considering the magnitude of the floods.

Government in its response stated (September 2020) that the contribution of Mullaperiyar dam to the inflows of Idukki during the period of severe floods from 15-18 August 2018 was very significant. Since sudden and unexpected releases from Mullaperiyar dam by Tamil Nadu Government was expected any moment without notice and the quantum of inflow to Idukki reservoir was not known in advance, KSEBL had to provide sufficient flood cushion to ensure safety of the dam as well as controlled release. But for the sudden release of 169.97 MCM of water from Mullaperiyar during the extreme flood days, the attenuation of downstream flood would have been more significant.

The departmental response indicates the need to prioritise and have in place an integrated reservoir management plan, particularly in multi dam basins. This is significant both because i) the control of reservoir/ dam operations in the State is distributed among KSEBL and the Irrigation department and ii) there is the likely impact of spills from dams under the control of one State in the downstream reservoirs and rivers of another State.

The National Disaster Management Plan lists among the responsibilities of the State (in the context of understanding floods), the implementing and monitoring of flood preparedness, river basin and reservoir management plans including updating rule curves and improving the system of water release from reservoirs.[69]

Audit examined the aspect of the compliance of dam operators to rule curves and the findings are as follows.

3.6.1. Compliance of dam owners to rule curves

A Rule Curve or rule level specifies the storage or empty space to be maintained in a reservoir during different times of the year with the assumption that a reservoir can best satisfy its purposes if these storage levels are maintained. The rule curve as such does not give the amount of water to be released from the reservoir as it will be dependent on the amount of inflows and other extractions. The rule curves are generally derived by operation studies using historic or generated flows[70]. Though it is always desirable to fill a reservoir up to Full Reservoir Level (FRL) (or upto Maximum Water Level (MWL) during emergency situations, if the dam is structurally stable), it is

[69] Paragraph 7.2.1, NDMP 2019

[70] Upper rule curve represents the water levels to be maintained in the reservoir such that if these are maintained throughout the year, all the demands from the reservoir can be fully met. Keeping the upper rule level below FRL (in monsoon months) can give extra room for flood absorption in the reservoir. Lower rule curve is calculated such that if the storage level goes below this level, only the highest priority demands can be met throughout the year. Generally, the water level in the reservoir is maintained between upper and lower rule curve values.

generally recommended that some spill should be made from the reservoir to keep up the downstream river channel and to avoid encroachment in the river.

During field visit, the IISc team accompanied by Audit personnel were informed by KSEBL that no rule curve was followed for reservoir operations during the flood period. However, Audit noticed that KSEBL had in its possession the Rule Curve framed in 1983 (**Appendix 3.2**). Audit observed that only after the floods of 2018, KSEBL developed new rule curves (KSEBL, 2019) which were updated in 2020 (KSEBL, 2020) though the Operation of Reservoir – Guidelines[71] envisaged (Paragraph 5.0) that the rule curves are to be reviewed constantly and if necessary, modified so as to have the best operation of reservoirs.

Audit made available to IISc, the rule curves (1983 and 2020) for the Idukki dam along with the rule curves for the operation of the Idamalayar reservoir (2020) (**Appendix 3.3**), for carrying out simulations of reservoir operation to determine the volume of spills that would have resulted if these rule curves were followed during the flood period. The simulations of the reservoir operation were carried out for the period June to September 2018. The steps followed in simulating the reservoir operation are given in **Appendix 3.4**. The results of the simulations are given below.

3.6.2. Operation of Idukki reservoir using the 1983 rule curve

The Idukki reservoir operation was simulated with the rule curves developed in the years 1983 (**Appendix 3.5)** and 2020 (**Appendix 3.6**) to determine the quantum of spills and to compare these spills with the actual spills that occurred during the 2018 flood period. **Table 3.6** shows the observed spills at Idukki dam during the flood period and the spills if the rule curves of 1983 were followed.

[71] IS 7323:1994, reaffirmed in1999

Table 3.6: Comparison between actual spills and the spills simulated using the rule curves of 1983 for Idukki dam

Date	Actual spills 2018 (MCM)**	Spills when rule levels are applied (MCM) Initial storage level for simulation (starting date - June 30)		
		Upper Rule Level#	Lower Rule Level*	Actual Storage Level##
14-08-2018	46.26	74.06	0.00	74.06
15-08-2018	111.24	154.94	0.00	154.94
16-08-2018	124.65	144.88	123.82	144.88
17-08-2018	115.20	101.59	101.59	101.59
18-08-2018	70.16	82.72	82.72	82.72
Total	**467.51**	**558.19**	**308.13**	**558.19**

#Start with upper level; Spills computed once storage crosses upper level
*Start with lower level; Spills computed once storage crosses upper level
##Start with actual level; Spills computed once storage crosses upper level
**The actual spills (2018) presented for a particular day are the observed spills during the 24 hours from 7 AM on that day to 7 AM on the next day
(Simulations were carried out from June to September 2018; results for the flood period alone are shown)
(Spills are accounted only if the simulated level exceeds the crest level)

(Source: Report of IISc, Bangalore)

The simulations revealed that the spills from Idukki reservoir during the flood period (14-18 August) would have been higher (558.19 MCM against the actual spills of 467.51 MCM) if the simulations started with the actual storage level or the upper rule level. Thus, for reservoir operations during the floods of 2018, the rule curve of 1983 for Idukki reservoir could not have been relied upon to achieve minimal or no spills. This shows the necessity for ensuring rule curves are regularly updated as required by the National Disaster Management Plan and by the Reservoir Operation Guidelines[72]. In the case of Idamalayar reservoir, there was no rule curve in place at the time of the 2018 floods for the guidance of dam operators.

However, subsequent to the floods of 2018, and based on the Central Water Commission's recommendations in their Study Report on 'Kerala Floods of 2018' to review rule curves for major reservoirs in the State, the existing rule curves were reviewed by KSEB. Subsequently, rule levels as prepared by CWC were approved by the Government of Kerala in May 2020. KSEBL also resolved to give approval to the modified rule levels prepared by CWC for operation of Idukki, Idamalayar, Kakki and Banasurasagar reservoirs. Audit also noted that in the new O&M Manual[73], reservoir operation protocols including "rule curves" were included.

3.6.3. Dam operations based on 2020 rule curves

In order to see how the application of Rule curve of 2020 for Idukki dam operations would impact spills from the reservoir in case a scenario similar to the floods of August 2018 were to happen again, simulation studies were carried out. Simulation of the reservoir operation of Idukki reservoir shows

[72] IS 7323:1994 (Paragraph 5.0) - Rule curves once prepared should be constantly reviewed and modified so as to have the best operation of the reservoirs.
[73] As per the guidelines of CWC of January 2018.

that if it was operated according to the rule curve of 2020, the spills from the reservoir during the flood period would be 531.03 MCM which is higher than the actual spills of 467.51 MCM (14-18 August, 2018) as shown in **Table 3.7**.

Table 3.7: Comparison between actual spills and the spills simulated using the rule curve of 2020 for Idukki dam

Date	**Actual spills (2018) (MCM)****	**Spills when rule level is applied (MCM)** Initial storage level for simulation (starting date -June 10)	
		Rule Level[#]	Actual Storage Level[##]
14-08-2018	46.26	68.63	68.63
15-08-2018	111.24	149.51	149.51
16-08-2018	124.65	139.45	139.45
17-08-2018	115.20	96.16	96.16
18-08-2018	70.16	77.29	77.29
Total	**467.51**	**531.03**	**531.03**

[#]Start with rule level; Spills computed once storage crosses rule level
[##]Start with actual level; Spills computed once storage crosses rule level
**The actual spills (2018) presented for a particular day are the observed spills during the 24 hours from 7 AM on that day to 7 AM on the next day
(Simulations were carried out from June to September 2018; results for the flood period alone are shown)
(Spills are accounted only if the simulated level exceeds the crest level)

(Source: Report of IISc, Bangalore)

When the exercise was carried out similarly (**Appendix 3.7**) for Idamalayar dam using the new rule curve of 2020, the study indicated that the spills when reservoir operations were carried out using the rule curve would be lesser than the actual spills in 2018. **Table 3.8** shows the observed spills at Idamalayar dam during the flood period and the spills if the rule curve of 2020 is followed.

Table 3.8: Comparison between actual spills and the spills simulated using the rule curve of 2020 for Idamalayar dam

Date	**Actual spills (2018) (MCM)****	**Spills when rule level is applied (MCM)** Initial storage level for simulation (starting date - June 10)	
		Rule Level[#]	Actual Storage Level[##]
14-08-2018	44.80	56.13	56.13
15-08-2018	81.23	97.20	97.20
16-08-2018	109.88	85.54	85.54
17-08-2018	70.65	51.24	51.24
18-08-2018	33.94	33.38	33.38
Total	**340.50**	**323.49**	**323.49**

[#]Start with rule level; Spills computed once storage crosses rule level
[##]Start with actual level; Spills computed once storage crosses rule level
**The actual spills (2018) presented for a particular day are the observed spills during the 24 hours from 7 AM on that day to 7 AM on the next day
(Simulations were carried out from June to September 2018; results for the flood period alone are shown)
(Spills are accounted only if the simulated level exceeds the crest level)

(Source: Report of IISc, Bangalore)

It is observed that if the Idamalayar reservoir was operated according to the rule curve of 2020, the spills from the reservoir during the flood period (14-18 August, 2018) would be 323.49 MCM (less than the actual spills of 340.50

MCM). Even if the rule curve of 2020 was followed considering the observed actual level on June 10 for initialisation, the spills during the flood period would still have been 323.49 MCM which is less than the actual spills of 340.50 MCM.

Hence, the simulation studies using the 2020 rule curve for Idamalayar gave a result indicating lesser spills unlike in the case of Idukki.

The Department in its reply (December 2020) said that as per the rule curve of 2020, the water level to be maintained at the Idukki reservoir during 11 to 20 August is 2,386.81 feet with 1,725.71 MCM. This would give a dynamic flood cushion of 270.63 MCM (upto FRL 2,403 ft). The dynamic flood cushion would enable the dam managers to transiently accommodate the heavy inflow into the reservoir during the flooding period and distribute the consequent spill in a regulated manner.

Audit notes that even after a considered decision by KSEBL in consultation with KSDMA in August 2018 to introduce a dynamic flood cushion of four feet below FRL (68.87 MCM) (the rule curve of 1983 for Idukki reservoir permitted KSEBL to store water during the month of August 2018 upto FRL), spills of 467 MCM could not be avoided. Audit also saw that despite such decision, the outflow did exceed inflow in respect of Idamalayar reservoir on two days (16-17 August, 2018) and in respect of Idukki on one day (17 August 2018).

Hence, KSEBL may consider the feasibility of conducting simulation or other studies to ensure that the approved rule curve of 2020 along with provision of dynamic flood cushion would suffice to handle situations similar to the extreme rain event of 2018 with minimal spills, if any.

Need for assurance about the adequacy of the new rule curves is emphasised also because IISc's studies[74] to examine the effect of reservoir spills on the flood inundation depth and extent showed that if the discharge from Bhoothathankettu barrage consisted only of the runoff generated with heavy rainfall[75], the extent of simulated flood spread would have reduced from 520.04 sq. km to 441.44 sq. km and the maximum simulated depth (with respect to ground level) at Neeleswaram would have reduced from 12.32 m to 9.68 m[76]. KSEBL acknowledged (June 2020) that the 15 *per cent* reduction of area was a realistic assessment.

The Secretary, Power Department (December 2020) in his response to the audit observation said that the methodology followed by KSEBL in controlling the flow is to operate within the dynamic flood cushion below the FRL and ensure that the levels do not exceed the FRL. Keeping in view this principle, the inflow and outflow in both Idukki and Idamalayar were coordinated. While so coordinating, the sudden inflow without notice from

[74] using HEC-RAS
[75] and no contribution from reservoir spills
[76] Simulations by IISc using HEC-HMS modelling showed that the flood peaks obtained from the 'with-dam scenario' were attenuated when compared to the virgin simulations (no dam scenario).

Mullaperiyar as well had to be reckoned. Still the crisis situation was managed well within the prescribed parameters. In Idamalayar on 15 August 2018, the FRL was breached by 0.15 m and the outflow maintained was less than inflow and on 16 August 2018 the FRL was again breached by 0.75m and still the outflow was maintained at a lower level. At that point of time, due to the extreme flood situation, the inflow increased drastically and there was no other alternative but to increase the outflow to maintain the FRL, considering the safety of dam, as well. The Secretary, Power Department further stated that the position as explained above would indicate that the reservoir operation in the crisis situation was prudently managed and spills were maintained at optimum levels.

The Government vide letter dated 16 April 2021 also informed that in the case of Idamalayar reservoir, the difference between total outflow and total inflow was only 9.86 MCM which is only 2.90 *per cent* of the total inflow of 338 MCM into this reservoir. Considering the total combined inflows of 946.40 MCM (608.40 + 338), a total combined outflow of 815.37 MCM (excluding PH discharge from Idukki reservoir) was only discharged to the Periyar basin from both reservoirs (between 14 and 18 August 2018). The integrated operation by KSEBL resulted in moderation of 131.03 MCM. KSEBL had let the outflow exceed inflow only in the recession limb of the flood hydrograph which is a standard operation procedure. The response indicated that in Idamalayar, for five hours on 15 August 2018, the outflow was marginally more than the inflow (in the rising limb of the flood hydrograph) but this was before the flood hydrograph's sharp rising and touching its peak inflow. This was unavoidable as Idamalayar reservoir levels breached its FRL and integrated reservoir operation necessitated such release. Attenuation of 1,128 cumecs when the peak inflow of 2,328 cumecs occurred at 03:00 hrs on 16 August 2018 in Idamalayar reservoir was also pointed out. Further, as Idukki PH discharges to the adjacent Muvattupuzha basin and not to Periyar basin, the same should not be added to the outflows to the Periyar basin.

The departmental reply above seeks to indicate that spills that took place, including outflow exceeding inflow (on two days in the case of Idamalayar reservoir and one in Idukki reservoir), during the August 2018 floods were optimal and acceptable given the circumstances such as inflow from Mullaperiyar without warning and the fact that the outflow exceeded the inflow on the receding limb. However, the KSEB's response that outflow exceeds inflow only in the receding limb, is silent about the downstream conditions. The Neeleswaram CWC Gauge station in the month of August 2018 recorded very high-water flow on 15 and 16 August (as well as on 17 and 18 August). On all these days (15 to 18 August 2018), the flow (refer **Table 3.4** of this Report) exceeded 363 MCM/day which was adequate for the river to breach its banks[77]. The water level as measured at Neeleswaram CWC Gauge station on 16, 17 and 18 August was similarly very high at 12.10 m,

[77] Response of KSEBL dated June 2020 relying on research article by Dr K.P Sudheer, IIT Madras, et al, 'Role of dams on the floods of August 2018 in Periyar River Basin, Kerala'.

12.12 m and 10.55 m respectively when compared to average water level of 4.55 m[78] for the month of August 2018. Thus, the release of water from the dams so close to the peak inflow (even if it was in the recession limb) could aggravate the flood situation downstream. Further, on 17 August 2018, the hourly data indicates that the outflows from Idukki dam exceeded the inflows during 16 hours of the day and on 16 and 17 August, the outflows from Idamalayar reservoir exceeded the inflows for 10 and 21 hours of the day respectively. Besides, even if PH discharge were to be excluded for Idukki, the net inflow would be negative (-3.50 MCM) for Idukki on 17 August. Further, in the case of Idamalayar, though attenuation occurred at peak inflow, the fact is that net inflow over the 14-18 August period was negative (-9.86 MCM). Besides, the Guidelines for operation of spillway gates of Cheruthoni dam (1990) specify that outflow is never to exceed inflow except under emergencies and when the reservoir is to be depleted to the desired level. Thus, Audit feels that it cannot be cited as a standard operating procedure, even during the receding limb of a flood hydrograph, particularly so close to the peak inflow.

Hence, Audit reiterates the need for assurance about the adequacy of the new rule curve along with the provision of dynamic flood cushion given the fact that the frequency of incidents of excessive rainfall and flooding in the State has increased in recent years. As the rainfalls in July 2018 had resulted in an average inflow of 25 MCM per day to Idukki and the average inflow to Idukki between 09 August 2018 and 19 August 2018 was more than three times and of the order of 79 MCM per day, which was unprecedented in the history of the dam, there is an urgent need to be prepared for such extreme rainfall events in the future including through establishment of inflow forecasting stations[79]. The possibility of unscheduled releases from upstream reservoirs also needs to be considered along with the factoring of downstream conditions. It is desirable further to develop the rule curves keeping in view the integrated operation of the major reservoirs in the basin. Rule curves developed considering various aspects including integrated operation of reservoirs would provide more assurance.

Recommendation 3.5:

a) KSEB may ensure flood release operations for reservoirs are based on approved rule curves which further need to be regularly reviewed and updated.

b) KSEB may conduct simulation or other studies to ensure that the approved rule curves of 2020 for Idukki and Idamalayar would be adequate to handle situations similar to the extreme rainfall event of 2018, without consequential flooding.

[78] Water level on 14 August was 5.91 m as per CWC data.

[79] The reservoir level can be better managed by providing a dynamic cushion to moderate flood through meticulous planning by reviewing the reservoir levels and inflow forecast at all time steps. *(Source: Rule curve for major reservoirs of KSEB – May 2019)*

c) Feasibility of putting in place rule curves based on integrated operation of reservoirs within an approved time frame must also be considered.

3.7. Siltation of reservoirs and reduction in storage capacity

Dams and Reservoirs are subject to siltation. Sedimentation causes loss of active storage volume, and thus reduced ability to compensate for outflows for hydro power, irrigation, drinking water and flood retention. Uncontrolled deforestation, forest-fires, overgrazing, improper methods of tillage, unwise agriculture practices and other activities are mainly responsible for accelerated soil erosion which causes siltation in dams. Paragraph 7.10 of Reservoir Operation Guidelines[80] issued by the Bureau of Indian Standards requires capacity surveys of reservoirs to be undertaken once in three to five years or when the loss of capacity was five *per cent*, whichever was earlier.

- Audit observed that of the 18 reservoirs[81] under the ownership of KSEBL, sedimentation studies of only 11[82] were carried out during the period from 1989 to 2011. As on the date of audit (August 2019), no capacity surveys or sedimentation studies were conducted in any of the KSEBL reservoirs after 2011. Though the sedimentation surveys (in 2007 and 1995 respectively) indicated significant capacity loss as in Kallarkutty dam (47 *per cent* of gross storage in 45 years) and Anayirankal reservoir (30.92 *per cent* in 33 years), KSEBL had not conducted any further study to assess the change in silt deposit and reduction in the capacity of the dams. Though KSEBL identified (2010) six dams[83] for conducting desiltation, none of them had been desilted till the date of audit (August 2019).

  Secretary, Power Department stated (September 2020) that the live storage in five major reservoirs *viz.* Idukki, Idamalayar, Kakki, Banasurasagar and Sholayar (out of 18 reservoirs[84]) constitutes 92.27 *per cent*. Siltation is negligible in these major reservoirs as its annual storage loss is less than 0.2 *per cent* as per the sedimentation studies conducted through various agencies. In respect of the eight small reservoirs for which studies were conducted, desilting could not be carried out due to difficulty in depositing removed silt and obtaining permission from Forest Department. The Handbook on assessing and managing reservoir sedimentation published by CWC in February 2019 indicates that the annual storage loss due to sedimentation is significantly low in Kerala reservoirs.

