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Estimation of Design Inflow Flood for Existing Reservoir-Case Study of Linganamakki Reservoir

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SYNOPSIS

Periodical review of design flood of existing dams is necessary from safety point of view and also for assessment of design inflow floods of any proposed new dams downstream. A review of design flood of Linganamakki dam was made when a new dam was planned for construction downstream. In this article the method adopted for estimation of probable maximum flood of Linganamakki dam and the constraints imposed on the routed flood for safety of the Honnavar town are explained. The recommendations of a Commission of Enquiry appointed by Government of Karnataka for ensuring the safety of downstream people are also explained.

1.0 INTRODUCTION

1.1 RIVER SHARAVATHI

Sharavathi river is the first important river in Karnataka from the point of view of hydro power potential. This west flowing river rises at an elevation of about 710 m on the eastern slopes of Western ghats near Ambuthirtha in Shimoga district of Karnataka State. The river is 132 km long and is joined by several important tributaries in its course and cover a total catchment area of 1992 sq km at Linganamakki dam. The river generally flows in north-easterly direction until it penetates the Western ghats at a gap near Jog where it takes a turn to the West and leaps 253 m over the famous Jog falls and races down the deep narrow gorge before it merges into the Arabian sea near Honnavar. The entire catchment is very steep and thickly wooded with patches of cultivated lands. The terrain is undulating broken up by chains of rocky hills and scoured by deep ravines. The location map and index of the project are in plate-1.

1.2 LINGANAMAKKI DAM

The existing Mahatma Gandhi Hydel Scheme (MGHE) was completed in 1942 by constructing a small head work for diverting Sharavathi water and using the head available at Jog Falls. It has an installed capacity of 120 MW. However, for optimal utilisation of hydel potential, construction of Sharavathi Generating Scheme(SGS) was started in 1955 proposing storing the available flow and its augmentation by diversion of water from other nearby streams. The scheme commissioned in 1965 consists of a 55 m high masonry dam across Sharavathi river near Linganamakki, intercepting a catchment area of 1992 sq km and has a gross storage capacity of 4417 Mm^3 with a dam power house having an installed capacity of 55 MW. Water from Linganamakki reservoir after generating power from dam power house is transferred to a balancing reservoir on a near by stream called Talakalale stream. Talakalale reservoir with a gross storage capacity of 130 Mm^3 is formed by constructing a 62.5 m high masonry dam which intercepts a free catchment area of 46 sq km. Water from the reservoir is fed to the Sharavathi generating station which has an installed capacity of 891 MW.

With a veiw to augment the supplies to the Sharavathi Generating Station the water from adjacent independent west flowing river Chakra and its tributory Savehaklu have been diverted to Linganamakki reservoir by constructing two storage reservoirs on these rivers.

2.0 PREVIOUS STUDIES

Flood studies were made earlier by synthetic unit hydrograph method in 1961-62 at Central Water Commission (CWC), New Delhi. The storm depths based on fre.quency analysis of observed regional rainfall data were utilised for computing the design flood hydrograph of Linganamakki dam. The design flood peak as per the previous study was 14,368 cumecs.

3.0 REVIEW OF DESIGN FLOOD OF LINGANAMAKKI DAM

3.1 Sharavathi Tailrace Project(STR Project)

Sharavathi Tailrace Project was proposed to be constructed downstream of Linganamakki dam. This project is a terminal developmental scheme proposed for harnessing the balance potential of hydel energy in the valley. This project envisages construction of 56 m high composite dam by intercepting free catchment of 140.6 sq km to have gross storage capacity of 131 Mm^3. The reservoir touches the tailrace channel from Sharavathi Generating Station House. The project envisages to utilise the head of about 55 m to have an installed capacity of 240 MW.

3.2 NEED FOR REVIEW OF FLOOD STUDIES

The design inflow flood of Linganamakki dam had to be reviewed for the following reasons:

(a) For dam safety analysis purposes

(b) Availability of latest methodologies and upto date hydrological data.

(c) For arriving at the design inflow flood of proposed STR dam downstream.