  Audit observes that the statement that sedimentation in the five major KSEBL reservoirs is negligible is not based on any recent study or

[80] IS 7323:1994, Paragraph 7.10
[81] Eighteen storage reservoirs which are formed under 32 dams.
[82] Kakki, Kallarkutty, Lower Periyar, Ponmudy, Poringalkuthu, Kundala, Madupetty, Anayirankal, Pamba, Kuttiadi, Idukki and Idamalayar reservoirs
[83] Lower Periyar, Kallarkutty, Ayyappancovil and Kulamavu area of Idukki Hydro Electric Project, Anayirankal, Kundala and Madupetty Reservoirs
[84] with live storage capacities ranging from 0.39 to 1460 MCM

assessment (through CWC or otherwise) as sedimentation assessment of Idukki, Idamalayar, Kakki and Sholayar were conducted during 2004, 2011, 1999 and 2003 respectively. In respect of Banasurasagar reservoir, commissioned during 2005, no sedimentation study is seen conducted. Thus, 9 to 20 years have elapsed since conduct of capacity survey or sedimentation study, even though Reservoir operation guidelines (IS 7323:1994) provide for capacity survey every three to five years.

Kerala State Electricity Board Ltd. informed vide letter dated 01 February 2021 that sedimentation study had been repeated for Poringalkuthu and Kundala reservoirs in 2020. KSEBL also completed sedimentation surveys for five more reservoirs *viz.* Kallarkutty, Madupetty, Ponmudy, Anayirankal and Sengulam in 2020 but reports of the survey are awaited. Proposals for conducting sedimentation studies for the remaining reservoirs are now included under Dam Rehabilitation and Improvement Project (DRIP) - II and submitted to CWC for their approval. Chief Engineer (Civil – Dam Safety and DRIP) further stated (February 2021) in the backdrop of the 2018 floods that it was decided to carry out the sedimentation study for Idukki, Idamalayar, Kakki, Banasurasagar and Sholayar reservoirs and the same is included in Dam Rehabilitation and Improvement Project-II.

- Audit observed that the position was slightly better in the case of 20 reservoirs under the control of the Water Resources Department. Siltation study was conducted in respect of all these reservoirs. The study revealed significant levels of siltation in Aruvikkara reservoir (43 *per cent*), Mangalam reservoir (21.98 *per cent*), Peppara reservoir (21.70 *per cent*) etc. However, desiltation activities were not undertaken in any of these reservoirs. Though sanction was accorded (September 2017) by GoK for desiltation of Mangalam and Chulliyar reservoirs, the works were yet to commence as of the date of audit (November 2019).

In its reply, the Water Resources Department (November 2020) stated that silting was generally less in Irrigation dams. However, Audit observed that sedimentation in Peppara, Mangalam and Kanjirampuzha reservoirs of 21.70, 21.98 and 21.27 *per cent* of its storage capacity was significant.

During the Exit Conference (02 February 2021) and subsequently, vide letter from ACS, Water Resources Department dated 19 April 2021, Audit was informed that the desilting of Mangalam dam commenced[85] in the first week of December 2020 and that of Meenkara, Valayar and Chulliyar reservoirs entrusted to Kerala State Mineral Development Corporation Ltd. and Kerala Irrigation Infrastructure Development Corporation. With respect to

[85] ACS, WRD reply dated 19 April 2021 indicated that work for desilting Mangalam dam is a three-year long project which started on 17 December 2020. As on 10 April 2021, 0.098 MCM sediments (3.32 *per cent*) removed out of a total estimated quantity of 2.95 MCM.

Kanjirappuzha reservoir, bathymetric survey has been completed. Administrative sanction was accorded for the desiltation of Aruvikkara reservoir in January 2021 and two bids received are under consideration of the High-Level Empowered Committee. Further, though all efforts are taken to get the dams desilted, as the participation in tendering process was very low, the works had to be retendered more than once. ACS also stated that with the constitution of River Basin Conservation and Management Authority, the coordination work could be institutionalised and turned into a regular process.

Recommendation 3.6: In view of the possible loss of active storage volume of dams through sedimentation and its consequential adverse impact on flood control, KSEB and Irrigation Department may ensure that sedimentation studies as prescribed in Reservoir Operation Guidelines issued by Bureau of Indian Standards are conducted and timely action taken to arrest the capacity loss of reservoirs.

December 20, 2019
Cheruthoni riverbed,
Idukki District

CHAPTER IV
IMPACT OF CHANGE IN LAND USE AND LAND COVER

4 IMPACT OF CHANGE IN LAND USE AND LAND COVER

'Land Cover' refers to the Earth's surface cover such as forest land, wasteland, grassland, barren soil, river/ water bodies and built-up area etc. whereas the utilisation/ modification of the land for various socio-economic purposes such as urbanisation, afforestation and cultivation is classified as Land Use. Change in the Land Use and Land Cover (LULC) alters the natural hydrological processes of a region. Increased urbanisation results in the loss of existing natural drainage capacity of that area and prevents rainwater infiltration into the soil. This results in a rapid increase in the surface runoff generated which leads to surface flooding which can only be mitigated with proper drainage infrastructure.

Towards assessing the impact of changes in land use pattern on the floods of 2018, Audit availed the services of IISc to conduct an LULC analysis of the Periyar basin with specific reference to the two selected districts of Idukki and Ernakulam. To make the assessment, LULC data and maps of 100 m resolution of Idukki and Ernakulam districts for the years 1985, 1995 and 2005 were sourced from National Aeronautics and Space Agency (NASA). For the years 2005 and 2015, the LULC data and maps[86] were obtained from Kerala State Remote Sensing and Environment Centre (KSREC). The common year 2005 for which data was available from both the sources was used to validate the two datasets against each other to enable a continuous LULC change analysis over the three decades from 1985-2015. The results of the analysis of LULC in the Periyar basin and in the test-checked districts of Idukki and Ernakulam are given below. Further, this chapter includes findings on illegal constructions on Cheruthoni riverbed, diversion canal for Chengalthodu inadequate to prevent inundation and obstruction to flood discharge through Thottappally spillway.

4.1. Result of LULC study in the Periyar basin

The Periyar basin has an area of 5,159.71 sq. km, out of which about 97 *per cent* is in Kerala and about three *per cent* is in Tamil Nadu. Within Kerala, the basin has 3,011.65 sq. km in Idukki district (~58 *per cent*), 1,724.34 sq.km in Ernakulam district (~33 *per cent*) and 282.34 sq. km in Thrissur district (~six *per cent*). The LULC analysis for the entire Periyar basin including the test-checked Idukki and Ernakulam districts revealed that the built-up area increased by nearly 450 *per cent* during 1985-2015 (from 60 sq. km in 1985 to 330 sq. km in 2015). During the same period, the water bodies decreased by nearly 17 *per cent* (from 267 sq. km in 1985 to 221.44 sq. km in 2015). During the last decade 2005 to 2015 alone, the built-up area increased by nearly 139 *per cent* (from 138 sq. km in 2005 to 330 sq. km in 2015) and the water bodies

[86] The LULC maps on a scale of 1:50,000 were procured from KSREC (converted to raster of 30 m resolution)

decreased by 1.26 *per cent* (from 224.26 sq. km in 2005 to 221.44 sq. km in 2015) in the Periyar basin.

During the course of the audit, instances of encroachment of water bodies, river banks were noticed in the test-checked districts. Encroachment of water bodies accentuates risk and exacerbates the State's vulnerability to natural disasters[87]. The Kerala Land Conservancy Act 1957, contained provisions for removal of any encroachment or obstruction in river bank or *kadavu* and it was the responsibility of the Village Officer to report to the District Collector promptly all cases of encroachments on lands which are the property of Government. However, Audit observed 913 encroachments on four rivers/ water bodies in the districts of Thrissur, Idukki and Alappuzha which obstructed the free flow of the river and consequent inundation of adjacent areas during the 2018 flood. Issues such as lack of timely action in preventing encroachments, failure of revenue authorities to remove encroachment, non-conducting of survey to determine the boundaries of a river etc. contributed to shrinkage in areas covered by water bodies as indicated in **Appendix 2.1**.

4.1.1. Land Use and Land Cover in Idukki district

As stated above, 3,011.65 sq.km of land in Idukki district is situated in the Periyar Basin. The LULC analysis revealed that in Idukki district, a very significant increase of around 658 *per cent* (**Appendix 4.1**) in built-up area has occurred during the decade of 2005-2015. Such an increase in the built-up area adversely affects the flood runoff, exacerbating the inundation during heavy rain events. A study of the transition of land use[88] (in percentage) from one type to another in Idukki district from 2005 to 2015 revealed that 7.30 *per cent*[89] of agricultural land, 1.04 *per cent*[90] of forest land and 1.34 *per cent*[91] of water bodies in 2005, were converted to built-up land by 2015. Thus, in Idukki, the increase in built-up land from 2005 to 2015 was mainly the result of conversion of agricultural land, forest land and water bodies etc.

4.1.2. Land Use and Land Cover in Ernakulam district

Periyar Basin also comprises of 1,724.34 sq.km in Ernakulam district. Analysis of data for Ernakulam district revealed (**Appendix 4.2**) a very significant increase in built-up area of around 212 *per cent* during the three decades 1985-2015 and an increase of around 73 *per cent* in built-up area in the decade of 2005-2015. Also, the extent of water bodies in the district decreased by nearly 14 *per cent* during 1985-2015. Such an increase in the built-up area, accompanied by a decrease in water bodies adversely affects the flood runoff, intensifying the inundation during heavy rain. As in the case of

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87 Rebuild Kerala Development Programme, Chapter 1, Encroachment of water bodies as an example of poor maintenance of existing assets

88 Transition of land use is change from one type of land use to another, which may be human induced or naturally occurring, over the years. *(Source: IISc Bangalore's Report on Kerala Floods 2018)*

89 103.40 sq. km out of total agricultural land of 1,416.15 sq. km in 2005

90 22.84 sq. km out of total forest land of 2,196.35 sq. km in 2005

91 1.46 sq. km out of total water bodies of 109.02 sq. km in 2005

Idukki district, a study of the transition of land use in Ernakulam district revealed that 12 *per cent*[92] of agricultural land in 2005 was converted to built-up area during the period 2005-2015. Audit also observed that 1.10 *per cent*[93] of water bodies were converted to built-up area during 2005-2015.

4.1.3. Land Use and Land Cover in flood prone region of Ernakulam district

The floods of 2018 severely impacted areas downstream of the Neeleswaram gauge station till the Arabian Sea covering the towns of Kalady, Perumbavoor, Aluva, North Paravur and parts of Ernakulam city and Cochin International Airport (flood affected region) with a total area of about 791 sq. km (about 46 *per cent* of Ernakulam district). Audit examined the LULC over the last three decades of the flood affected region to assess the impact of floods because of change in LULC. This is necessary to understand whether the increase in built-up area in the Ernakulam district and the reduction in extent of water bodies resulted in the enormous damage to the region during 2018 floods.

In the flood-affected region, 86.76 sq. km of agricultural land (of total agricultural land of 566.34 sq. km in 2005) and 1.09 sq. km of water bodies (of total area of water bodies 69.62 sq. km in 2005) was converted to built-up area between 2005 and 2015 (**Appendix 4.3**).

The change in land use during the past three decades (1985-2015) resulted in a notable impact on the floods of 2018. Significant increase in built-up area and notable decrease in water bodies in recent years have rendered the Periyar basin vulnerable to floods. The results of Hydrologic modelling[94] also revealed that had the same rainfall and spills of 2018 occurred with 1985 land use conditions, the flood depth at Neeleswaram gauge station would have reduced from 12.32 m to 10.03 m and the flood inundated area would have reduced from 520.04 sq. km to 414.76 sq. km.

In response to the audit observations on LULC, the Revenue and Disaster Management Department stated (November 2020) that Kerala has witnessed rapid urbanisation in the last two decades with 47.10 *per cent* of the population living in urban areas and the rise in number of urban settlements expected to continue. The State Disaster Management Authority, on identifying land use as a major determinant factor of vulnerability in the State, had identified and succeeded in ensuring risk sensitive land use restrictions[95] in the State through the State Disaster Management Plan besides a disaster

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92 208.5 sq. km out of total agricultural land of 1,737.86 sq. km in 2005

93 2.09 sq. km out of total water bodies of 190.70 sq. km in 2005

94 IISc used a two-dimensional (2D) HEC-RAS model for this purpose

95 No permission for blasting type quarrying in high hazard zones of Kerala, Restriction on construction types in Wayanad district owing to hazard proneness based on KSDMA's advice, Limiting extraction of groundwater to 25 *per cent* of the permitted amount in the light of drought, Prevention of obstruction of streams and natural drains through amendment in the Kerala Municipality/ Panchayat Building Rules in 2019, Report of the Technical Committee suggesting amendments to the techno-legal regime issued to the Local Self-Government Department to amend the Kerala Municipal/ Panchayat Building Rules by the State Executive Committee of KSDMA.

vulnerability linked relocation scheme. Enactment of a new integrated, risk sensitive and terrain specific legislation as highlighted in the Rebuild Kerala Development Programme (seeking to explore solutions to Kerala's urbanisation problems) was the only means of reducing disaster vulnerabilities of the State. Hence audit observation only reiterated known facts and the State has already started local and customised solutions.

The exercise undertaken in audit brought to light the extent of drastic change in land use in the Periyar basin during the past three decades (1985-2015), which resulted in a notable impact on the floods of 2018. The study underscores the need for urgent and coordinated efforts of stakeholders in arresting the rapid conversion of Land cover, to mitigate the severity of future flood scenarios in the State. Whereas urbanisation is essential to cater to the needs of growing population, unplanned and imprudent increase in built up area would trigger further depletion of pervious land cover. Besides the steps already undertaken, the State needs to review the need for a legislation on flood plain zones/ initiate steps to prioritise the identification and demarcation of flood plain zones.

Audit notes that the Rebuild Kerala Development Programme of Rebuild Kerala Initiative draws attention to the fact that rapid urbanisation influenced habitations into uncontrolled expansion on both banks of the rivers/ water bodies thereby encroaching into water channels/ bodies and constricting the flood plains. Arresting further unplanned increase in coverage of built-up area of land cover is the critical need of the hour.

Recommendation 4.1: In view of the drastic change in land use over the past few decades with its impact on the recent floods, Government may initiate urgent steps to review the adequacy of the measures initiated to reduce the risk of vulnerability to floods, attributable to changes in land use.

Government may also initiate steps for an integrated and comprehensive legislation and a land use policy after reviewing the existing land management related Acts/ rules/ regulations/ policies etc. to reduce disaster vulnerabilities, as highlighted in the Rebuild Kerala Development Programme.

4.2. Illegal constructions on Cheruthoni riverbed in Idukki district

Cheruthoni river is located in Idukki district. The water from Cheruthoni dam along with that of two other dams at Idukki and Kulamavu, is used by KSEBL for production of electricity at the Moolamattom Power house. The spillway of Idukki Hydro Electric Project in the Cheruthoni Dam, when opened, releases water from the dam into Cheruthoni river.

The Disaster Management Plan 2016 had warned that consequent upon encroachment of the riverbed downstream of this dam, opening the shutters of the dam would result in damage to property. However, lack of continuous monitoring and timely action to evict encroachers led to the obstruction of free

flow of the river and consequent damages in 2018 floods. Audit observed that the Idukki Township Area Development Scheme, 1980, classified 238.72 hectares of land, situated downstream of Cheruthoni Dam in between the road from Cheruthoni town to Neriyamangalam and Cheruthoni river, as Construction Free Zone (CFZ). This area falls under Maximum Flood Level (MFL) demarcated by KSEBL. No construction could be done in this area as the opening of dam shutters would damage buildings and habitations in this area. But disregarding the apparent danger, buildings were constructed along the course of the Cheruthoni River within CFZ/ MFL. It is evident from a letter written (March 1993) by Chairman, KSEBL to GoK that KSEBL had constraints in opening the dam spillway fearing the adverse effects on life and property downstream of the river.

Consequent to a mass petition filed by residents of Idukki (March 2008) before Hon'ble Chief Minister regarding illegal constructions of multi-storied buildings in CFZ at Cheruthoni, a detailed enquiry by the LSGD and Power departments identified 62 buildings in the CFZ which would be inundated in the event of opening of dam shutters. Though GoK directed (November 2009) Secretary, Vazhathope Grama Panchayat to remove the buildings constructed in CFZ, no action was taken to comply with the direction resulting in many buildings and houses[96] being washed away and foundations of several buildings getting damaged consequent to the opening of shutters of Cheruthoni dam during the floods of August 2018. More importantly, the Tahsildar Idukki reported (April 2019) that new buildings were again coming up in the area where the buildings were washed away in 2018. The constructions were in violation of the orders (August 2016) of the District Collector in his capacity as Chairman of DDMA prohibiting construction in areas within the MFL of the Cheruthoni River. The Deputy Superintendent of Police, Idukki also reported (April 2019) that there was reconstruction of old buildings which were damaged in the floods of 2018, in violation of the order of District Collector. No action has also been

Figure 4.1: Reconstruction of hotel building washed away in flood of 2018.
20 December 2019, Cheruthoni riverbed, Idukki District,
Photo taken by Audit party, attested by Tahsildar, Idukki Taluk

[96] Palace Hotel, Central Bakery, Kerala Bakery, Newspaper shop, Sreenilayam stores, Akshaya Kendra, Muthoot shop, KTM veg store, comfort stations, other vegetable shops etc. and eight numbers of houses

taken to remove or relocate 155 encroachments identified by a joint verification team[97] constituted (November 2019) by the District Collector. Complaints on encroachments received by the Revenue Department were also not acted upon by the department. The Tahsildar (Land Records), Idukki affirmed to Audit (November 2019) that none of the 34 complaints received upto 2019 by the Taluk Surveyor/ Village Officer relating to encroachment of rivers/ canals were acted upon.

Lack of continuous monitoring and timely action to evict the encroachers led to the obstruction of free flow of the river and consequent damages in 2018 floods. Further, the encroachment caused operational bottlenecks for spillway opening as the people occupying these illegally constructed buildings were to be given sufficient time for evacuation before the gates were opened.

Principal Secretary, Revenue and Disaster Management Department stated (January 2021) that a joint inspection under the leadership of Town Planner, Idukki has reported that there are approximately 285 constructions in the CFZ and directions were given to Vazhathope GP for taking action against illegal construction. In the Exit Conference (January 2021), Commissioner, Disaster Management stated that the District Collector had been insisting on removal of structures in the CFZ and MFL region and orders were issued by District Collector in 2016. However, due to court cases both in High Court and National Green Tribunal, progress in eviction was slow. The Commissioner assured that the matter was being pursued nevertheless.

Recommendation 4.2: The Government needs to prioritise speedy resolution of the issues relating to removal of unauthorised constructions from the construction free zone in Cheruthoni as also to ensure no new construction is allowed to come up in future within the demarcated zone.

4.3. Diversion canal for Chengalthodu inadequate to prevent inundation

The Land Use and Land Cover analysis of the Periyar Basin as conducted by IISc revealed significant increase in built-up area and reduction in the extent of water bodies. Several towns downstream of Neeleswaram gauge station including parts of Ernakulam city and areas in and around Cochin International Airport experienced aggressive flooding in August 2018. The severity of floods in 2018 caused Cochin International Airport Limited (CIAL) to shut down the airport for 15 days. Audit, therefore, sought to validate the LULC analysis with field verification and scrutiny of records at various offices.

Scrutiny of records revealed that 1,253 acres of land were acquired for constructing the airport, which included wetlands utilised for paddy cultivation

[97] Dam Safety Officer, KSEB, Vazhathope, Town Planning Officer, Idukki, Tahsildar (LR), Idukki, Secretary Grama Panchayat, Vazhathope, Village Officer, Idukki and Taluk Surveyor, Taluk Office, Idukki.

with canals and a portion of the Chengalthodu[98] flowing through. Government of India accorded (March 1995) environmental clearance for construction of the airport, subject to the fulfilment of the condition that 'for diversion of Chengalthodu, appropriate measures such as construction of bund/ diversion canal etc. to regulate the flow of water from Periyar river into the existing Chengalthodu must be adopted, to ensure that the overall hydrology of the area does not change.'

Audit sought the dimensions of Chengalthodu which originally flowed through the area acquired by CIAL before construction of the airport, from Taluk/ Land Acquisition offices in Aluva. The said details were not available either in the office of the Special Tahsildar (Land Acquisition)[99], Nedumbassery or the Taluk office, Aluva. Consequently, as requested by Audit, the survey wing in Taluk office Aluva conducted a comprehensive survey[100] of the original flow route of Chengalthodu prior to construction of airport, after accessing basic records, lithomaps etc. and survey plans from District Survey Office and taluk/ village offices. The survey revealed that while the existing stretch of Chengalthodu originating from the Periyar and flowing till the northern boundary wall of CIAL was approximately 3.5 km long and 60 m wide, the total length of the flow route within CIAL area before construction of airport was estimated to be 2.06 km with approximate width of 52 m. Audit observed[101] that the stretch within the acquired area was filled up by CIAL, thereby disrupting the natural flow route of the water body causing stagnation of water and severe inundation during monsoons.

While conceding that the river had been blocked at the point where it touches the northern boundary wall of the airport, CIAL informed (December 2020) that the stretch of Chengalthodu which flowed through the middle portion of the runway area was diverted in the process of converting the acquired area into airport, more specifically the runway and taxiway. It was also stated that CIAL had created a diversion canal approximately 3.5 km long and 38 m[102] wide in 1999 itself and that the length of the canal remained unaltered even today. However, the minutes of post 2018 flood meetings attended by Revenue and Disaster Management and Irrigation Departments/ CIAL/ LSGI authorities mentioned that the said channel remained without having been deepened and cleaned, obstructing the smooth flow of water in monsoons, leading to local protests.

Audit observed from records that consequent upon an aggravated flood situation in August 2013, areas in the vicinity of CIAL were inundated, forcing suspension of normal operation of the airport for a day. Subsequently,

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98 A rivulet collecting excess water from Periyar river, starting in Kanjoor village and having natural course through Chengal, Thuravankara, Manjali, Chowara and finally merging with Periyar at Kuzhippallam. 'Thodu' is the Malayalam word for small river/ creek/ canal.

99 The office was severely affected by floods in 2018 and 2019, with many of its records getting dampened and termite-infested

100 The survey was conducted from December 2019 to January 2020

101 Chengalthodu Report of the Irrigation Division, Ernakulam post 2018 floods

102 The width stated by CIAL alongwith bund road; the survey sketch showed width of 20 m.

CIAL requested National Institute of Technology (NIT), Calicut to conduct a study to suggest remedial measures to prevent recurrence of such an event. NIT Calicut observed (2013) that as the diversion channel proposed by CIAL had very limited carrying capacity, it could not be expected to bring down the flood discharge and levels in Chengalthodu and adjoining areas considerably and eliminate the threat of submergence. As an additional safety measure, NIT recommended that CIAL may complete the diversion channel with maximum possible width, depth, and bed slope, taking sufficient precaution to prevent inundation of the land along its alignment. However, insufficiency of measures taken since then is evident from the report of Irrigation Department post the deluge in 2018 stating that the diversion canal constructed by CIAL was totally inadequate to drain off the excess influx from Periyar as well as rainwater from the areas in the vicinity, which resulted in acute flooding in the area.

Cochin International Airport Limited stated in the replies and during discussion (December 2020, January 2021) that the site for the airport was selected by the expert team from Airports Authority of India, and GoK vide Government Order dated 15 November 1996 approved diversion of Chengalthodu so as to carry out construction of runway and apron over Chengalthodu. It was also informed that the width of Chengalthodu varies from place to place and at places is 20 m as against 60 m indicated by Audit. Considering the 400 m wide operational area of airport and some meandering of the rivulet, the maximum length of the rivulet inside the operational area would be 600 m against the 2.06 km length stated by Audit. Audit should have relied upon the Survey of India Map of 1993 rather than follow a methodology of the superimposition of lithomap of Aluva taluk over satellite map of the area.

Cochin International Airport Limited further stated that historical data indicates that the maximum water flow from Chengalthodu to Periyar could be 41.53 cumecs. The unprecedented water flow in the Periyar during the 2018 flood calamity, near the Airport area was 6,500 cumecs due to very heavy rainfall and excess spillage from upstream dams. The water flow rather than the construction of the airport caused severe flooding in Periyar, its tributaries and flood arms. Areas downstream and upstream of Periyar were also badly flooded in 2018 floods.

Audit clarified (January 2021) that it had relied upon the actual measurements of the detailed survey conducted by the Survey wing of Taluk Office Aluva for over a month, to assess the extent of water body that has been filled to make way for the runway of the airport, from the point at which it was blocked at the northern boundary wall of CIAL till the point at which it continues to flow outside the airport boundary. The superimposition[103] of the lithomap over satellite map was only for reconfirmation, which also revealed the length of Chengalthodu within CIAL area to be over 2 km. CIAL requested to share the

[103] At Land Use Board Thiruvananthapuram

survey sketch with them, which was complied with by Audit. Minutes of the conference were approved (February 2021) by Audit and CIAL.

Audit observed that action to survey and demarcate the flood plains of Chengalthodu, as well as conserve and ensure unhindered flow route for the river had not been taken even after the flooding in 2013. Despite passage of 20 years since the commissioning of the airport and incidents of severe flooding in the area, the Irrigation/ Revenue and Disaster Management wings/ LSGIs concerned/ CIAL have not been able to ensure a diversion canal adequate to carry the Chengalthodu waters (in the event of heavy flooding) into the Periyar river to sustain the overall hydrology of the area and ward off the potential risks of riverine flooding to the resident population. Considering that the flood hydrograph in NIT Report had observed that the peak flood discharge near the mouth of Chengalthodu (entrance from Periyar river) at Neeleswaram on Periyar river was 472 cumecs in 2013 (the time taken by the flood wave to travel from Neeleswaram to the mouth of the Chengalthodu is just about 14 minutes[104]) and also the flood flow through Chengalthodu 6,500 cumecs in 2018, the Government needs to ensure adequacy of the dimensions of the diverted route of Chengalthodu as well as its maintenance, so as to lessen the impact of possible inundation in the airport and surrounding areas during the monsoons.

CIAL stated (December 2020) that GoK had accorded sanction (February 2019) to a comprehensive flood mitigation plan for safeguarding the areas in the vicinity of airport from future floods. Of the 26 works taken up as part of the flood mitigation plan at a cost of ₹129.30 crore, 13 works were stated as completed and the remaining works were still in progress. CIAL informed (January 2021) that the works relating to the diversion canal were expected to be completed before the upcoming monsoon. Government of Kerala informed (January 2021) that reply to the matter has been furnished (December 2020) to Audit by CIAL.

Recommendation 4.3: Government may a) ensure the adequacy of planned/ ongoing works under the comprehensive flood mitigation plan for safeguarding CIAL and its surrounding areas and b) review the pace of progress vis-à-vis the targets so that risk of loss to life and property in case of extreme rainfall/ flooding is minimised.

4.4. Obstruction to flood discharge through Thottappally Spillway

The Thottappally Spillway[105] (TSW) situated 20 km south of Alappuzha was commissioned in 1955 as an easy and only direct outlet for the combined flood discharge of Pamba, Achencovil and Manimala rivers into the sea before it reaches lower Kuttanad area, preventing heavy damages to the life and

[104] NIT Report 2013

[105] The TSW included a regulator cum bridge 360 metres long having 40 vents and a leading channel 1,310 m long and 365 m wide, starting from the confluence point of Pamba and Achencovil rivers at Veeyapuram.

property of people in Kuttanad. TSW was to include a regulator cum bridge 365 m long having 40 vents and a leading channel 1,310 m long and 365 m wide, starting from the confluence point of Pamba and Achencovil rivers at Veeyapuram. Audit scrutiny of records revealed that in the upstream side of the spillway, the width of the leading channel was only about 80 m from Veeyapuram to Thottappally, which reduced the discharge capacity of TSW to 700 cumecs against the envisaged capacity of 1800 cumecs.

Consequently, water discharged through the spillway to the sea was severely restricted, during the flood of 2018, resulting in heavy flooding[106] and casualties in Kuttanad and other regions in Alappuzha and parts of Pathanamthitta.

The Chief Engineer (Mechanical), Irrigation Department confirmed (July 2020) that against the targeted dredging of the east side of Thottappally (lake side) for a length of 500 m with a width of 320 m, works were executed only in a stretch of 380 m length and 160 m width[107]. Audit notes that dredging works in the leading channel which remained to be completed imply reduced carrying capacity.

Scrutiny of records at Office of the Chief Engineer, Kuttanad[108] indicated that there was gradual accretion of sand on the south side of a breakwater which was constructed (2004) to facilitate opening of Thottappally Fishing Harbour about 100 m north of spillway mouth. The width and carrying capacity of the spillway mouth was further reduced to one third of its original state, after the Social Forestry Department, without seeking permission from Irrigation Department, planted (2010) casuarina trees on this sand base, right inside the spillway mouth. Incomplete dredging and widening of leading channel of Thottapally spillway and delay in removal of the trees planted inside the spillway mouth resulted in reduction of capacity of the spillway, thus contributing to the flood situation in Alappuzha in August 2018.

[106] Source: Letter from CE Kuttanad to Additional Chief Secretary, Water Resources Department (June 2019)

[107] Excluding a stretch of 80 metre length and 50 metre width

[108] Chief Engineer, Inland Navigation and Kuttanad package under Water Resources Department, Government of Kerala

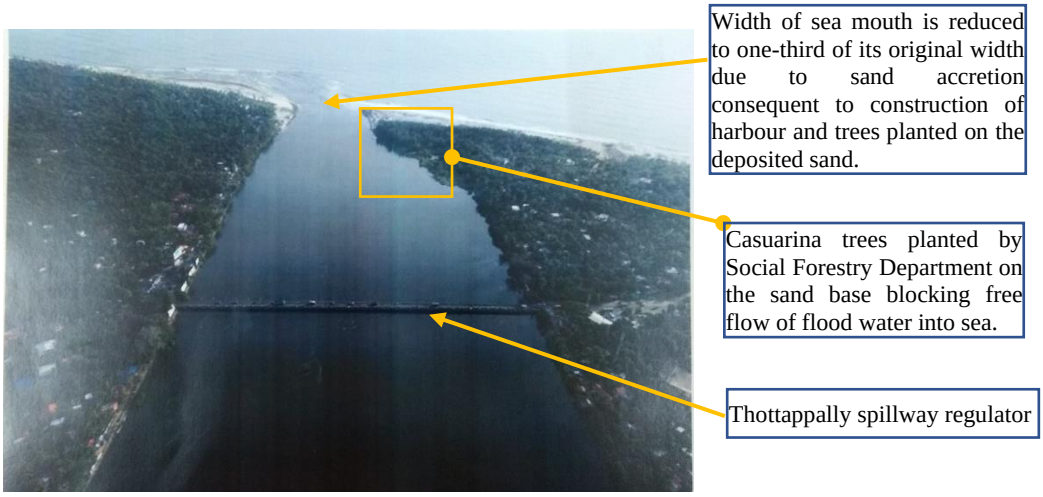

Figure 4.2: Thottappally spillway aerial view, July 2018, Alappuzha District
Source: Mechanical Division, Irrigation Department, Alappuzha

In the aftermath of the August 2018 floods, the Principal Chief Conservator of Forests (PCCF) issued instructions (May 2019) to cut down the trees in view of the risk of an impending disaster. However, the Social Forestry wing of the district, citing environmental reasons, did not comply with the order. Orders of the District Collector invoking the provisions of Disaster Management Act 2005 (June 2019), for taking immediate action to cut down these trees which were obstructing natural flow through the spillway mouth were also not complied with.

Chief Engineer, Kuttanad informed Audit during the joint site verification (04 October 2019) that though attempts were made to cut down the trees on the basis of District Collector's order, only four trees could be removed as the local people had vehemently resisted the move, stating that these trees acted as a protective shield against wind.

Water Resources Department confirmed (November 2020) that discharge envisaged through the spillway had been reduced from 1800 cumecs due to the siltation in the leading channel. Further, any change in width of the upstream channel requires rehabilitation of people from the heavily populated banks. Additional Chief Secretary, Water Resources Department informed (November 2020 and April 2021) Audit that 550 casuarina trees planted within the 380m width of the downstream, and reckoned to be obstructing the flow of floodwaters were cut down by the District Administration, Alappuzha on 22 May 2020, by which the width at the spillway mouth was extended by 230m thereby reaching the required width of 380m.

It was also informed that with a view to deepen and widen the estuary, Irrigation Department started removal of mineral sand from spillway mouth and downstream of the spillway on 20 May 2020. Accordingly, an estimated quantity of 2,42,831 cu.m sand was dredged; out of which a quantity of 1,75,319 cu.m sand was removed. Within a few months after completing the dredging, a sand bar has been formed at the spillway mouth, occupying a width of 75 m. The present accumulation of mineral sand at the downstream is

estimated to be 2,49,000 cu.m (April 2021). Steps were being taken to remove the since accumulated mineral sand from the downstream of the spillway mouth in order to ensure smooth flow of flood waters during the upcoming monsoon season.

Audit observes that Water Resources Department and District Administration Alappuzha would further need to ensure regular monitoring and deepening of the leading channel upstream of TSW and timely breaking of developing sand bar if any, which are crucial in ensuring unhindered flow of flood waters to the sea. Had the above authorities proactively intervened, to remove the trees obstructing the spillway mouth prior to 2018 monsoon, the flood situation in Alappuzha could have been mitigated to a considerable extent.

Recommendation 4.4: Government may, prioritise works such as deepening of the leading channel upstream of TSW and timely breaking of developing sand bar, if any, at the sea mouth so as to ensure unhindered flow of flood waters to the sea, giving due consideration to extant environment related instructions while so doing.

August 19, 2018
Alappuzha District

CHAPTER V
FINANCIAL MANAGEMENT AND SURVEY

5 FINANCIAL MANAGEMENT AND SURVEY

Financial management

Audit analysed the procedures followed in administration of the State Disaster Mitigation Fund and extent of utilisation of State Disaster Response Fund for immediate restoration activities in the post 2018 flood scenario and the resultant observations are presented in the following paragraphs.

5.1. Management of the State Disaster Mitigation Fund

In line with the stipulation in the Disaster Management Act, 2005 requiring[109] the State Disaster Management Authority to recommend making available funds for mitigation[110] and preparedness measures in relation to disasters, a State Disaster Mitigation Fund (SDMF) was constituted (December 2011) exclusively for projects meant for the mitigation of disasters. The Guidelines for administration of SDMF were issued (June 2012) by GoK to ensure consistency[111] in the use of the Mitigation Fund and promote measures to reduce future loss to life and property, protect the infrastructure and ultimately help build disaster resistant communities. The Guidelines envisage (Paragraph 2.5) that the State Disaster Management Plan formulated by the SDMA, SEOC and the Department of Revenue and Disaster Management[112] should form the basis for the effective utilisation of SDMF. Audit noticed the following deviations in the management of the Fund.

5.1.1. Need for proactive role of KSDMA to ensure higher provision of funds

The Guidelines stipulated that the annual contribution of GoK to SDMF for each financial year would be as recommended by SDMA, to be provided every year in the State budget. The budgetary provisions and expenditure under SDMF during the audit period from 2014-19 are detailed in **Table 5.1**.

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[109] Section 18(2)(f) of the Disaster Management Act 2005

[110] 'Mitigation' refers to the lessening or limitation of the adverse impacts of hazards and related disasters. (Source: Guidelines for the Administration of State Disaster Mitigation Fund, June 2012)

[111] Guidelines for the Administration of the State Disaster Mitigation Fund, June 2012

[112] Page 3 of State Disaster Management Plan 2016

Table 5.1: Budgetary provisions and expenditure of SDMF during 2014-19

(₹in crore)

Year	Funds provided in the Budget	Expenditure against budget provision
2014-15	0.05	0.00
2015-16	42.50	32.50
2016-17	10.10	1.00
2017-18	6.25	6.25
2018-19	1.00	0.81
Total	**59.90**	**40.56**

(Source: Detailed Appropriation Accounts of the respective years)

As seen above, the funds received from GoK were meagre in all years other than 2015-16 when GoK made available ₹42.50 crore for the fund. Also, contrary to stipulations in the Guidelines, KSDMA did not formulate a State level mitigation plan/ strategy detailing all mitigation activities to be undertaken in the State.

In reply, the Department of Revenue and Disaster Management stated (November 2020) the following:

- 'Mitigation' denotes the proactive steps aimed at reducing the risk, impact or effect of a disaster or threatening disaster situation. SDMF Guidelines require that the SDMF should be a demand-driven rather than supply-driven mechanism.
- It was further stated that Audit had ignored the fact that the Disaster Management Act of 2005 mandates Government of India to constitute a National Disaster Mitigation Fund, which remains to be created. Expenditure from SDMF is met entirely out of State Funds and allocation is based on recommendation of KSDMA, but subject to availability of funds, the ways and means position of the Government and Governmental priorities.
- Government further stated that there was no statutory obligation on KSDMA or SEC to frame mitigation plans (unlike the required preparation of Disaster Management Policy, the DM Plan and Guidelines for the integration of measures for prevention of disasters and mitigation) under the Disaster Management Act 2005.
- Under the DM Act (section 18(2)), in specific cases of mitigation, KSDMA has to a) recommend provision of funds for mitigation and preparedness measures (Kerala is one of the few States to have created the SDMF and utilised it, complying with the statutory requirement) and b) review the development plans of the different departments of the State and ensure that the prevention and mitigation measures are integrated therein. In compliance of the statutory requirements, KSDMA carried out a detailed examination of the budget heads and plans of departments and suggested action points as guidelines for mainstreaming disaster risk reduction.

- The mitigation plans are to be laid by the respective departments depending on the site-specific conditions with the general guidance of the State and District Disaster Management Plans. It is not a statutory requirement that the State Disaster Management Authority create a separate Disaster Mitigation Plan. SDMF is demand driven and when specific funding demands are submitted by departments or DDMAs to the SEC, they are examined and approval given based on merits.

The reply is not tenable since KSDMA was tasked with coordinating and implementing disaster mitigation projects through DDMAs, empanelled NGOs, other departments, local self-governments, self-help groups etc. As the coordinating and implementing agency, KSDMA should have taken proactive steps including interacting with various stakeholders for assessment of their needs and obtaining funds from GoK for attainment of such objectives. Contrary to requirements of the Guidelines (Paragraph 2.5) framed by KSDMA itself, no State level mitigation strategy was formulated, apart from including in the Disaster Management Plan, a Chapter on Disaster Preparedness and Mitigation, which had no indication of a Mitigation Strategy in the context of flood as threatening disaster other than Operation Anantha in Paragraph 3.14 and Mullaperiyar Crisis Management Plan (Paragraph 3.10). Audit observes that had KSDMA chalked out a Mitigation Plan detailing vulnerabilities and ensured a strategy in place to mitigate potential disasters, KSDMA's recommendations for funds would have been based on the same. Audit notes that the Guidelines (Paragraph 2.5) for the administration of the SDMF envisage that once the State level mitigation strategy has been detailed, the works which could be taken up at the district, block and grama Panchayat level for shorter duration could be culled out of the Long-term disaster mitigation/ prevention plans. Further, it also provides that in its functioning, the SDMF should be based on a risk reduction plan which suggests a definite set of measures - structural or non-structural. If these Guidelines had been adhered to, identified projects could have been presented before SEC for approval and sufficient funds for mitigation activities could have been provided in the budget. A passive approach by KSDMA in this regard possibly contributed to the low budgetary allocation for SDMF over the years. Audit notes that the Guidelines also provide scope for utilising the SDMF for supporting mitigation projects of short-term nature that may be implemented within a period of maximum three years that emerge out of a threatening situation (besides the projects identified through the State Disaster Management Plan) but this does not endorse the view that no State Level Mitigation Plan or Strategy was warranted.