4.0 AVAILABILITY OF DATA

4.1 RAINFALL

There are sixteen raingauge stations in the Sharavathi catchment which record daily rainfall data. Nine of these are self recording type which are useful for getting the short duration distribution of the recorded daily rainfall in the region.

4.2 DISCHARGE

Since the reservoir is already in existance, the various hydrological and energy parameters observed over a long period are utilised. The reservoir parameters are observed on daily basis during non monsoon period and on hourly basis during monsoon periods. The various available reservoir parameters are:

(a) Reservoir elevations

(b) Releases through sluices if any

(c) Releases through spillway if any

(d) Energy generation

4.3 COMPUTATION OF DISCHARGE

The quantum of inflow has been calculated by the arithmetic addition of the following quantities:

(a) Difference in capacities recorded over the time interval

(b) Evaporation loss

(c) Surplus over spillway if any

(d) Releases through slucies if any

(e) Quantity of water utilised for power generation.

5.0 SELECTION OF FLOOD EVENTS

After examining the hourly reservoir levels available at Linganamakki dam, fifteen peak flood events were identified for the purpose of these studies. These were shortlisted to eight by excluding those where concurrent short term rainfall was not available. Selected flood events were further subjected to qualitative consistency checks and five of them were finally selected for the purpose of the study. The flood events selected are given in Table :1

TABLE:1

FLOOD EVENTS IN LINGANAMAKKI

Sl.No.	Flood events	Base period (Hrs)	Peak discharge (cumecs)
1	2	3	4
1	August 1982	47	6332
2	July 1983	63	5023
3	July 1984	24	2001
4	June 1985	48	2693
5	August 1986	63	4046

The hourly inflow values to Linganamakki reservoir for the above events have been computed by taking into account the difference in reservoir capacities at various levels, surplus discharges through spillway, evaporation losses and releases through the penstock and river sluices etc.,

The concurrent hourly average catchment rainfall for these events have been computed by taking care of rainfall of 13 raingauge stations located in and around the catchment.

For each of the above events, the base flow is seperated and rainfall excesses are computed by equating the volumes of direct runoff and rainfall after seperating the losses. These are utilised for UG analysis at Linganamakki dam.

6.0 UNIT GRAPH ANALYSIS

Clarks approach in operationalised form has been used in this study. This approach has some inherent advantages such as;

(i) It condences and uses topographical parameters of the catchment.

(ii) It is more amenable to changes induced in the UG due to reservoir.

(iii) It requires fewer parameters and can be used in case of inadequate data.

An approximate estimation of Tc is done using California **formula.** The variations in the attenuation co-efficient (R) **has been** linked with Tc and the Parameter R/(R+Tc) is varied so as to keep control over independent variation of parameters.

The accurate value of Tc and R/(R+Tc) are arrived at by subjecting observed events for various values of the parameters ie., Tc and R/(R + Tc) The parameters which reproduce overall observed events best are considered for the development of the UG for the catchment. Clarks approach used in such an iterative and operationalised form becomes a more powerful tool for selection of an appropriate response function for the catchment.

The optimum parameters are decided by grid search technique. The observed and computed hydrographs developed by using various values of the above two parameters are compared for various errors indicators such as peak of hydrograph' centre of mass and time to peak. Standard error is computed for each trial of every event. Best fit parameters are arrived at by looking at the possible trend in the minimum standard error isopleths. For overall best fit parameters' minimum combined standard error isoplethes plotted for all the events are utilised. Proper weightage is also given to other error indicators such as location of centre of mass,time to peak, ability for producing the observed hydrograph etc.

7.0 SOFTWARE

A computer programme in Fortran language developed by Hydrology Directorate (s) of Central Water Commission New Delhi was utilised. The input to the programme are catchment area, time-area ratios, trial values of Tc and (R/(R+Tc) to compute the IUH and UG of the desired unit duration. To obtain the compute flood hydrograph, storm rainfall excess and base flow ordinates need to be fed. If observed flood hydrograph ordinates are fed as input, the program compares the observed and computed flood hydrographs quantitatively by computing errors in following aspects of the flood hydrographs.

a) Centre of mass from the origin
b) Peak discharge
c) Time to peak.

The standard error (SE) by combining the error in the above aspects is computed. In addition to these error indicators, a plot of observed and computed hydrographs can also be printed for visual inspection.

8.0 UG OF LINGANAMAKKI

The above software was used and it was decided that the parameters 1.0 Tc and $R/(R+T_c)$ =0.55 were best simulating the observed five flood events on an average. By using the above parameters, IUH and in turn one hour UG's have been developed. The UG for Linganamakki reservoir is annexed vide Plate:2.

9.0 DESIGN STORM ANALYSIS

The Sharavathi valley is located on the windward side of the Western ghats in Central Karnataka region at an elevation varying between 300 m to 900 m. The area receives very heavy rainfall due to active to vigorous monsoon conditions during South-West monsoon (June to October) without or in association of depressions formed in the Bay of Bengal and moving inlands and also during North-East monsoon months (Oct-Dec).

The annual rainfall over the project varies between 1900 mm to 7420 mm, 87% of which occurs during South-West monsoon months. The maximum one hour recorded rainfalls are 100 mm at Trivandrum and 70 mm at Castle rock. The one day maximum rainfall of 445 mm was recorded at Linganamakki which falls in the project catchment.

On the scrutiny of the long term (1901-85) daily rainfall data of the stations of the region located in and around the project catchment, the following storm events were identified.

TABLE:2

Sl.No.	Storm date	Storm centre	2 days rainfall (mm)
1	5-7 Aug 1914	Khanapur	564
2	28-30 June 1959	Agumbe	519
3	5-6 July 1959	Nagar town	803
4	17-18 July 1961	Castle rock	618
5	20-22 June 1975	Jog P colony	682
6	15-16 June 1978	Kudal	870
7	22-23 July 1983	Bakkod	805

10.0 STORM ANALYSIS

The depth - area - duration (DAD) analysis of the selected heavy storms was carried out. DAD values for Sharavathi complex are shown in table:

TABLE :3

DAD VALUES FOR VARIOUS STORM EVENTS

Sl.No.	Storm event	Centre	2 day DAD value (mm)
1	August 1914	Khanapur	447
2	July 1959	Agumbe	548
3	June 1975	Jog P.Colony	462
4	June 1978	Kudal	467
5	July 1983	Bakkod	487

0.1 SELECTION OF DESIGN STORM

Out of the above storm events, the heavy storms of August 1914, July 1959 and July 1983 were transposed over the Sharavathi catchment, for a reasonable value. The 2 day transposed values along with appropriate Moisture Adjustment Factors (MAF) and the final Probable maximum precipitation (PMP) depths are shown in table.

TABLE:4

PMP DEPTHS FOR VARIOUS STORMS

Sl.No.	Storm event	Centre	2 day transposed value (mm)	MAF	PMP(mm)
1.	Aug 1914	Khanapur	413	1.15	475
2	July 1959	Nagar Town	481	1.17	563
3	July 1983	Bakkod	417	1.15	514

The heaviest storm is July 1959 storm centred at Nagar town and is accepted as the design storm. This storm was transposed over the project catchment with Linganamakki as the storm centre. The transposed storm centered for Linganamakki catchment is arrived as 497 mm (2 day rainfall depth)

10.2 MOISTURE ADJUSTMENT FACTOR

The MAF computations are based on dew point temperature data at Bijapur station for August 1914 storm and Managalore station for July 1959 storm. As the storms area and project area have similar orographic features, no barrier correction has been applied. The values of MAF thus compputed for August 1914 and July 1919 storm events are 1.15 and 1.17 respectively.

The PMP depth for Linganamakki for storm centered over Linganamakki catchment is arrived as 582 mm. This PMP value has been utilised for computing design flood hydrograph for the Linganamakki catchment.

10.3 SHORT TERM TIME DISTRIVUTION OF DESIGN STORM

TABLE:5
SHORT TERM DISTRIBUTION OF DESIGN STORM

Time (Hrs)	3	6	12	24	48
Percentage	19	33	49	73	100

11.0 DESIGN FLOOD

The Design storm for Linganamakki (582 mm) is distributed hourly using the time distribution suggested in table-5 hourly rainfall excess values have been obtained after deducting a loss rate of 1mm/hr and arranged in critical sequence tobe conducted with ug. The flood hydrographs obtained have been added with the constant base flow value at the rate of 0.15cumecs/sq.km.to get the final inflow hydrograph. The peak of the design flood hydrograph is 6701 cumecs for pre-reservoir condition and 14369 cumecs for post reservoir condition. This is the design inflow flood of Linganamakki reservoir. The flood hydrograph is annexed vide Plate: 3.