That the National Disaster Mitigation Fund has not been constituted in the country, makes it all the more important for KSDMA to formulate a State level Mitigation Plan/ Strategy and make recommendations based on the same for securing funds for the SDMF.

5.1.2. Deviation from procedures laid down for administration of State Disaster Mitigation Fund

The Guidelines for administration of SDMF envisage that the Fund is utilised for supporting mitigation projects (as distinguished from preparedness and response measures) of short-term nature that may be implemented within a period of maximum of three years, either identified in State Disaster Management Plan or emerging out of a threatening situation. The guidelines also envisaged utilisation of the funds only for such mitigation activities that were not covered under any of the existing plan schemes and stipulated that the interventions should be in areas which were otherwise not supported by regular or other Government schemes.

The mitigation projects evolved by any agency shall be assessed and approved by DDMAs which shall forward them to SDMA. The proposals accepted by SDMA with respect to financial feasibility, compliance with guidelines etc. shall be placed before SEC. All project proposals seeking assistance from SDMF were to have seven elements[113] as chapters to be evaluated with marks. The SEC was solely responsible for selection, approval/ disapproval of a project proposal after reviewing all pertinent information regarding the project proposal.

Audit observed that only seven projects as listed below in **Table 5.2**[114], were taken up under SDMF during the seven-year period till March 2019.

Table 5.2: Projects taken up under SDMF till March 2019

(₹ in crore)

Sl. No.	Name of project (Proposed by)	Amount expended
1.	Mullaperiyar Crisis Management Plan (DDMA Idukki and SDMA)	1.31
2.	Operation Anantha in Thiruvananthapuram and Kannur districts (DDMA Thiruvananthapuram)	23.72
3.	Pulimuttu Construction (Harbour Engineering Department)	10.00
4.	Side wall construction for a residence (DDMA, Thiruvananthapuram)	0.25
5.	Drought Mitigation (Kerala Water Authority)	6.00
6.	Urgent rectification works to left bank of Muvattupuzha river (Government)	0.50
7.	Mud flow prevention at Wayanad (Government)	0.04
	Total	**41.82**

(Source: Details furnished by KSDMA)

Audit could not obtain documentary evidence for adherence to the aforementioned stages in administration of SDMF from connected records at KSDMA/ GoK. Proposals were not seen routed by DDMAs to SEC through

[113] (i) Introduction (ii) Identification of hazards/ proposed implementation site (iii) Materials and methods (iv) Deliverables (v) Financial budgeting (vi) Timeline (vii) Profile of proposing or implementing authority/ agency and technical advisor

[114] **Table 5.2** shows the total expenditure incurred on all the seven projects funded by SDMF from 2012 till March 2019, whereas **Table 5.1** details expenditure on SDMF projects during the audit period from 2014-15 to 2018-19.

KSDMA and project proposals not seen approved by SEC, except in Sl.No.2 for which ratification was obtained.

Though project proposals seeking assistance from SDMF were to be evaluated by SEC with marks to be allotted on the basis of seven elements, there were no recordings in the files to indicate that this process had been complied with and that projects had in fact been approved by SEC. Audit however observed that bypassing crucial stages in selection of projects like routing proposals from DDMAs to KSDMA to SEC for approval, SEC's review of the chapters in project proposals prior to approving/ disapproving a proposal etc. is a cause for concern as regards transparency in prioritisation of projects.

Government in its reply (November 2020) stated that the SEC and the Government were adequately satisfied with the projects and proposals that are sanctioned from SDMF as testified by documents and justifications pertaining to each of the project and that the guidelines have been scrupulously followed in each case.

However, Audit notes that the role that is envisaged for the SEC is that of an approving and sanctioning authority for project proposals, rather than a role where it steps into the picture after the decision has already been taken to sanction from SDMF.

The clarification of Member Secretary, KSDMA in the Exit Conference (January 2021) on delegation of financial powers wherein works upto ₹ one crore could be approved at the level of Principal Secretary (Revenue and Disaster Management Department) cannot be regarded as a justification to evade the stipulated sequence of phases of approval of project proposals by SEC. The approval of the project by the SEC after following due procedure is to precede the financial sanction. Even the Government order[115] only delegates the financial powers of the SEC to the Additional Chief Secretary, Revenue and Disaster Management.

Audit was also informed (November 2020) that it had been ensured that all listed mitigation activities did not have funding from any other source. As regards items at 4 and 6 in **Table 5.2**, it was indicated as follows:

In the case of work cited at Sl. No. 4, it was stated that competent authorities examined the matter and reported the potential loss to life and property and the District Collector reported the matter to the Government. The Government decided to release funds from SDMF and recover the costs from the concerned parties who may have triggered the failure to the cliff. As regards Sl. No. 6, it was stated that based on the report of DDMA Kottayam, Government decided to support this 'proactive measure' in the light of the specific fact that this was a mitigation activity requiring immediate application of resources to avoid a threatening disaster situation as corroborated by the technical report of Irrigation Department[116]. In both cases, powers vested upon SDMA and

[115] GO (Rt) No. 2167/2016/DMD
[116] The nodal department for flood preparedness and mitigation

DDMA under Section 50 of Disaster Management Act, 2005 were complied with.

Chapter 3 of the Mitigation Fund Guidelines warrants execution of necessary measures by the Secretary SDMA for the prevention/ mitigation of threatening disaster situation where immediate measures are necessary to protect the community from an anticipated disaster. However, in such cases, approval from the Convenor and Chairperson of SEC are to be kept in the file. Any such action taken by KSDMA should be submitted for ratification before the SEC in the subsequent meeting. In both cases, no records in support of the above were available in DDMA/ KSDMA/ Government. Audit observes that if action was warranted under Section 50 of the Act in respect of both these cases, then these procedures as per Chapter 3 should also have been complied with.

Audit observed that as per Paragraph 2.6 of the Guidelines, the Secretary, State Disaster Management Authority will ensure financial feasibility of the project, ensure that no other funding from Government of Kerala is available or possible for the proposed project and ensure compliance with the guidelines for the utilisation of the SDMF before presenting to the SEC for its consideration.

Audit observes that in the specific instance of these two works, they failed to meet the criterion of other sources of funding not being available/ possible. Audit does not agree with the manner in which SDMF has been operationalised merely as a funding window to accommodate projects, without adequate justification in file to show what considerations had been taken into account in reaching the decision that SDMF funds could be sanctioned for the same.

Audit noted that despite the District Collector Thiruvananthapuram requesting funds (07 June 2017) under State Disaster Response Fund (SDRF) to execute Sl. No. 4 on an urgent basis and the Council of Ministers also deciding (14 June 2017) to sanction ₹25 lakh from SDRF, it was noticed that Revenue and Disaster Management Department sanctioned (22 June 2017) funds for executing the work from SDMF, without offering any justification in files. Due to non-availability of sufficient funds under SDMF, the amount could be released to District Collector only on 27 January 2018, of which ₹8.96 lakh alone had been spent till date, for the completed first phase of the work. Hence, clearly, this was not an instance where power under Section 50 of the Disaster Management Act should have been utilised to permit emergency procurement.

The work at Sl. No. 6, belonged to the category of works for which funding was possible under Flood Control/ River Management Fund by Water Resources Department/ District Collector. Even the Finance Department had raised this query. Audit observes that even if funds were not immediately available under the Flood Control/ River Management Fund, this does not appear to be an adequate justification for utilisation of SDMF since the work

was seen completed only in June 2020, after a period of over two years. The Secretary, KSDMA should have ensured that not only was no other funding from Government of Kerala available at that point of consideration but also that no other funding was possible for the proposed project. Clearing such items for consideration under SDMF, from the financial perspective, may be at the cost of other potential proposals for which no other source of funding was possible at all.

Recommendation 5.1: a) In order to ensure effective utilisation of SDMF, a State level Mitigation Plan/ Strategy may be formulated as envisaged in the Guidelines for administration of SDMF, based on which shorter duration flood mitigation works could be taken up at the district, block and Panchayat levels.

b) KSDMA also may ensure that all project proposals seeking assistance from SDMF are presented before SEC for selection and approval.

5.2. Execution of immediate restoration activities in post flood scenario

Section 48 (1) (a) of the Disaster Management Act, 2005 stipulates constitution of State Disaster Response Fund (SDRF) at the State level. Based on the recommendations of the Finance Commission, Government of India and State Government contribute funds to SDRF in the ratio 75:25 (during 2018-19 the sharing pattern was 90:10). The Revenue and Disaster Management (R&DM) Department sanctions funds from SDRF for meeting the expenditure towards relief assistance to victims of disasters, immediate repair and restoration of infrastructure damaged during disasters etc. The details of funds expended under SDRF during 2014-15 to 2018-19 are detailed in **Table 5.3**.

Table 5.3: Details of funds expended under SDRF during 2014-15 to 2018-19

(₹in crore)

Year	Opening Balance	Funds received from			Total	Expenditure	Closing Balance
		GoI	NDRF[117]	GoK			
2014-15	77.73	119.50	…	39.83	237.06	215.15	21.91
2015-16	21.91	138.75	…	46.00	206.66	134.14	72.52
2016-17	72.52	145.50	…	48.50	266.52	150.66	115.86
2017-18	115.86	153.00	164.72	51.00	484.58	197.50	287.08
2018-19	287.08	192.60	2904.85	21.40	3425.10[118]	1311.12	2113.98

(Source: Finance Accounts of the respective years)

Consequent upon the floods in 2018, R&DM Department allotted funds from SDRF to all District Disaster Management Authorities (DDMA) to meet the immediate post deluge needs such as evacuation of people, supply of food items, immediate relief assistance etc. In addition to the funds allotted to

[117] National Disaster Response Fund; The additional assistance received from NDRF during 2017-18 and 2018-19 were for Ockhi and Flood respectively

[118] includes ₹19.17 crore provided by GoK as arrears of interest on uninvested balance in the Fund

DDMAs, R&DM Department sanctioned ₹891.85 crore between August 2018 and June 2019 to various departments/ agencies such as Water Resources, Police, Public Works, Directorate of Health Services, Clean Kerala Company etc. to meet the expenses in connection with distribution of food items, removal of non-biodegradable waste in flood affected areas, supply of drinking water, search and rescue operations, restoration of infrastructure like roads, bridges, irrigation structures etc.

Audit observed that Water Resources (Irrigation) Department, which was the nodal department for flood preparedness was sanctioned ₹536.27 crore for immediate repair and restoration of damaged infrastructure during 2018 flood based on the proposal submitted by six[119] Chief Engineers of Water Resources (Irrigation) Department. The Apex Committee of the Irrigation Department approved (May/ July/ August 2019) a total of 7124 works such as rectification of flood damages in Regulator-cum-Bridges, rectification works in canals, removal of silt and debris etc. for an amount of ₹515.51 crore. Of these, only 1406 works (20 *per cent*) for an amount of ₹49.47 crore were seen completed (January 2020).

As per the SDRF guidelines, the works of immediate nature alone could be funded from SDRF. Though these works were said to be immediate repair and restoration works, even after a lapse of two years and eight months, they were yet to be completed (April 2021). As the works taken up were priority items such as rectification of damaged structures, removal of silt and debris from canals, streams etc. and deepening them for increasing their carrying capacity etc. partial/ non-completion of these works would increase the impact of floods in ensuing years also.

Government replied (November 2020) that as the works under SDRF were proposed to rectify the urgent damages inflicted to the infrastructure during the flood, the cost of most of the works offered were small, due to which many of the works had to be retendered. Further, during the implementation stage of works undertaken, the State was lashed with another flood.

Audit notes that as per Paragraph 8.38 of Manual of Administration of State Disaster Response Fund, assistance for damage to infrastructure is permissible for repair/ restoration of immediate nature. Such expenditure is normally incurred within a short span mostly during the initial period of immediate relief operations itself and that such aspects were to be kept in view while projecting the requirement under this sector. GoK also informed that 63 *per cent* of the approved works have been undertaken and that the expenditure stands at 49 *per cent* (November 2020).

In the Exit conference (February 2021), Additional Chief Secretary (Water Resources Department), while agreeing to the audit contention that works could have been executed much faster, stated that there was delay in planning and obtaining Administrative Sanctions from the Revenue and Disaster

[119] Chief Engineers in Irrigation and Administration, Project I, Project II, Kuttanad Package, IDRB and Mechanical

Management Department for execution of works. It was also assured that efforts are being taken to complete all works by May 2021.

In its reply (December 2020), the Revenue and Disaster Management stated that vide GO dated 27 March 2018, the time limit for implementation is decided as one year and six months from date of release of funds. However, in the specific case of works relating to 2018 floods, the 2019 floods that followed within a period of one year created *force majeure* conditions after taking up the works which delayed the execution of most of the civil works in the State.

In his reply (April 2021), ACS, Water Resources Department informed that as on 16 April 2021, agreement have been executed for 95.39 *per cent* of the works[120] and 82.62 *per cent* of works have already been completed. It was also stated that all the works were expected to be completed within a period of two months.

Audit observes that even after the passage of several months after the 2019 floods, the fact remains that works (which had been approved in the wake of the August 2018 floods) are expected to be completed only by May-June 2021.

Recommendation 5.2: Government may put in place a system of periodic monitoring of status of works of immediate nature funded by SDRF to ensure that works sanctioned are completed on priority basis, given the State's increasing vulnerability to severe flooding events.

Results of survey

One of the objectives of the Performance Audit was to assess whether the preparedness and response to the floods in 2018 was adequate and timely. During the Entry Conference (June 2019), Audit intimated Government that it was proposed to conduct a survey of affected people in the selected districts. The Principal Secretary to Government, Revenue and Disaster Management Department informed that most of the immediate response activities undertaken in 2018 floods could not be sufficiently documented and hence were not readily available for verification by Audit. It was also suggested that the authenticity of details recorded under the survey need to be verified by the institutional heads concerned. Audit conducted a survey among 800 persons affected by 2018 flood during the period from September 2019 to February 2020 in 32 LSGIs of the four selected districts. Two taluks in each district and four LSGIs in each taluk were selected for the survey. The respondents for the survey were selected randomly from the list of flood affected persons maintained by the LSGIs. The name of LSGI, taluk and number of respondents are detailed in **Appendix 5.1**. The individual responses of 800 flood victims to queries relating to pre-flood preparedness, operational phase of flood management and post flood review, duly attested by the Secretaries of LSGIs, have been compiled and the summary is presented below.

[120] ACS informed vide letter dated 19 April 2021 that a total of 6,923 works amounting to ₹52,940.39 lakh were progressing under the supervision of the six Chief Engineers of Irrigation Department.

5.3. Pre-flood preparedness

The National Disaster Management Plan, 2016 envisages[121] that the Revenue and Disaster Management Department, SDMA, SEOC, DDMA and all other relevant Departments/ Agencies are responsible for disseminating early warning signals and information to the District Administration, local authorities and the public at large upto the last mile in the areas likely to be affected by a disaster so as to reduce loss of life and property.

- Six hundred and one persons (75 *per cent*) stated that they had not received any warnings/ alerts from village/ taluk/ local body authorities before the occurrence of the 2018 floods. Out of those who had not received the alerts, 411 persons came to know about the catastrophe only when water level rose suddenly and 99 persons faced the reality in the form of landslides which ravaged their houses and property.
- Seventy-three *per cent* (582) stated that they were not informed of any steps for evacuation from their areas in view of the impending flood.
- Five hundred and fifty four respondents were ignorant about the meaning of yellow/ orange/ red alerts issued by authorities at the time of disaster.

The responses on pre-flood preparedness indicate that warnings/alerts by local administration/ Disaster Management authorities to the public before the impending floods were not adequate at the last mile. This also reinforces the audit observation on inadequate early warning and communication facilities detailed in Paragraph 3.5.2 of this Report. Ignorance of the people at the grassroots level about the colour coding of various alerts points to the fact that the steps taken by Disaster Management authorities to generate awareness about the importance/ relevance of each type of alerts and precautionary steps to be taken by the public based on specific alerts were insufficient.

5.4. Flood Management - Operational phase

State Government, SDMA, SEOC, DDMA, all other relevant Departments/ Agencies, State Disaster Response Force and Civil Defence had to make quick assessment of evacuation needs such as the number of people and animals to be evacuated and mode of evacuation, mobilise transport and resources for evacuation, identify and prepare sites for temporary relocation of affected people and animals. The State Disaster Management Plan 2016 was to include

[121] Paragraph 4.9, Responsibility matrix on preparedness and response, Page 101

specific provisions[122] for evacuation, safety and the rehabilitation of animals affected by flood.

- It was stated by 534 respondents that no Government/ LSGI officials had approached them and briefed them about the gravity of the situation, when water level started rising.
- Four hundred and ninety four out of 800 persons informed that no authorities had asked them to move to safer locations, 252 persons stated that they were asked to move to safer spots by various Government officials who visited their households when the water level was rising and 225 had conveyed their willingness to move.
- Of the 496 victims who owned pet animals, 402 persons could not shift their cattle/ poultry/ pet animals to safe locations. However, 88 out of the 94 persons who were able to safeguard their animals informed that they did not obtain help from departmental officials in moving the animals to safer locations.

5.5. Post flood review

- Of the 458 persons who moved to the relief camps, 445 opined that sufficient quantity of quality food, drinking water, medical supplies and toilet facilities were available in the relief camps. 391 among these persons opined that adequate drainage facilities were provided in the camps and 326 stated that they even received counselling in the camps to deal with the trauma. The commendable standard of facilities provided in the relief camps which operated during the crisis is evident from the above.
- Out of the 800 affected persons covered in the survey, 672 persons (84 *per cent*) confirmed the receipt of the immediate assistance of ₹10,000 provided by the Government to the victims in flood affected regions for cleaning and removing the dirt and mud deposited inside houses. This is indicative of the efficacy of response system as regards disbursement of monetary assistance during the crisis situation.

Government, in its reply (November 2020) contested the results emanating from the survey citing the following grounds:

- The survey was based on a sample population of only 800 individual victims which is not representative enough for generalisation as at least 30 *per cent* of the total population needs to be covered for a

[122] Sl. Nos. 2 and 15 of Responsibility Matrix for preparedness and response under paragraph 4.8 in National Disaster Management Plan 2016 delegate to States the responsibility of quick assessment of evacuation needs such as the number of people and animals to be evacuated and mode of evacuation, mobilising transport and resources for evacuation, identifying and preparing sites for temporary relocation of affected people and animals etc. and require the States to include these provisions in the State Disaster Management Plans.

prudent/ credible statistical survey. The reactions were of selected public, whose reactions could not be considered as reliable and dependable. Further, effectiveness of survey conducted 15 months after the event was also doubtful. The original records relating to the survey findings were not provided by Audit to KSDMA till date for examining the reliability of data and results.

- There are factual contradictions in the data mentioned in paragraph 5.3 and 5.4. Whereas in 5.3 it is stated that 582 persons held that they were not informed of any steps for evacuation, in 5.4 it is mentioned that 534 respondents were not briefed about gravity of the situation.
- Audit cannot expect the State to disseminate an early warning as IMD had not predicted the 'extremely heavy rain' which resulted in the deluge. Based on the National Disaster Management Plan of 2016[123], Audit observation concerning responsibility for dissemination of warning signals was not correct. Central Agencies are to provide the information to the State Agencies and they in turn have to pass it on to the district Administration and local authorities. There was no early warning available to the State regarding the August 2018 floods. The actual rainfall exceeded several fold the IMD's predicted rainfall and forecast of dates also varied. Prediction system of IMD and CWC, the Central agencies involved itself could not capture the extremely heavy rainfall which led to the floods and hence the communication itself could be based only on the level of alert. Deluge resulted from extremely heavy rainfall and such rainfall was not predicted before 15 August 2018.
- All information available with KSDMA and the Government and the warnings/ advisories issued besides the Hon'ble Chief Minister's directions and briefings were shared with the public through print, audio, visual and social media including KSDMA's Facebook page. In spite of the absence of dedicated disaster communication radio channel or nation-wide last mile connectivity other than through print, visual, audio and social media, the State Government, with the support of CDoT[124], NDMA and BSNL, started using location-based messaging system for the first time in the country during the 2018 floods and sent out 16 lakh advisory messages to public. Mike announcements were also carried out in critical areas.
- Audit failed to consider the drawbacks of the early warning systems of IMD and CWC which is the first link of the chain in early warning.