12.0 FLOOD IN THE YEAR 1980

During 1980, heavy floods were experienced in the Sharavathi basin, leading to damages downstream of Linganamakki dam, especially in the vicinity of Honnavar town which is the confluence of Sharavathi river with sea. Karnataka appointed a one man Committee to enquire into the causes of floods downstream of dam as well as to suggest measures to prevent recurrence of such floods by suitable routing at Linganamakki dam.

12.1. **REPORT OF THE ONE MAN COMMITTEE**

The Committee submitted a report to the Government of Karnataka wherein the major cause of the changes was indicated as below;

The flood of August 1980 was unusual and heavy in nature caused due to unprecedented rainfall intensity,both in the catchment of the reservoir and down below in the valley. The project staff at the site started regulation of the flood after the level built upto 559.92 m which is the FRL sof the reservoir and is not a standard practice.Some cushion should have been kept to absorb the flooods of such a heavy intensity as per the standard practice.

12.2. **REMEDIAL MEASURES SUGGESTED BY THE COMMITTEE**

The Committee has suggested number of remedial measures and the major remedial point suggested is as below:

12.2.1. Due provision for flood absorption should immediately be made for taking care of floods in excess of 3540 scumecs (1,25,000 cusecs) in Linganamakki dam.

12.2.2. Flood pplain zoning maps should be prepared indicating therein the extent of area covered by floods of various discharges.

12.2.3. An efficient flood forecasting system is to be built up.

12.2.4. An experienced hydrologist needs to be posted to project site.

12.2.5 To develop suitable guidelines for reservoir regulations.

12.2.6 Satisfactory arrangement for providing access to gate hoists installed over the piers to facilitate periodical inspection.

12.2.7 A few foot bridges at creeks connecting the islands for quick transportation of men and material during floods.

13.0. **ROUTING STUDIES**

Routing studies have been made for restricted outflow discharge of 3540 cumecs (1,25,000 cusecs) and to determine the reservoir levels at which the flood routing has commenced in order to utilise the full flood lift of 0.49m.above FRL of 559.92. The level of the reservoir for the commencement of rating for the above outflow discharge is EL 558.95m(1833.8')

An analysis was also made to determine the reservoir level at which the flood routing has to be started for an observed maxium flood of 6332 cumecs (2,23,615 cusecs). It was found that the level arrived at was EL 559.65m (RL 1836.12').

Since commencement of flood routing at very low levels may result in non filling of reservoir at the end of monsoons, there would be considerable loss of energy. Hence, the decision of commencement of reservoir routing has to be taken depending upon the rate of rise in Reservoir elevation, Month of occurrance of heavy rainfall weather forecast. A judicious decision depending on all the above parameters have to be made in order to ensure both safety of dam as well as Un-necessary spilling of waters from reservoir.

A review of design inflow of existing Linganamakki reservoir was made for dam safety purposes and for estimation of inflow flood of STR dam proposed downstream. The UG was developed by Clarks method. The design storm adopted was 582 mm and the design inflow flood value arrived was 14369 cumecs. During the year 1980 unprecedented floods occured in the catchment and an enquiry committee was apppointed for suggesting remedial measures for preventing recurrence of such floods d/s. The Committee suggested a number of remedial measures and major point was to restrict the routed flood at Linganamakki dam to 3250 cumecs. It may be seen that the flood occured after 1980 were having higher intensities. But due to careful reservoir operation, floods downstream have been controlled to safe disposal values.

BIBLIOGRAPHY

(i) CWC : "Estimation of Design flood -CWC recommended Procedure"

(ii) IS 11223: 1985

(iii) CWC : Note on Design flood studies of Sharavathi project.

PLATE - 1

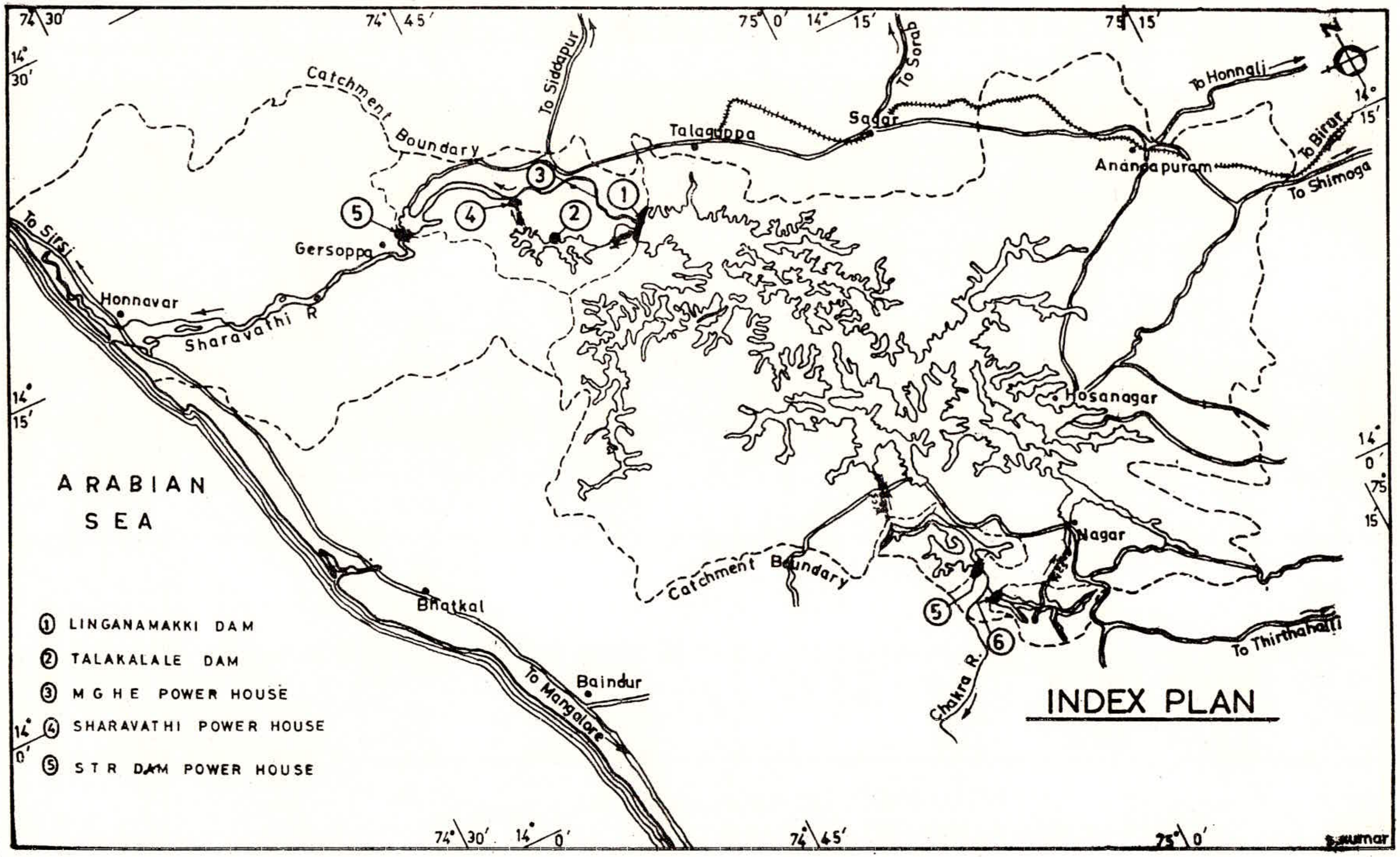

INDEX PLAN
ARABIAN SEA
Catchment Boundary
Catchment Boundary
To Siddapur
To Sorab
To Honnali
To Birur
To Shimoga
To Sirsi
To Mangalore
To Thirthahalli
Talaguppa
Sagar
Anandapuram
Hosanagar
Nagar
Gersoppa
Honnavar
Sharavathi R
Bhatkal
Baindur
Chakra R.
① LINGANAMAKKI DAM
② TALAKALALE DAM
③ M G H E POWER HOUSE
④ SHARAVATHI POWER HOUSE
⑤ S T R DAM POWER HOUSE