[123] As per the National Disaster Management Plan 2016, it is the responsibility of the Central Agencies to undertake a) to issue forecasts, alerts, warnings, b) provide early warnings (wherever possible) to reduce loss of life and property, and c) disseminate warnings and information to Central Ministries/ departments/ agencies and to the State Government. It is the responsibility of State agencies to i) disseminate early warning signals to the district administration, local authorities and public at large in areas likely to be affected by a disaster so as to reduce loss of life and property ii) disseminate warnings and information upto the last mile.

[124] Centre for Development of Telematics

As even IMD started issuing colour coded alerts to Kerala only from 08 August 2018, it is not proper for Audit to suggest imparting training on colour coded warnings to public when Kerala was in the midst of the fury of floods. KSDMA issues specific action protocols for public, district authorities and departments based on SOPs which are in simple Malayalam and do not need training.

- During crisis, Government/ LSGI officials and the public as well as voluntary organisations join hands and combat the situation. Audit has attempted selective reading to serve the purpose of pointing fingers, without examining the real situation and on-the-spot requirement during floods.
- There is no statutory obligation under Disaster Management Act, 2005 upon KSDMA, Government or LSGI officials to physically visit individuals and brief them of the gravity of any situation in almost 30 *per cent* of the State's populated area. During crisis management, physical presence of rescue forces was ensured for rescue operations. The public was alerted at large and conveyance was provided to those unable to move by themselves.
- Specific public alerts were issued in all media to let loose pets and domestic animals. Carrying pets along with evacuated families is not the best practice in a severe flood situation.

The response of Audit to the points contested is as follows;

- The purpose of the survey was to understand the public perception in the context of flood preparedness, operational phase of flood management and post flood activities of the Government. This was sought to be carried out with Audit's limited resources, through survey questionnaires issued to 800 persons in flood ravaged areas and the results of the survey indicated a mixture of positive and negative feedback. Since the survey was conducted in the presence of Revenue/ Local Self-Government officials and the survey responses sheets also bear the seal and signature of the Secretary of the GPs in each instance, there is no reason to doubt the results of survey or the process followed. Confidentiality has been maintained as regards sharing the filled in questionnaires as data collected includes personal data such as name, address, mobile number and ration card number.
- There is no contradiction between response sets obtained in respect of any of the questions. The response to questions in 5.3 pertained to pre-flood scenario and that in 5.4, related to actual crisis situation. Audit notes that a person who had been briefed about the gravity of the situation may not have been informed about the steps for evacuation.
- Audit notes that the contention that the State could not be expected to disseminate early warning in the absence of alerts from competent

Central agencies is not acceptable based on the laws and procedures in place (SOPs);

(i) Section 38, 2 (h) of the DM Act, 2005 states that it is the responsibility of the State Government to "establish adequate warning system up to the level of vulnerable group". Early Warning Dissemination is one of the most important roles of Emergency Operations Centre (EOC) (EOCESFP[125] 2015, Paragraph 4). The EOC utilises Information and Communication Technology (ICT) tools and various other modes available for transmission of early warning to the vulnerable groups and also activate the responders.

(ii) While IMD is a competent agency for weather warnings (EOCESFP 2015, Paragraph 4.1), the functions of SEOC, vide the same paragraph, include issuing warnings to district administrations and, if necessary, to public based on predefined thresholds of environmental variables (rainfall, water level, seismological inputs, wave height etc.) and specific warnings from India Meteorological Department (IMD), Central Water Commission etc. Thus, there should have been an effective system in place to issue warnings based on predefined thresholds of environmental variables and SEOC/ KSDMA should not have merely depended on the receipt of early warnings from IMD, CWC etc.

(iii) The SEOC is a nerve centre of, *inter alia*, early warning (EOCESFP 2015, Paragraph 1.1). One of the objectives of the SEOC is to conceptualise and implement hazard early warning systems (EOCESFP 2015, Paragraph 2.1). Paragraph 2.1 also envisages that once made operational, the Decision Support System (DSS) of SEOC would enable the prediction and early warning of major hydro-meteorological hazards and provide support for emergency operations in the event of hazards. However, in the absence of real time data, the DSS could not fulfil the envisaged role of providing early warning of major hazards during the August 2018 floods. Unless real time data is made available, the DSS would not be able to enable the prediction and early warning of major hydro-meteorological hazards in the future also.

(iv) The State Disaster Management Plan 2016 also requires the Water Resources Department, the nodal department for disaster preparedness, to ensure proper early warning mechanism for flood by monitoring water level of surface water bodies.

[125] Emergency Operations Centres and Emergency Support Functions Plan 2015 of KSDMA, renamed as Orange Book of Disaster Management in May 2019.

- Audit acknowledges the positive steps taken by the DM authorities to communicate with the public during the floods of 2018 utilising different media and other resources. However, Audit notes that at least one other Report (Post Disaster Needs Assessment, October 2018)[126] also documents gaps/ challenges in early warning communication to the last mile[127] indicating that the system certainly needs to be made more effective to ensure better preparedness for the future.

- The National Disaster Management Plan 2016 details matrix of responsibilities assigned to Government/ agencies/ community at different levels for coordinated preparedness/response. The questionnaire was prepared in line with the delegation of responsibilities underscored by NDMP. Audit proposed to assess whether warnings with respect to the impending likely disastrous situation of inundation, consequent on continuous heavy rainfall and opening of shutters of all dams in the State had been disseminated till the last mile by Government. It was also a review of the extent of compliance to instructions from State/ DDMAs by officials at taluk/ village/ LSGI level during crisis situation, sourced from the public who were the direct victims of the deluge. Situations in which people got to know of the disaster during odd hours at night when water rushed into their houses were reported to Audit in the course of the survey. The audit exercise may be viewed as a constructive aid in improving response operations in future disaster scenarios. The Action Plan for Rebuild Kerala Development Programme on 2018 floods by Rebuild Kerala Initiative of Government of Kerala mentions limited/ restricted/ restrained dissemination of disaster risk information and lack of awareness of disaster risks as among the underlying multi-sector issues that contributed to the heavy impact of floods which exacerbated the vulnerability of State to disasters.

- District specific colour coded alerts were disseminated to the public through visual media. The intention of Audit was to highlight the necessity of imparting timely information to the public on the colour coded warnings, as to what is to be done on receipt of specific type of alerts. Colour coding of IMD has been in place for some years and the authorities as well as the public in Kerala and particularly in

[126] Commissioned by the Kerala Government, the Kerala PDNA was undertaken jointly by experts from the line Ministries and the United Nations.

[127] There were two major problems identified in early warning communication to the last mile; 1) warnings not understood: Some of the district administrations indicated that the warnings like red alert or orange alert issued by the IMD for the entire district were not understood well enough to elicit response action or preparedness planning. More detailed localised warnings indicating the taluks and panchayats are required to take appropriate actions and 2) warnings understood but ignored: Although Kerala is prone to floods, it does not experience regular flooding. Hence community preparedness to respond to such a disaster was low. Although the flood warnings were provided to the community, there was reluctance to respond to them due to lack of knowledge about the impact of the flood.
(Extracted from the Chapter on Disaster Risk Reduction in the PDNA Report)

hazard prone areas ought to have been made familiar with the coding system and its implications much before the floods as part of the disaster preparedness.

- Audit also notes that had a strong early warning system and timely evacuation been in place, possibly more animals which were sources of livelihood to many, could have been saved through shifting to safe shelters etc.

CHAPTER VI
CONCLUSION AND RECOMMENDATIONS

6 CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Kerala State Disaster Management Plan 2016 records that the State has a higher degree of disaster risks as compared to the rest of the country. As noted in the Rebuild Kerala Development Programme, floods are the most common of natural hazards that affect the people, infrastructure and natural environment in Kerala, and incidence of floods in the State is becoming more frequent and severe. Audit observed that in the context of management of floods, better planning, implementation and integration of efforts of different authorities/ bodies are among the measures urgently required to enable the State to be better prepared to face any eventuality of extreme rainfall and severe flooding in the future.

The preparation of a State Level Master Plan for water resources development, formulation of Master Plans for the major rivers of the State and constitution of a State Level Authority for coordinating all water related activities at the river basin level need to be prioritised. Flood plains of the State are yet to be demarcated and flood plain zoning legislation remains to be enacted. The State needs to explore options for having in place a reliable large-scale flood hazard map. Infrastructure needs to be strengthened and shortages of equipment met for effective functioning of Fire and Rescue personnel. Flood forecasting stations need to be set up on priority and real time data be made available at the earliest for optimal results through systems such as the DSS. Vendor selection should be such as would ensure projects deliver expected outputs and within the prescribed time frame. Effective functioning of communication infrastructure at all times requires to be ensured, particularly in flood prone locations across the State.

Even after a considered decision by KSEBL in consultation with KSDMA in August 2018 to introduce a dynamic flood cushion of four feet below FRL (68.87 MCM), spills of 467 MCM could not be avoided in respect of Idukki reservoir. Extreme care needs to be taken to ensure that outflow does not exceed inflow except under emergencies in respect of operations of major reservoirs to avoid potential flooding disasters. Integrated reservoir operations in multi-dam basins needs to be ensured.

Land Use and Land Cover change analysis of the Periyar basin revealed significant increase in built-up area and notable decrease in water bodies in recent years, rendering the basin vulnerable to floods. Continuous monitoring and timely action is essential for eviction of encroachers obstructing free flow of the river waters and to ensure removal of operational bottlenecks hindering smooth spillway operations.

Works of immediate repair and restoration approved for execution under SDRF in the wake of the 2018 floods remained to be completed even after a

lapse of two years and eight months. Strict monitoring by Revenue and Disaster Management/ Local Self-Government/ Water Resources Departments of the progress of works meant to lower the potential risk of riverine flooding and of dredging works in channels etc. is a must to ensure that optimal results accrue without delay.

6.2. Recommendations

Government of Kerala may consider revision of the State Water Policy to include aspects relating to flood management, in line with the National Water Policy and after considering the specific requirements of the State. Feasibility of bringing a legislation for flood plain zoning, and an Authority to identify and demarcate flood plain zones of the State and to prohibit or restrict the use of these lands is to be considered. The State may initiate action to operationalise the Civil Defence Training Institute in Thrissur for the fulfilment of the intended objective of training and equipping sufficient number of Civil Defence volunteers to respond to emergency/ disaster situations. Priority needs to be given to review the adequacy of equipment, vehicles and infrastructural facilities in the Fire and Rescue Services Academy as well as in Fire and Rescue stations so that the GoK's dedicated force for rescue services may be adequately equipped to handle any flood or other disaster situation.

Government may ensure adequacy of the number of rain gauges capable of generating real time data in order to ensure accuracy of rainfall estimation. Projects for procurement/ installation of systems meant for flood management such as decision support system etc., may be entered into only after ensuring timely availability of input data from all sources including external sources. Kerala State Disaster Management Authority may ensure that fail-safe communication infrastructure is available in vital installations such as at dam sites and that a built-in redundancy of different layers of communication capable of functioning during the most adverse circumstances exists in flood-prone locations across the State.

Kerala State Electricity Board may ensure flood release operations for reservoirs are based on approved rule curves and that the approved rule curves of 2020 for Idukki and Idamalayar would be adequate to handle situations similar to the extreme rainfall event of 2018, without consequential flooding. In view of the drastic change in land use over the past few decades with its impact on the recent floods, Government may initiate urgent steps to review the adequacy of the measures initiated to reduce the risk of vulnerability to floods, attributable to changes in land use. Government may also initiate steps for an integrated and comprehensive legislation and a land use policy.

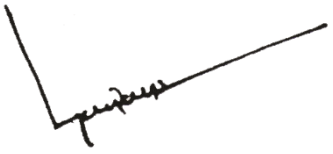
The Government needs to prioritise speedy resolution of the issues relating to removal of unauthorised constructions from the construction free zone in Cheruthoni as also to ensure no new construction is allowed to come up in future within the demarcated zone. Adequacy of planned/ ongoing works under the comprehensive flood mitigation plan for safeguarding Cochin

International Airport Ltd. and its surrounding areas may be ensured and the pace of implementation is to be reviewed so that risk of loss to life and property in case of extreme rainfall/ flooding is minimised. Government may also prioritise works such as deepening of the leading channel upstream of Thottappally Spillway and timely breaking of developing sand bar, if any, at the sea mouth so as to ensure unhindered flow of flood waters to the sea, even while ensuring compliance with extant environment related instructions. A system of periodic monitoring of status of works of immediate nature funded by State Disaster Response Fund may be followed to ensure that works sanctioned are completed on priority basis.

(ANIM CHERIAN)
Principal Accountant General
(Audit - I), Kerala

Thiruvananthapuram,
The 05 October 2021

Countersigned



(GIRISH CHANDRA MURMU)
Comptroller and Auditor General of India

New Delhi,
The 12 October 2021

August 19, 2018
Alappuzha District

APPENDICES

Appendix 1.1

Statement showing list of institutions covered by Audit

(Reference: Paragraph 1.4)

Sl. No.	Name of District	Name of institutions covered by Audit
1.	Alappuzha	District Disaster Management Authority, District Emergency Operations Centre, Chengannur Taluk, Kuttanad Taluk, Major Irrigation Division, Minor Irrigation Division, Mechanical Division, Chief Engineer Kuttanad Package, Kuttanad Development Division Thanneermukkom, Fire Stations at Thakazhi and Chengannur
2.	Ernakulam	District Disaster Management Authority, District Emergency Operations Centre, Aluva Taluk, Paravur Taluk, Office of the Special Tahsildar, Nedumbassery, Village Office, Nedumbassery, Major Irrigation Division, Minor Irrigation Division, Fire stations at Aluva and North Paravur, Idamalayar dam, Bhoothathankettu barrage, Central Water Commission Regional Office
3.	Idukki	District Disaster Management Authority, District Emergency Operations Centre, Idukki Taluk, Devikulam Taluk, Major Irrigation Division, Minor Irrigation Division, Idukki dam, Lower Periyar dam, Madupetty dam, Kallarkutty dam, Fire Stations
4.	Thrissur	District Disaster Management Authority, District Emergency Operations Centre, Chalakkudy Taluk, Thalappilly Taluk, Major Irrigation Division, Minor Irrigation Division, Vazhani Dam, Poringalkuthu Dam, Lower Sholayar Dam, Civil Defence Training Institute, Fire and Rescue Services Academy
5.	Thiruvananthapuram	Revenue Disaster Management Department, Water Resources (Irrigation) Department, Finance Department, Transport Department, Kerala State Disaster Management Authority, State Emergency Operations Centre, India Meteorological Department, Fire and Rescue Headquarters, Chief Engineer Irrigation, Design and Research Board, Chief Engineer Irrigation and Administration, Chief Engineer Mechanical, Chief Engineer Project II, Institute of Land and Disaster Management, Dam Safety Organisation, Kerala State Electricity Board Limited, Land Use Board, Commissionerate of Land Revenue
6.	Dam Safety Organisation of KSEBL, Pallom, Kottayam district	

Appendix 2.1

Details of encroachment of water bodies noticed in the test-checked districts and status of action taken by Departments*

(Reference: Paragraphs 2.1, 2.3, 4.1)

Sl. No.	Location details	Number of encroachments	Extent of land (in Ha)	Whether complaints received or not
1.	**Deviyarpuzha at Adimali-Valara stretch (Survey no. 205 and 206) in Idukki district**	**23**	**0.2221**	**8 nos. from 2013 to 2016**
Performance Audit Party examined 11 files relating to the encroachment of Deviyarpuzha maintained at Taluk Office, Devikulam. All these files pertained to the complaints of local people and departments regarding illegal construction of buildings by encroachment of the river bed and obstructing the free flow of the river. However, no action was taken to identify the extent of encroachment by surveying the area. Superintendent of Police (Intelligence), Special Branch CID, Thiruvananthapuram reported (December 2012) to the District Collector, Idukki about encroachments of Deviyarpuzha by constructing multi-storied buildings and warned that non-eviction of these encroachments would lead to further encroachments of the area. In one case, Village Officer, Mannamkandam Village after conducting preliminary enquiry reported (January 2015) that there were 23 number of encroachments (0.2221 ha) of Deviyarpuzha at Adimali-Valara stretch near Irumbupalam. The encroachers had been occupying the land for more than five years. No further action was taken in this regard. A joint site verification (December 2019) revealed that the riverbank was encroached upon by constructing huge buildings which reduced the width of the river to a narrow stretch and thereby obstructed the free flow of the river which caused inundation of adjacent area in 2018 flood. No survey of the river to demarcate the boundaries was conducted to identify and evict the encroachers. Taluk Officer, Devikulam Taluk replied that out of 53 complaints and KLC cases regarding the encroachment of rivers and water bodies received in Devikulam Taluk upto 2018-19, only one eviction has taken place till date. Other cases were pending in the office either with the surveyor or with the village officer.				
2.	**Kanoli Canal in Thrissur district**	**832**	**17.97**	**Yes in May 2008**
Kanoli Canal is part of west coast canal network of Kerala and the canal was constructed by combining the rivers and streams along the coasts. In Thrissur District Kanoli canal starts from Kodungallur Taluk and passes through Kodungallur, Thrissur, Chavakkad and Mukundapuram Taluks. A complaint regarding encroachment of land in Kanoli Canal was received (May 2008) in the Chief Minister's Public Grievance Cell, Thiruvananthapuram. Chief Minister ordered time bound disposal of the case and stringent action against the encroachers. Deputy Director, Survey, Thrissur reported (January 2011) to the District Collector that there were 832 number of encroachments covering an area of 17.9673 hectares on the sides of Kanoli canal in four taluks in Thrissur District. District Collector, Thrissur (August 2011) informed Revenue Department that details of all encroachments with their sketches were passed on to Additional Irrigation Division, Thrissur for eviction. Executive Engineer, Additional Irrigation Division, Thrissur reported to the District Collector, Thrissur (April 2018) that since Kanoli Canal was declared as National Waterway 3 in 2016, eviction of encroachments would be undertaken by National Waterway Authority of India. But the fact remains that encroachments continued without eviction even after the lapse of nine years from the date of identification of encroachments. A joint site verification of Kanoli Canal (December 2019) at Chavakkad Taluk revealed large scale cultivation of coconut trees on both sides and across the canal obstructing and diverting the free flow of the river. Around six meters of the canal was filled with sand and fenced for private use. Local residents stated that the area adjacent to the canal was flooded in 2018 and they were shifted to relief camps.				
3.	**Bharathapuzha at Nambiar Pallam in Thrissur**	**11**	**0.5136**	**Yes in March 2017**
A complaint was received at District Collectorate, Thrissur regarding the encroachment of Bharathapuzha at Nambiar Pallam in March 2017. Tahsildar (Land Records), Thalappilly reported (June 2017) that encroachment was found in Bharathapuzha at Nambiar Pallam on preliminary enquiry but no natural boundary and survey stones were available to fix the river purambokku. After conducting the survey of the area in December 2018, Tahsildar, Thalappilly identified 11 number of encroachments covering an area of 0.5136 ha at Nambiar Pallam and requested the District Collector to release an amount of ₹28,000 incurred for planting survey stones at the site. Though funds were available in River Management Fund, the amount was not released till date. Encroachers were occupying the land for eight to 40 years. It was observed that though the complaint regarding river encroachment was received in March 2017, the survey to identify the extent of encroachment was carried out in December 2018 and no further action was taken till date.				

Sl. No.	Location details	Number of encroachments	Extent of land (in Ha)	Whether complaints received or not
4.	**Uttarappalliyar river (Alappuzha)**	**47**	**NA****	**Yes in 2007 and 2015**
The original river course through Venmani, Ala, Cheriyanadu, Puliyoor and Ennakkad villages was blocked due to intermittent encroachments. As part of rejuvenation activities, survey and demarcation of boundaries of the river was attempted in April 2017. Though complaints were received in 2007 and 2015, action in this regard was initiated by the Revenue Department only on 17 April 2017 when Uttarappalliyar Rejuvenation Campaign was launched by pooling funds from River Management Fund for survey and demarcation of boundaries of the river. However, survey could not be conducted in three villages, as the resurvey records contained little or no trace of the river route in these villages. Unless a fresh survey is conducted using the Lithomaps and records prior to resurvey, and boundaries of the river demarcated, effective control of encroachment and rejuvenation of river path will not be realised. Though the Land Revenue Commissioner repeatedly sought detailed report from the District Collector on the scope of re-establishing the flow route of the river through the five villages, there was no response in file (December 2019). As the river used to serve as a balancing channel between the water levels in Achencovil river and Pamba river, its stagnancy caused severe floods in the villages during 2018.				
5.	**Kuttamperoor river (Alappuzha)**	**NA****	**NA****	**Yes May 2008**
The river flows through Ennakkad and Mannar Villages in Chengannur Taluk. The river has a length of 7.2 km in Alappuzha district. Continuous encroachment identified on either side of the river causing shrinkage of the width of the river to about 15m to 20m against the actual width of 70m. No survey of the entire stretch of the river was conducted till 2018 floods. The villages through which the river flowed were severely affected during 2018 flood. Irrigation Department took up (March 2019) rejuvenation of the river under NABARD assisted scheme, which is yet to be completed.				
6. District Collector Ernakulam stated that noticeable encroachments were not reported in the District. The justification is not tenable as survey of rivers is to be conducted in order to identify illegal encroachments in rivers. However, Audit observed that no survey of water bodies was conducted in Paravur, one of the selected Taluks. Detection of encroachments is not possible in the absence of survey and demarcation of boundaries of rivers.				

* Based on examination of files at respective field offices. ** Details not available

Appendix 2.2

Statement showing shortage of equipment, vehicles and infrastructural facilities in Kerala Fire and Rescue Services Academy

(Reference: Paragraph 2.6)

Sl. No.	Nature of shortage	Description	Number of items in possession	Number of items in shortage
1.	Equipment	Trailer Pump	5	Nil
2.		Portable Pump (serviceable)	1	Nil
3.		Generator (230 volt)	1	Nil
4.		BA Set (serviceable)	8	50
5.		SCUBA Set (serviceable)	3	20
6.		BA Compressor set (serviceable)	1	2
7.		Float pump	2	Nil
8.		Hydraulic equipment set (serviceable)	1	1
9.		Chain saw (serviceable)	2	10
10.		Concrete cutters (serviceable)	2	3
11.		Rubber Dinghy with OB engine	Nil	2
12.		Fibre Boat	Nil	2
13.		Fire Fighting Suit	Nil	70
14.		Chemical suits	Nil	25
15.		Pneumatic rescue tools	Nil	2 sets
16.		High pressure portable pumps	Nil	3
17.		Rope rescue kit and accessories	Nil	10 sets
18.		Life detectors	Nil	5
19.		Demolition hammers	Nil	3 sets
20.		Thermal imaging cameras	Nil	3
21.		Extinguishers	Nil	50
22.		Rope Launcher	Nil	2
23.		Leak arrest kit	Nil	5
24.		Canister	Nil	20
25.		Inflatable Tent	Nil	2
26.		Inflatable Light	1	3
27.		Portable Water Mist	Nil	5
28.		Exhaust Blower	Nil	2
29.		Basic life support accessories - Mannequins, AED etc. Choking arrester kits Stretchers etc.	 Nil 2	 3 sets each 10
30.		Multi-Purpose Rescue Tools	1	Nil
31.	Vehicles	Fire tender	1	Nil
32.		Mobilising bus (old - proposed for condemnation)	1	1
33.		Excavator	1	Nil
34.		Jeep	2	Nil
35.		Bolero Jeep	2	Nil
36.		Ambulance	Nil	2
37.		Water mist tender	Nil	1
38.		Emergency Rescue tender	1	1
39.		Quick response vehicle	1	1
40.		SCUBA Van	Nil	1
41.		Mess Van	Nil	1

Sl. No.	Nature of shortage	Description	Number of items in possession	Number of items in shortage
42.	Shortage of infrastructure facilities	Fire lab		
43.		Multipurpose rescue tower		
44.		Smart class rooms		
45.		Computer lab		
46.		BA smoke room gallery		
47.		Fire lift		
48.		Fixed firefighting installations models		
49.		Drill grounds - 8 acres additional		
50.		Conference room-under construction		
51.		Barrack-under proposal, design and approval stage		
52.		Library		
53.		Health club		

Appendix 3.1

Salient features of Mullaperiyar, Idukki, Idamalayar, Lower Periyar dams and Bhoothathankettu barrage

(Reference: Chapter 3, Paragraph on Reservoir operation)

Name of Dam/ Barrage and source of data	FRL[128] (m, MSL)	MWL[129] (m, MSL)	MDDL[130] (m, MSL)	Capacity at FRL (MCM)	Live[131] storage capacity (MCM)	Capacity at dead storage[132] level (MCM)	Free board[133] over MWL (m)	Spillway type and discharge design volume (cumecs)	Number, type and size of gates	Extent of catchment area (sq. km)	Discharge capacity (cumecs)
Mullaperiyar Dam (Irrigation Department)	-*	-*	41.45	-*	299.26	144.17	0.91	Vertical and radial shutter type, 3454.65	13 numbers 10.97 x 4.87 m (3 number of vertical gates) 12.19 x 4.87 m (10 number of radial gates)	602.95	59.46
Idukki dam/ Cheruthoni dam (KSEBL)	732.43	734.11	694.94	1996.34	1459.49	536.81	1.79	Chute, 5012	5 numbers of radial gates, 12.19 x 10.36 m	650.00	557.50
Idamalayar dam (KSEBL)	169.00	171.20	115.00	1089.80	1017.80	72.00	0.80	Ogee, 3248	4 number of radial gates, 11.5 x 9.7 m	380.79 (excluding 101 sq. km Nirar catchment)	NA
Lower Periyar dam (KSEBL)	253.00	256.00	237.74	5.30	4.50	0.80	1.00	Ogee, 11200	5 number of radial gates, 13.5 x 15.65 m	584.00	338.94
Bhoothathankettu barrage (Irrigation Department)	34.95			-				Electrically operated framed steel shutters with vertical lifting arrangements of chain pulley blocks equipped with counterweight boxes, 7079	3 numbers 9.14 x 10.36 m 12 numbers 12.19 x 9.14 m	3048.00	

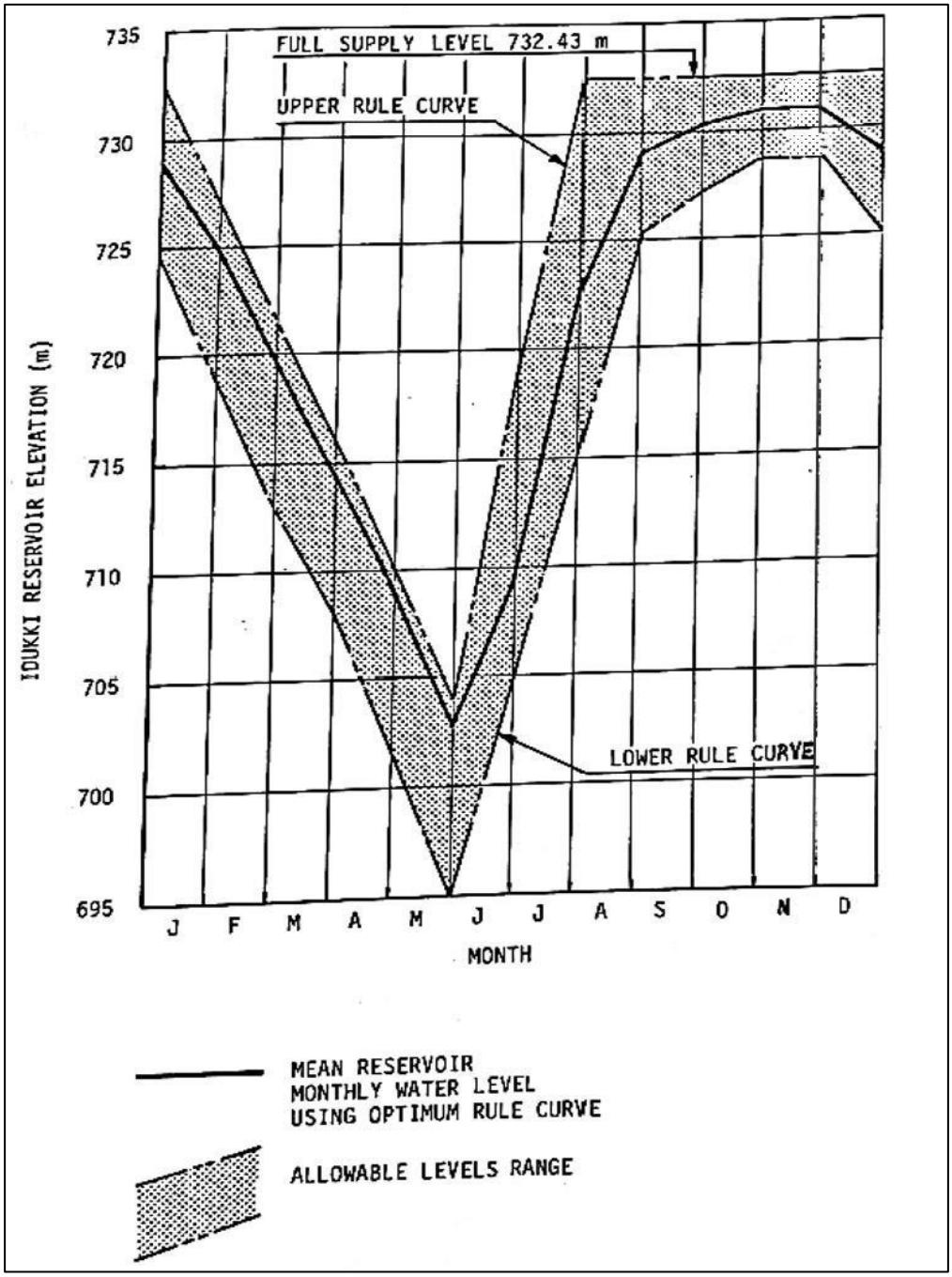
* matter is sub judice

[128] Full Reservoir Level (FRL) corresponds to the water level when the dam is filled to its full capacity.
[129] Maximum Water Level (MWL) corresponds typically to the top level of the gates. At MWL, the flow over spillway will be at design flood discharge.
[130] Minimum Drawn Down Level
[131] Live storage is the storage between FRL and the dead storage level
[132] Dead storage is the minimum amount of water to be maintained in the dam
[133] The storage between MWL and FRL is available as flood cushion.

Appendix 3.2

Rule curve framed in 1983 for Idukki dam

(Reference: Paragraph 3.6.1)



(Source: Records at KSEBL)

Appendix 3.3

Rule curve framed in 2020 for Idukki and Idamalayar dams

(Reference: Paragraph 3.6.1)

Time Step	Reservoir Level in meter	
	Idukki	Idamalayar
June 10th	723.29	161.00
June 20th	723.29	161.00
June 30th	723.29	161.00
July 10th	724.00	161.50
July 20th	724.80	161.75
July 31st	725.60	162.50
August 10th	726.50	163.00
August 20th	727.50	163.50
August 31st	728.50	164.00
September 10th	729.25	165.00
September 20th	730.00	166.00
September 30th	730.59	166.30
October 10th	730.84	166.60
October 20th	731.17	166.80
October 31st	731.31	167.00
November 10th	731.46	168.50
November 20th	731.53	168.50
November 30th	731.53	168.50

Appendix 3.4

Procedure followed for conduct of simulations of reservoir operations using rule curves

(Reference: Paragraph 3.6.1)

The Idukki reservoir operation is analysed with the rule curves developed both in 1983 and 2020 whereas the Idamalayar reservoir operation is analysed with only the rule curve of 2020.
The reservoir operation was simulated by IISc, Bangalore for its study as follows

$$S_{t+1} = S_t + Q_t - R_t - E_t - Spill_t \quad \text{(Eq. A)}$$

where,

$S_{t+1:}$ reservoir storage at the end of the period t

S_t: reservoir storage at the beginning of the period t

Q_t: the inflow to the reservoir during the period t

R_t: release from the reservoir during the period t

E_t: evaporation loss from the water surface in the reservoir during the period t

$Spill_t$: excess water spilled from the reservoir during the period t

Period t is the time interval for which the reservoir operation is simulated. This may be for example a month, a day, an hour etc. All terms are expressed in volume units (MCM). Eq. A uses the principle of continuity. The rule curve analysis is carried out for the entire monsoon period from June to September 2018.

Appendix 3.5

Sample simulations of Idukki reservoir using 1983 rule curve

(Reference: Paragraph 3.6.2)

Day	Storage for upper levels (MCM)	Storage for lower rule levels (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6)	Spills (MCM)	Storage after spills (MCM)
	1a	1b	2	3	4	5	6	7	8	9
30-06-2018	1315.47	805.58	805.58	705.00	1.83	9.81	0.13	813.44	0.00	813.44
01-07-2018	1337.36	816.83	813.44	705.26	0.00	8.89	0.13	822.20	0.00	822.20
02-07-2018	1359.24	828.08	822.20	705.56	0.00	10.72	0.13	832.78	0.00	832.78
03-07-2018	1381.12	839.32	832.78	705.91	0.00	8.00	0.13	840.66	0.00	840.66
04-07-2018	1403.01	850.57	840.66	706.17	0.00	6.53	0.13	847.05	0.00	847.05
05-07-2018	1424.89	861.81	847.05	706.39	0.00	5.56	0.13	852.48	0.00	852.48
06-07-2018	1446.78	873.06	852.48	706.57	0.00	5.04	0.13	857.39	0.00	857.39
07-07-2018	1468.66	884.31	857.39	706.73	0.00	6.46	0.13	863.72	0.00	863.72
08-07-2018	1490.54	895.55	863.72	706.95	0.00	9.50	0.13	873.09	0.00	873.09
09-07-2018	1512.43	906.80	873.09	707.24	0.00	19.66	0.13	892.62	0.00	892.62
10-07-2018	1534.31	918.05	892.62	707.80	0.00	34.60	0.13	927.09	0.00	927.09
11-07-2018	1556.19	929.29	927.09	708.78	0.00	32.70	0.13	959.66	0.00	959.66
12-07-2018	1578.08	940.54	959.66	709.71	2.06	28.23	0.13	985.69	0.00	985.69
13-07-2018	1599.96	951.78	985.69	710.46	1.94	40.69	0.13	1024.31	0.00	1024.31
14-07-2018	1621.84	963.03	1024.31	711.56	1.85	33.21	0.13	1055.54	0.00	1055.54
15-07-2018	1643.73	974.28	1055.54	712.45	1.39	53.77	0.13	1107.78	0.00	1107.78
16-07-2018	1665.61	985.52	1107.78	713.85	1.59	61.92	0.13	1167.99	0.00	1167.99
17-07-2018	1687.49	996.77	1167.99	715.34	3.27	41.73	0.13	1206.32	0.00	1206.32
18-07-2018	1709.38	1008.02	1206.32	716.29	5.01	38.02	0.13	1239.20	0.00	1239.20
19-07-2018	1731.26	1019.26	1239.20	717.11	5.92	35.83	0.13	1268.98	0.00	1268.98
20-07-2018	1753.14	1030.51	1268.98	717.85	6.74	29.70	0.13	1291.81	0.00	1291.81
21-07-2018	1775.03	1041.75	1291.81	718.41	5.63	22.64	0.13	1308.69	0.00	1308.69
22-07-2018	1796.91	1053.00	1308.69	718.83	5.40	20.09	0.13	1323.25	0.00	1323.25
23-07-2018	1818.79	1064.25	1323.25	719.19	6.83	23.50	0.13	1339.79	0.00	1339.79
24-07-2018	1840.68	1075.49	1339.79	719.57	8.87	39.11	0.13	1369.90	0.00	1369.90

Day	Storage for upper levels (MCM)	Storage for lower rule levels (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6)	Spills (MCM)	Storage after spills (MCM)
	1a	1b	2	3	4	5	6	7	8	9
25-07-2018	1862.56	1086.74	1369.90	720.21	9.12	39.35	0.13	1399.99	0.00	1399.99
26-07-2018	1884.44	1097.99	1399.99	720.86	9.74	39.98	0.13	1430.10	0.00	1430.10
27-07-2018	1906.33	1109.23	1430.10	721.51	9.82	24.83	0.13	1444.99	0.00	1444.99
28-07-2018	1928.21	1120.48	1444.99	721.83	9.68	24.36	0.13	1459.54	0.00	1459.54
29-07-2018	1950.09	1131.72	1459.54	722.14	10.05	23.41	0.13	1472.78	0.00	1472.78
30-07-2018	1971.98	1142.97	1472.78	722.42	10.04	21.75	0.13	1484.36	0.00	1484.36
31-07-2018	1993.86	1154.22	1484.36	722.67	10.07	19.14	0.13	1493.29	0.00	1493.29
01-08-2018	1993.86	1168.36	1493.29	722.86	10.07	14.83	0.13	1497.92	0.00	1497.92
02-08-2018	1993.86	1182.51	1497.92	722.96	10.09	12.53	0.13	1500.23	0.00	1500.23
03-08-2018	1993.86	1196.66	1500.23	723.01	9.59	11.37	0.13	1501.89	0.00	1501.89
04-08-2018	1993.86	1210.81	1501.89	723.05	9.30	9.10	0.13	1501.55	0.00	1501.55
05-08-2018	1993.86	1224.96	1501.55	723.04	9.50	7.97	0.13	1499.89	0.00	1499.89
06-08-2018	1993.86	1239.11	1499.89	723.00	9.00	8.46	0.13	1499.23	0.00	1499.23
07-08-2018	1993.86	1253.26	1499.23	722.99	9.05	16.46	0.13	1506.50	0.00	1506.50
08-08-2018	1993.86	1267.40	1506.50	723.15	9.99	39.58	0.13	1535.96	0.00	1535.96
09-08-2018	1993.86	1281.55	1535.96	723.78	9.95	57.45	0.13	1583.33	0.00	1583.33
10-08-2018	1993.86	1295.70	1583.33	724.80	9.98	61.03	0.13	1634.26	0.00	1634.26
11-08-2018	1993.86	1309.85	1634.26	725.82	9.96	45.44	0.13	1669.62	0.00	1669.62
12-08-2018	1993.86	1324.00	1669.62	726.48	9.99	48.44	0.13	1707.94	0.00	1707.94
13-08-2018	1993.86	1338.15	1707.94	727.18	10.00	45.99	0.13	1743.80	0.00	1743.80
14-08-2018	1993.86	1352.30	1743.80	727.84	9.99	84.18	0.13	1817.86	0.00	1817.86
15-08-2018	1993.86	1366.44	1817.86	729.21	9.99	165.06	0.13	1972.80	0.00	1972.80
16-08-2018	1993.86	1380.59	1972.80	732.03	9.95	154.96	0.13	2117.68	123.82	1993.86
17-08-2018	1993.86	1394.74	1993.86	732.40	9.98	111.70	0.13	2095.45	101.59	1993.86
18-08-2018	1993.86	1408.89	1993.86	732.40	9.66	92.51	0.13	2076.58	82.72	1993.86
19-08-2018	1993.86	1423.04	1993.86	732.40	9.98	62.88	0.13	2046.63	52.77	1993.86
20-08-2018	1993.86	1437.19	1993.86	732.40	9.95	37.54	0.13	2021.33	27.46	1993.86
21-08-2018	1993.86	1451.34	1993.86	732.40	9.68	29.95	0.13	2014.00	20.14	1993.86
22-08-2018	1993.86	1465.48	1993.86	732.40	9.98	24.60	0.13	2008.35	14.49	1993.86
23-08-2018	1993.86	1479.63	1993.86	732.40	9.96	20.39	0.13	2004.16	10.30	1993.86

Day	Storage for upper levels (MCM)	Storage for lower rule levels (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6)	Spills (MCM)	Storage after spills (MCM)
	1a	1b	2	3	4	5	6	7	8	9
24-08-2018	1993.86	1493.78	1993.86	732.40	9.96	18.96	0.13	2002.72	8.86	1993.86
25-08-2018	1993.86	1507.93	1993.86	732.40	9.96	17.77	0.13	2001.55	7.68	1993.86
26-08-2018	1993.86	1522.08	1993.86	732.40	9.93	16.42	0.13	2000.22	6.35	1993.86
27-08-2018	1993.86	1536.23	1993.86	732.40	9.97	18.44	0.13	2002.20	8.34	1993.86
28-08-2018	1993.86	1550.38	1993.86	732.40	9.91	18.71	0.13	2002.53	8.67	1993.86
29-08-2018	1993.86	1564.52	1993.86	732.40	9.97	15.79	0.13	1999.55	5.69	1993.86
30-08-2018	1993.86	1578.67	1993.86	732.40	8.69	15.17	0.13	2000.21	6.35	1993.86
31-08-2018	1993.86	1592.82	1993.86	732.40	10.01	15.83	0.13	1999.56	5.69	1993.86
01-09-2018	1993.86	1596.33	1993.86	732.40	10.01	14.17	0.13	1997.89	4.03	1993.86
02-09-2018	1993.86	1599.84	1993.86	732.40	9.96	8.49	0.13	1992.26	0.00	1992.26
03-09-2018	1993.86	1603.35	1992.26	732.37	9.74	7.58	0.13	1989.98	0.00	1989.98
04-09-2018	1993.86	1606.86	1989.98	732.33	9.20	7.38	0.13	1988.03	0.00	1988.03
05-09-2018	1993.86	1610.36	1988.03	732.30	9.14	6.99	0.13	1985.74	0.00	1985.74
06-09-2018	1993.86	1613.87	1985.74	732.26	10.03	6.88	0.13	1982.47	0.00	1982.47
07-09-2018	1993.86	1617.38	1982.47	732.20	9.89	4.57	0.13	1977.01	0.00	1977.01
08-09-2018	1993.86	1620.89	1977.01	732.11	9.55	3.39	0.13	1970.72	0.00	1970.72
09-09-2018	1993.86	1624.40	1970.72	732.00	9.31	3.82	0.13	1965.09	0.00	1965.09
10-09-2018	1993.86	1627.91	1965.09	731.90	9.76	3.61	0.13	1958.81	0.00	1958.81
11-09-2018	1993.86	1631.42	1958.81	731.79	8.51	3.68	0.13	1953.85	0.00	1953.85
12-09-2018	1993.86	1634.93	1953.85	731.70	7.73	2.89	0.13	1948.89	0.00	1948.89
13-09-2018	1993.86	1638.43	1948.89	731.61	6.89	4.70	0.13	1946.57	0.00	1946.57
14-09-2018	1993.86	1641.94	1946.57	731.57	6.49	0.99	0.13	1940.94	0.00	1940.94
15-09-2018	1993.86	1645.45	1940.94	731.47	7.14	2.64	0.13	1936.31	0.00	1936.31
16-09-2018	1993.86	1648.96	1936.31	731.39	5.89	3.04	0.13	1933.33	0.00	1933.33
17-09-2018	1993.86	1652.47	1933.33	731.33	5.28	2.76	0.13	1930.68	0.00	1930.68
18-09-2018	1993.86	1655.98	1930.68	731.28	5.11	2.93	0.13	1928.37	0.00	1928.37
19-09-2018	1993.86	1659.49	1928.37	731.24	4.96	3.77	0.13	1927.04	0.00	1927.04
20-09-2018	1993.86	1662.99	1927.04	731.22	6.40	3.55	0.13	1924.06	0.00	1924.06
21-09-2018	1993.86	1666.50	1924.06	731.16	7.30	2.46	0.13	1919.10	0.00	1919.10
22-09-2018	1993.86	1670.01	1919.10	731.07	7.05	2.22	0.13	1914.13	0.00	1914.13

Day	Storage for upper levels (MCM)	Storage for lower rule levels (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6)	Spills (MCM)	Storage after spills (MCM)
	1a	1b	2	3	4	5	6	7	8	9
23-09-2018	1993.86	1673.52	1914.13	730.98	4.16	3.96	0.13	1913.80	0.00	1913.80
24-09-2018	1993.86	1677.03	1913.80	730.97	6.13	7.58	0.13	1915.12	0.00	1915.12
25-09-2018	1993.86	1680.54	1915.12	731.00	5.20	4.34	0.13	1914.13	0.00	1914.13
26-09-2018	1993.86	1684.05	1914.13	730.98	6.14	5.61	0.13	1913.47	0.00	1913.47
27-09-2018	1993.86	1687.56	1913.47	730.97	5.02	5.81	0.13	1914.13	0.00	1914.13
28-09-2018	1993.86	1691.06	1914.13	730.98	5.77	9.54	0.13	1917.77	0.00	1917.77
29-09-2018	1993.86	1694.57	1917.77	731.05	5.32	10.42	0.13	1922.74	0.00	1922.74

(Source: IISc, Bangalore's Report on Kerala Floods 2018)

Appendix 3.6

Sample simulations of Idukki reservoir using 2020 rule curve

(Reference: Paragraph 3.6.2)

Day	Storage for rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation Loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
10-06-2018	1513.98	1513.98	723.30	2.38	43.53	0.13	1555.00	41.02	1513.98
11-06-2018	1513.98	1513.98	723.30	3.52	52.36	0.13	1562.69	48.71	1513.98
12-06-2018	1513.98	1513.98	723.30	4.26	34.28	0.13	1543.87	29.89	1513.98
13-06-2018	1513.98	1513.98	723.30	2.18	25.39	0.13	1537.07	23.09	1513.98
14-06-2018	1513.98	1513.98	723.30	2.13	16.99	0.13	1528.71	14.73	1513.98
15-06-2018	1513.98	1513.98	723.30	1.33	12.95	0.13	1525.47	11.49	1513.98
16-06-2018	1513.98	1513.98	723.30	1.67	13.84	0.13	1526.02	12.04	1513.98
17-06-2018	1513.98	1513.98	723.30	2.10	7.62	0.13	1519.38	5.40	1513.98
18-06-2018	1513.98	1513.98	723.30	2.90	8.42	0.13	1519.38	5.39	1513.98
19-06-2018	1513.98	1513.98	723.30	1.63	9.86	0.13	1522.08	8.10	1513.98
20-06-2018	1513.98	1513.98	723.30	2.55	12.27	0.13	1523.57	9.58	1513.98
21-06-2018	1513.98	1513.98	723.30	2.27	13.21	0.13	1524.79	10.81	1513.98
22-06-2018	1513.98	1513.98	723.30	2.21	12.42	0.13	1524.06	10.08	1513.98
23-06-2018	1513.98	1513.98	723.30	3.88	12.61	0.13	1522.58	8.60	1513.98
24-06-2018	1513.98	1513.98	723.30	2.49	9.00	0.13	1520.37	6.39	1513.98
25-06-2018	1513.98	1513.98	723.30	2.43	10.90	0.13	1522.32	8.34	1513.98
26-06-2018	1513.98	1513.98	723.30	1.96	9.22	0.13	1521.10	7.12	1513.98
27-06-2018	1513.98	1513.98	723.30	1.40	10.37	0.13	1522.83	8.85	1513.98
28-06-2018	1513.98	1513.98	723.30	1.62	10.35	0.13	1522.58	8.60	1513.98
29-06-2018	1513.98	1513.98	723.30	1.37	8.87	0.13	1521.35	7.37	1513.98
30-06-2018	1513.98	1513.98	723.30	1.83	9.81	0.13	1521.83	4.59	1517.24
01-07-2018	1517.24	1517.24	723.37	1.40	8.89	0.13	1524.60	4.10	1520.50

Day	Storage for rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation Loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
02-07-2018	1520.50	1520.50	723.44	2.49	10.72	0.13	1528.60	4.84	1523.76
03-07-2018	1523.76	1523.76	723.51	2.23	8.00	0.13	1529.41	2.38	1527.03
04-07-2018	1527.03	1527.03	723.58	2.72	6.53	0.13	1530.70	0.41	1530.29
05-07-2018	1530.29	1530.29	723.65	2.99	5.56	0.13	1532.73	0.00	1532.73
06-07-2018	1533.55	1532.73	723.70	2.71	5.04	0.13	1534.92	0.00	1534.92
07-07-2018	1536.81	1534.92	723.75	2.66	6.46	0.13	1538.59	0.00	1538.59
08-07-2018	1540.07	1538.59	723.83	1.03	9.50	0.13	1546.93	3.59	1543.33
09-07-2018	1543.33	1543.33	723.93	1.85	19.66	0.13	1561.02	14.42	1546.59
10-07-2018	1546.59	1546.59	724.00	3.05	34.60	0.13	1578.01	27.60	1550.41
11-07-2018	1550.41	1550.41	724.08	1.16	32.70	0.13	1581.82	27.59	1554.23
12-07-2018	1554.23	1554.23	724.17	2.06	28.23	0.13	1580.26	22.22	1558.05
13-07-2018	1558.05	1558.05	724.25	1.94	40.69	0.13	1596.66	34.80	1561.86
14-07-2018	1561.86	1561.86	724.33	1.85	33.21	0.13	1593.10	27.42	1565.68
15-07-2018	1565.68	1565.68	724.42	1.39	53.77	0.13	1617.92	48.42	1569.50
16-07-2018	1569.50	1569.50	724.50	1.59	61.92	0.13	1629.70	56.39	1573.32
17-07-2018	1573.32	1573.32	724.57	3.27	41.73	0.13	1611.65	34.52	1577.13
18-07-2018	1577.13	1577.13	724.65	5.01	38.02	0.13	1610.01	29.06	1580.95
19-07-2018	1580.95	1580.95	724.72	5.92	35.83	0.13	1610.73	25.96	1584.77
20-07-2018	1584.77	1584.77	724.80	6.74	29.70	0.13	1607.60	19.13	1588.47
21-07-2018	1588.47	1588.47	724.87	5.63	22.64	0.13	1605.35	13.18	1592.16
22-07-2018	1592.16	1592.16	724.95	5.40	20.09	0.13	1606.72	10.86	1595.86
23-07-2018	1595.86	1595.86	725.02	6.83	23.50	0.13	1612.40	12.84	1599.56
24-07-2018	1599.56	1599.56	725.09	8.87	39.11	0.13	1629.67	26.41	1603.26
25-07-2018	1603.26	1603.26	725.16	9.12	39.35	0.13	1633.36	26.40	1606.96
26-07-2018	1606.96	1606.96	725.24	9.74	39.98	0.13	1637.07	26.41	1610.66
27-07-2018	1610.66	1610.66	725.31	9.82	24.83	0.13	1625.54	11.19	1614.35
28-07-2018	1614.35	1614.35	725.38	9.68	24.36	0.13	1628.91	10.85	1618.05
29-07-2018	1618.05	1618.05	725.45	10.05	23.41	0.13	1631.29	9.54	1621.75

Day	Storage for rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation Loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
30-07-2018	1621.75	1621.75	725.53	10.04	21.75	0.13	1633.33	7.88	1625.45
31-07-2018	1625.45	1625.45	725.60	10.07	19.14	0.13	1634.38	4.30	1630.08
01-08-2018	1630.08	1630.08	725.69	10.07	14.83	0.13	1634.71	0.00	1634.71
02-08-2018	1634.71	1634.71	725.78	10.09	12.53	0.13	1637.02	0.00	1637.02
03-08-2018	1639.34	1637.02	725.83	9.59	11.37	0.13	1638.67	0.00	1638.67
04-08-2018	1643.97	1638.67	725.86	9.30	9.10	0.13	1638.34	0.00	1638.34
05-08-2018	1648.60	1638.34	725.85	9.50	7.97	0.13	1636.68	0.00	1636.68
06-08-2018	1653.23	1636.68	725.82	9.00	8.46	0.13	1636.01	0.00	1636.01
07-08-2018	1657.86	1636.01	725.81	9.05	16.46	0.13	1643.29	0.00	1643.29
08-08-2018	1662.49	1643.29	725.95	9.99	39.58	0.13	1672.75	5.63	1667.12
09-08-2018	1667.12	1667.12	726.41	9.95	57.45	0.13	1714.49	42.74	1671.75
10-08-2018	1671.75	1671.75	726.50	9.98	61.03	0.13	1722.68	45.50	1677.18
11-08-2018	1677.18	1677.18	726.60	9.96	45.44	0.13	1712.54	29.92	1682.61
12-08-2018	1682.61	1682.61	726.70	9.99	48.44	0.13	1720.93	32.89	1688.04
13-08-2018	1688.04	1688.04	726.80	10.00	45.99	0.13	1723.90	30.43	1693.47
14-08-2018	1693.47	1693.47	726.90	9.99	84.18	0.13	1767.54	68.63	1698.91
15-08-2018	1698.91	1698.91	727.00	9.99	165.06	0.13	1853.85	149.51	1704.34
16-08-2018	1704.34	1704.34	727.10	9.95	154.96	0.13	1849.22	139.45	1709.77
17-08-2018	1709.77	1709.77	727.20	9.98	111.70	0.13	1811.36	96.16	1715.20
18-08-2018	1715.20	1715.20	727.30	9.66	92.51	0.13	1797.92	77.29	1720.63
19-08-2018	1720.63	1720.63	727.40	9.98	62.88	0.13	1773.40	47.34	1726.06
20-08-2018	1726.06	1726.06	727.50	9.95	37.54	0.13	1753.53	22.51	1731.01
21-08-2018	1731.01	1731.01	727.59	9.68	29.95	0.13	1751.16	15.19	1735.96
22-08-2018	1735.96	1735.96	727.68	9.98	24.60	0.13	1750.45	9.53	1740.91
23-08-2018	1740.91	1740.91	727.77	9.96	20.39	0.13	1751.21	5.35	1745.86
24-08-2018	1745.86	1745.86	727.86	9.96	18.96	0.13	1754.73	3.91	1750.81
25-08-2018	1750.81	1750.81	727.95	9.96	17.77	0.13	1758.50	2.73	1755.76
26-08-2018	1755.76	1755.76	728.05	9.93	16.42	0.13	1762.12	1.40	1760.71
27-08-2018	1760.71	1760.71	728.14	9.97	18.44	0.13	1769.05	3.39	1765.66

Day	Storage for rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation Loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
28-08-2018	1765.66	1765.66	728.23	9.91	18.71	0.13	1774.33	3.72	1770.62
29-08-2018	1770.62	1770.62	728.32	9.97	15.79	0.13	1776.31	0.74	1775.57
30-08-2018	1775.57	1775.57	728.41	8.69	15.17	0.13	1781.92	1.40	1780.52
31-08-2018	1780.52	1780.52	728.50	10.01	15.83	0.13	1786.21	1.66	1784.55
01-09-2018	1784.55	1784.55	728.57	10.01	14.17	0.13	1788.58	0.00	1788.58
02-09-2018	1788.58	1788.58	728.65	9.96	8.49	0.13	1786.98	0.00	1786.98
03-09-2018	1792.61	1786.98	728.62	9.74	7.58	0.13	1784.70	0.00	1784.70
04-09-2018	1796.65	1784.70	728.58	9.20	7.38	0.13	1782.74	0.00	1782.74
05-09-2018	1800.68	1782.74	728.54	9.14	6.99	0.13	1780.46	0.00	1780.46
06-09-2018	1804.71	1780.46	728.50	10.03	6.88	0.13	1777.18	0.00	1777.18
07-09-2018	1808.74	1777.18	728.44	9.89	4.57	0.13	1771.73	0.00	1771.73
08-09-2018	1812.78	1771.73	728.34	9.55	3.39	0.13	1765.44	0.00	1765.44
09-09-2018	1816.81	1765.44	728.22	9.31	3.82	0.13	1759.81	0.00	1759.81
10-09-2018	1820.84	1759.81	728.12	9.76	3.61	0.13	1753.53	0.00	1753.53
11-09-2018	1824.88	1753.53	728.00	8.51	3.68	0.13	1748.57	0.00	1748.57
12-09-2018	1828.92	1748.57	727.91	7.73	2.89	0.13	1743.61	0.00	1743.61
13-09-2018	1832.95	1743.61	727.82	6.89	4.70	0.13	1741.29	0.00	1741.29
14-09-2018	1836.99	1741.29	727.78	6.49	0.99	0.13	1735.66	0.00	1735.66
15-09-2018	1841.03	1735.66	727.68	7.14	2.64	0.13	1731.03	0.00	1731.03
16-09-2018	1845.07	1731.03	727.59	5.89	3.04	0.13	1728.05	0.00	1728.05
17-09-2018	1849.10	1728.05	727.54	5.28	2.76	0.13	1725.40	0.00	1725.40
18-09-2018	1853.14	1725.40	727.49	5.11	2.93	0.13	1723.08	0.00	1723.08
19-09-2018	1857.18	1723.08	727.45	4.96	3.77	0.13	1721.76	0.00	1721.76
20-09-2018	1861.22	1721.76	727.42	6.40	3.55	0.13	1718.78	0.00	1718.78
21-09-2018	1864.41	1718.78	727.37	7.30	2.46	0.13	1713.82	0.00	1713.82
22-09-2018	1867.60	1713.82	727.28	7.05	2.22	0.13	1708.85	0.00	1708.85
23-09-2018	1870.80	1708.85	727.18	4.16	3.96	0.13	1708.52	0.00	1708.52
24-09-2018	1873.99	1708.52	727.18	6.13	7.58	0.13	1709.84	0.00	1709.84
25-09-2018	1877.19	1709.84	727.20	5.20	4.34	0.13	1708.85	0.00	1708.85

Day	Storage for rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation Loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
26-09-2018	1880.38	1708.85	727.18	6.14	5.61	0.13	1708.19	0.00	1708.19
27-09-2018	1883.57	1708.19	727.17	5.02	5.81	0.13	1708.85	0.00	1708.85
28-09-2018	1886.77	1708.85	727.18	5.77	9.54	0.13	1712.49	0.00	1712.49
29-09-2018	1889.96	1712.49	727.25	5.32	10.42	0.13	1717.46	0.00	1717.46

(Source: IISc, Bangalore's Report on Kerala Floods 2018)

Appendix 3.7

Sample simulations of Idamalayar reservoir using 2020 rule curve

(Reference: Paragraph 3.6.3)

Day	Storage for the rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
10-06-2018	860.00	860.00	161.00	1.77	28.30	0.00	886.53	26.53	860.00
11-06-2018	860.00	860.00	161.00	1.12	23.16	0.00	882.04	22.04	860.00
12-06-2018	860.00	860.00	161.00	1.38	26.34	0.00	884.96	24.96	860.00
13-06-2018	860.00	860.00	161.00	1.30	22.60	0.00	881.30	21.30	860.00
14-06-2018	860.00	860.00	161.00	2.16	24.18	0.05	881.96	21.96	860.00
15-06-2018	860.00	860.00	161.00	0.32	16.33	0.04	875.98	15.98	860.00
16-06-2018	860.00	860.00	161.00	0.56	10.58	0.02	869.99	9.99	860.00
17-06-2018	860.00	860.00	161.00	1.15	11.14	0.00	869.99	9.99	860.00
18-06-2018	860.00	860.00	161.00	0.81	8.28	0.02	867.46	7.46	860.00
19-06-2018	860.00	860.00	161.00	1.95	8.46	0.05	866.46	6.46	860.00
20-06-2018	860.00	860.00	161.00	0.76	10.68	0.04	869.88	9.88	860.00
21-06-2018	860.00	860.00	161.00	0.59	13.29	0.00	872.70	12.70	860.00
22-06-2018	860.00	860.00	161.00	0.61	13.66	0.02	873.04	13.04	860.00
23-06-2018	860.00	860.00	161.00	0.53	12.93	0.02	872.38	12.38	860.00
24-06-2018	860.00	860.00	161.00	0.54	7.53	0.03	866.97	6.97	860.00
25-06-2018	860.00	860.00	161.00	0.62	7.62	0.03	866.97	6.97	860.00
26-06-2018	860.00	860.00	161.00	0.34	8.85	0.00	868.51	8.51	860.00
27-06-2018	860.00	860.00	161.00	0.68	7.30	0.03	866.58	6.58	860.00
28-06-2018	860.00	860.00	161.00	1.49	10.02	0.01	868.51	8.51	860.00
29-06-2018	860.00	860.00	161.00	0.54	10.21	0.00	869.67	9.67	860.00
30-06-2018	860.00	860.00	161.00	0.44	9.86	0.03	869.38	7.97	861.41
01-07-2018	861.41	861.41	161.05	0.36	7.63	0.02	868.66	5.83	862.83
02-07-2018	862.83	862.83	161.10	0.28	7.25	0.04	869.76	5.51	864.25

Day	Storage for the rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
03-07-2018	864.25	864.25	161.15	0.73	7.87	0.00	871.39	5.73	865.66
04-07-2018	865.66	865.66	161.20	0.75	5.83	0.04	870.70	3.62	867.08
05-07-2018	867.08	867.08	161.25	0.61	4.03	0.06	870.44	1.95	868.49
06-07-2018	868.49	868.49	161.30	1.20	3.74	0.02	871.01	1.10	869.90
07-07-2018	869.90	869.90	161.35	1.63	4.21	0.06	872.42	1.10	871.32
08-07-2018	871.32	871.32	161.40	1.26	6.72	0.00	876.78	4.05	872.73
09-07-2018	872.73	872.73	161.45	0.29	9.49	0.00	881.93	7.78	874.15
10-07-2018	874.15	874.15	161.50	0.29	17.45	0.00	891.31	16.45	874.86
11-07-2018	874.86	874.86	161.53	0.45	39.76	0.00	914.18	38.61	875.56
12-07-2018	875.56	875.56	161.55	0.35	29.87	0.00	905.08	28.81	876.27
13-07-2018	876.27	876.27	161.58	0.56	21.40	0.00	897.12	20.14	876.98
14-07-2018	876.98	876.98	161.60	0.53	28.63	0.02	905.06	27.38	877.69
15-07-2018	877.69	877.69	161.63	0.34	27.81	0.00	905.16	26.77	878.39
16-07-2018	878.39	878.39	161.65	0.42	40.34	0.00	918.31	39.21	879.10
17-07-2018	879.10	879.10	161.68	0.18	37.63	0.00	916.55	36.74	879.81
18-07-2018	879.81	879.81	161.70	0.61	32.01	0.00	911.21	30.69	880.52
19-07-2018	880.52	880.52	161.73	0.49	28.81	0.06	908.78	27.55	881.23
20-07-2018	881.23	881.23	161.75	0.82	24.34	0.00	904.75	21.58	883.17
21-07-2018	883.17	883.17	161.82	1.64	24.18	0.03	905.68	20.56	885.11
22-07-2018	885.11	885.11	161.89	0.98	19.46	0.08	903.51	16.45	887.05
23-07-2018	887.05	887.05	161.95	2.30	15.41	0.00	900.16	11.17	889.00
24-07-2018	889.00	889.00	162.02	4.02	23.14	0.00	908.12	17.18	890.94
25-07-2018	890.94	890.94	162.09	4.90	39.95	0.00	925.99	33.11	892.88
26-07-2018	892.88	892.88	162.16	5.93	21.48	0.00	908.44	13.61	894.83
27-07-2018	894.83	894.83	162.23	5.76	19.60	0.02	908.65	11.88	896.77
28-07-2018	896.77	896.77	162.30	5.19	12.42	0.03	903.97	5.26	898.71
29-07-2018	898.71	898.71	162.36	5.84	16.78	0.00	909.66	9.00	900.66

Day	Storage for the rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
30-07-2018	900.66	900.66	162.43	5.73	13.83	0.03	908.72	6.12	902.60
31-07-2018	902.60	902.60	162.50	5.84	19.96	0.00	916.72	12.69	904.03
01-08-2018	904.03	904.03	162.55	5.81	10.74	0.02	908.94	3.48	905.46
02-08-2018	905.46	905.46	162.60	5.82	9.03	0.03	908.64	1.75	906.89
03-08-2018	906.89	906.89	162.65	5.81	9.62	0.05	910.65	2.33	908.32
04-08-2018	908.32	908.32	162.70	5.77	7.61	0.11	910.05	0.30	909.75
05-08-2018	909.75	909.75	162.75	5.77	6.72	0.08	910.62	0.00	910.62
06-08-2018	911.18	910.62	162.78	5.78	7.83	0.03	912.64	0.03	912.61
07-08-2018	912.61	912.61	162.85	5.77	19.07	0.00	925.91	11.87	914.04
08-08-2018	914.04	914.04	162.90	5.71	61.93	0.00	970.27	54.80	915.47
09-08-2018	915.47	915.47	162.95	5.67	46.37	0.00	956.18	39.28	916.90
10-08-2018	916.90	916.90	163.00	5.67	33.92	0.00	945.15	26.82	918.33
11-08-2018	918.33	918.33	163.05	5.69	17.28	0.00	929.92	10.16	919.76
12-08-2018	919.76	919.76	163.10	5.69	31.81	0.07	945.80	24.61	921.19
13-08-2018	921.19	921.19	163.15	5.47	37.08	0.00	952.80	30.18	922.62
14-08-2018	922.62	922.62	163.20	5.40	62.96	0.00	980.18	56.13	924.05
15-08-2018	924.05	924.05	163.25	1.96	100.59	0.00	1022.68	97.20	925.48
16-08-2018	925.48	925.48	163.30	0.00	86.97	0.00	1012.45	85.54	926.91
17-08-2018	926.91	926.91	163.35	0.00	52.67	0.00	979.58	51.24	928.34
18-08-2018	928.34	928.34	163.40	0.00	34.81	0.00	963.15	33.38	929.77
19-08-2018	929.77	929.77	163.45	0.01	28.17	0.00	957.92	26.72	931.20
20-08-2018	931.20	931.20	163.50	3.91	21.94	0.00	949.23	16.73	932.50
21-08-2018	932.50	932.50	163.55	4.48	15.16	0.00	943.17	9.37	933.80
22-08-2018	933.80	933.80	163.59	5.82	12.41	0.03	940.36	5.26	935.10
23-08-2018	935.10	935.10	163.64	5.26	10.39	0.00	940.23	3.83	936.40
24-08-2018	936.40	936.40	163.68	4.93	8.57	0.04	940.01	2.31	937.70
25-08-2018	937.70	937.70	163.73	5.70	6.89	0.06	938.83	0.00	938.83

Day	Storage for the rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
26-08-2018	939.00	938.83	163.77	5.77	7.14	0.04	940.17	0.00	940.17
27-08-2018	940.30	940.17	163.81	5.77	7.57	0.06	941.90	0.30	941.60
28-08-2018	941.60	941.60	163.86	5.72	7.43	0.02	943.29	0.39	942.90
29-08-2018	942.90	942.90	163.91	5.84	7.11	0.05	944.12	0.00	944.12
30-08-2018	944.20	944.12	163.95	5.85	5.80	0.03	944.05	0.00	944.05
31-08-2018	945.50	944.05	163.95	5.84	6.71	0.02	944.90	0.00	944.90
01-09-2018	948.38	944.90	163.98	5.85	6.71	0.01	945.75	0.00	945.75
02-09-2018	951.26	945.75	164.01	5.84	6.42	0.06	946.27	0.00	946.27
03-09-2018	954.14	946.27	164.03	5.84	6.42	0.05	946.79	0.00	946.79
04-09-2018	957.02	946.79	164.04	5.87	5.87	0.08	946.71	0.00	946.71
05-09-2018	959.90	946.71	164.04	5.88	5.88	0.05	946.66	0.00	946.66
06-09-2018	962.78	946.66	164.04	5.92	5.64	0.14	946.24	0.00	946.24
07-09-2018	965.66	946.24	164.03	5.99	5.71	0.10	945.87	0.00	945.87
08-09-2018	968.54	945.87	164.01	6.01	5.76	0.06	945.55	0.00	945.55
09-09-2018	971.42	945.55	164.00	6.01	6.19	0.09	945.64	0.00	945.64
10-09-2018	974.30	945.64	164.00	5.99	4.54	0.11	944.08	0.00	944.08
11-09-2018	977.18	944.08	163.95	6.00	0.00	0.11	937.98	0.00	937.98
12-09-2018	980.06	937.98	163.74	6.00	1.53	0.09	933.42	0.00	933.42
13-09-2018	982.94	933.42	163.58	6.00	0.98	0.11	928.29	0.00	928.29
14-09-2018	985.82	928.29	163.40	5.36	0.93	0.14	923.73	0.00	923.73
15-09-2018	988.70	923.73	163.24	5.94	1.14	0.05	918.88	0.00	918.88
16-09-2018	991.58	918.88	163.07	5.55	0.79	0.09	914.04	0.00	914.04
17-09-2018	994.46	914.04	162.90	5.46	0.95	0.05	909.48	0.00	909.48
18-09-2018	997.34	909.48	162.74	5.75	1.84	0.05	905.51	0.00	905.51
19-09-2018	1000.22	905.51	162.60	5.45	0.00	0.04	900.03	0.00	900.03
20-09-2018	1003.10	900.03	162.41	4.53	1.43	0.02	896.91	0.00	896.91
21-09-2018	1003.96	896.91	162.30	5.43	0.10	0.05	891.54	0.00	891.54

Day	Storage for the rule level (MCM)	Storage at the beginning of the day (MCM)	Reservoir level (m, MSL)	PH discharge (MCM)	Inflows to reservoir (MCM)	Evaporation loss (MCM)	Storage at the end of the day before spills (2)+(5)-(4)-(6) (MCM)	Spills (MCM)	Storage after spills (MCM)
	1	2	3	4	5	6	7	8	9
22-09-2018	1004.83	891.54	162.11	5.65	0.63	0.07	886.44	0.00	886.44
23-09-2018	1005.69	886.44	161.93	5.89	1.18	0.10	881.63	0.00	881.63
24-09-2018	1006.56	881.63	161.76	4.67	2.81	0.10	879.67	0.00	879.67
25-09-2018	1007.42	879.67	161.69	5.89	3.09	0.00	876.87	0.00	876.87
26-09-2018	1008.28	876.87	161.60	5.38	0.65	0.03	872.11	0.00	872.11
27-09-2018	1009.15	872.11	161.43	5.94	1.26	0.08	867.35	0.00	867.35
28-09-2018	1010.01	867.35	161.26	5.70	0.73	0.07	862.31	0.00	862.31
29-09-2018	1010.88	862.31	161.08	5.68	2.42	0.10	858.95	0.00	858.95

(Source: IISc, Bangalore's Report on Kerala Floods 2018)

Appendix 4.1

LULC analysis for Idukki district

(Reference: Paragraph 4.1.1)

Land Use	Area 1985 (from NASA)	Area 1995 (from NASA)	Area 2005 (from KSREC)	Area 2015 (from KSREC)	Areal change from 2005 to 2015	Change from 2005 to 2015 (%)*	Areal change from 1985 to 2015	Change from 1985 to 2015 (%)*
	sq. km	sq. km	sq. km	sq. km	sq. km		sq. km	
Forest land	1966.78	1955.22	2196.35	2124.99	-71.35	-3.25	158.21	8.04
Agricultural land	1589.22	1601.99	1416.15	1598.35	182.20	12.87	9.13	0.57
Built-up (Cities/ Towns/ Villages)	11.39	11.40	20.40	154.57	134.16	657.56	143.18	1257.02
Wasteland	99.73	96.80	142.33	142.81	0.48	0.34	43.08	43.20
Grassland	591.01	592.33	478.58	231.64	-246.94	-51.60	-359.37	-60.81
Water bodies	120.26	120.65	109.02	113.24	4.22	3.87	-7.02	-5.84
Total	**4378.39**	**4378.39**	**4362.82[$]**	**4365.59[$]**				

*Negative sign indicates a decrease in area for a particular class and positive sign indicates an increase in area.

[$]The difference in the total areas is due to a slight inconsistency in the data for the two years obtained from KSREC. However, this difference is negligible.

LULC transition matrix for Idukki district (2005-2015)

(in *per cent*)

		2015					
		Forest land	**Agricultural land**	**Grassland**	**Wasteland**	**Water bodies**	**Built-up (Cities/Towns/ Villages)**
2005	**Forest land**	88.12	8.39	1.78	0.49	0.18	1.04
	Agricultural land	0.60	91.00	0.48	0.33	0.29	7.30
	Grassland	32.67	21.52	35.22	7.91	1.23	1.45
	Wasteland	12.98	10.61	11.51	63.03	0.05	1.82
	Water bodies	3.69	3.72	0.26	0.03	90.96	1.34
	Built-up (Cities/ Towns/ Villages)	2.05	11.19	0.02	0.30	0.50	85.94

(Source: IISc, Bangalore's Report on Kerala Floods 2018)

Appendix 4.2

LULC analysis for Ernakulam district

(Reference: Paragraph 4.1.2)

Land Use	Area 1985 (from NASA)	Area 1995 (from NASA)	Area 2005 (from KSREC)	Area 2015 (from KSREC)	Areal change from 2005 to 2015	Change from 2005 to 2015 (%)*	Areal change from 1985 to 2015	Change from 1985 to 2015 (%)*
	sq. km	sq. km	sq. km	sq. km	sq. km		sq. km	
Forest land	654.78	624.79	830.58	837.21	6.63	0.80	182.43	27.86
Agricultural land	1961.04	1916.65	1737.86	1555.66	-182.2	-10.48	-405.38	-20.67
Built-up (Cities/Towns/ Villages)	140.65	182.26	253.93	439.14	185.21	72.94	298.49	212.22
Wasteland	2.73	2.73	15.83	26.12	10.29	65.00	23.39	856.78
Grassland	86.53	116.49	39.63	21.32	-18.31	-46.20	-65.21	-75.36
Water bodies	219.51	222.32	190.70	188.81	-1.89	-0.99	-30.7	-13.99
Total	**3065.24**	**3065.24**	**3068.54[$]**	**3068.26[$]**				

*Negative sign indicates a decrease in area for a particular class and positive sign indicates an increase in area.

[$]The difference in the total areas is due to a slight inconsistency in the data for the two years obtained from KSREC. However, this difference is negligible.

LULC transition matrix for Ernakulam district (2005-2015)

(in *per cent*)

		2015					
		Forest land	**Agricultural land**	**Grassland**	**Wasteland**	**Water bodies**	**Built-up (Cities/Towns/ Villages)**
2005	**Forest land**	97.29	1.06	0.73	0.63	0.21	0.08
	Agricultural land	1.31	85.56	0.06	0.33	0.74	12.00
	Grassland	7.82	44.58	30.71	6.59	0.13	10.17
	Wasteland	11.12	6.51	1.23	73.32	6.44	1.38
	Water bodies	1.11	7.12	1.00	0.01	89.66	1.10
	Built-up (Cities/ Towns/Villages)	0.11	10.83	0.01	0.39	0.58	88.08

(Source: IISc, Bangalore's Report on Kerala Floods 2018)

Appendix 4.3

LULC analysis for flood prone region of Ernakulam district

(Reference: Paragraph 4.1.3)

Land Use	Area 1985 (from NASA)	Area 1995 (from NASA)	Area 2005 (from KSREC)	Area 2015 (from KSREC)	Areal change from 2005 to 2015	Change from 2005 to 2015 (%)*	Areal change from 1985 to 2015	Change from 1985 to 2015 (%)*
	sq. km	sq. km	sq. km	sq. km	sq. km		sq. km	
Forest land	27.44	27.38	38.26	49.56	11.30	29.53	22.12	80.63
Agricultural land	613.15	588.99	566.34	489.68	-76.66	-13.54	-123.47	-20.14
Built-up (Cities/Towns/ Villages)	48.44	72.02	104.26	182.59	78.33	75.13	134.15	276.94
Wasteland	0.59	0.59	1.47	3.76	2.29	155.53	3.17	538.08
Grassland	7.65	7.65	11.50	2.22	-9.28	-80.69	-5.43	-70.98
Water bodies	92.90	93.54	69.62	63.50	-6.12	-8.79	-29.40	-31.64
Total	**790.17**	**790.17**	**791.46[$]**	**791.32[$]**				

*Negative sign indicates a decrease in area for a particular class and positive sign indicates an increase in area.

[$]The difference in the total areas is due to a slight inconsistency in the data for the two years obtained from KSREC. However, this difference is negligible.

LULC transition matrix for flood prone region of Ernakulam district (2005-2015)

(in *per cent*)

		2015					
		Forest land	Agricultural land	Grassland	Wasteland	Water bodies	Built-up (Cities/ Towns/ Villages)
2005	**Forest land**	90.75	6.85	0.00	1.52	0.39	0.49
	Agricultural land	2.49	81.01	0.04	0.27	0.87	15.32
	Grassland	6.84	60.90	17.16	5.05	0.00	10.05
	Wasteland	0.24	28.71	0.18	62.07	0.00	8.80
	Water bodies	0.04	15.21	0.00	0.00	83.18	1.57
	Built-up (Cities/ Towns/ Villages)	0.02	9.74	0.00	0.12	0.52	89.60

(Source: IISc, Bangalore's Report on Kerala Floods 2018)

Appendix 5.1

Statement showing name of LSGI, Taluk and number of respondents covered by Audit in selected districts while conducting survey of affected persons

(Reference: Chapter 5, Paragraph on Results of survey)

Sl. No.	Name of District	Name of Taluk Office	Name of LSGI	Number of persons surveyed
1.	Alappuzha	Chengannur	Chengannur Municipality	25
2.			Pandanad Grama Panchayat	25
3.			Thiruvanvandoor Grama Panchayat	25
4.			Ala Grama Panchayat	25
5.		Kuttanad	Champakkulam Grama Panchayat	25
6.			Muttar Grama Panchayat	25
7.			Nedumudi Grama Panchayat	27
8.			Neelamperoor Grama Panchayat	25
9.	Ernakulam	Aluva	Aluva Municipality	26
10.			Kalady Grama Panchayat	26
11.			Parakkadavu Grama Panchayat	31
12.			Sreemoolanagaram Grama Panchayat	28
13.		Paravur	Alangad Grama Panchayat	30
14.			Chendamangalam Grama Panchayat	30
15.			Karumalloor Grama Panchayat	22
16.			Puthenvelikkara Grama Panchayat	26
17.	Idukki	Idukki	Kanjikuzhy Grama Panchayat	15
18.			Konnathady Grama Panchayat	20
19.			Vathikudy Grama Panchayat	20
20.			Vazhathope Grama Panchayat	24
21.		Devikulam	Adimaly Grama Panchayat	20
22.			Mankulam Grama Panchayat	25
23.			Munnar Grama Panchayat	19
24.			Vellathooval Grama Panchayat	17
25.	Thrissur	Chalakkudy	Chalakkudy Municipality	19
26.			Kadukutty Grama Panchayat	28
27.			Koratty Grama Panchayat	24
28.			Melur Grama Panchayat	34
29.		Thalappilly	Chelakkara Grama Panchayat	32
30.			Pazhayannur Grama Panchayat	22
31.			Vallathol Nagar Grama Panchayat	32
32.			Wadakkancherry Municipality	28

https://cag.gov.in/ag1/kerala/en