PLATE - 2

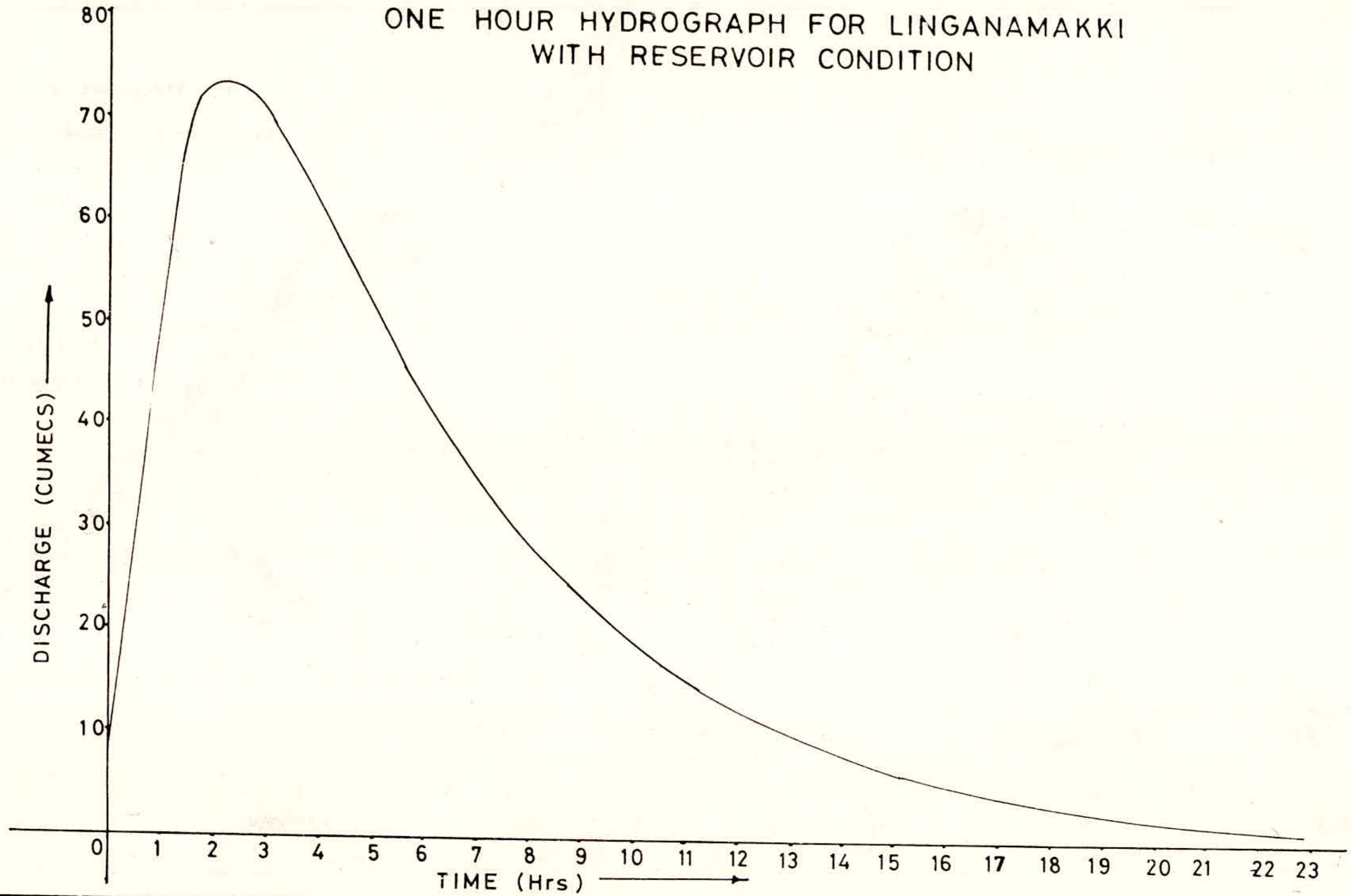
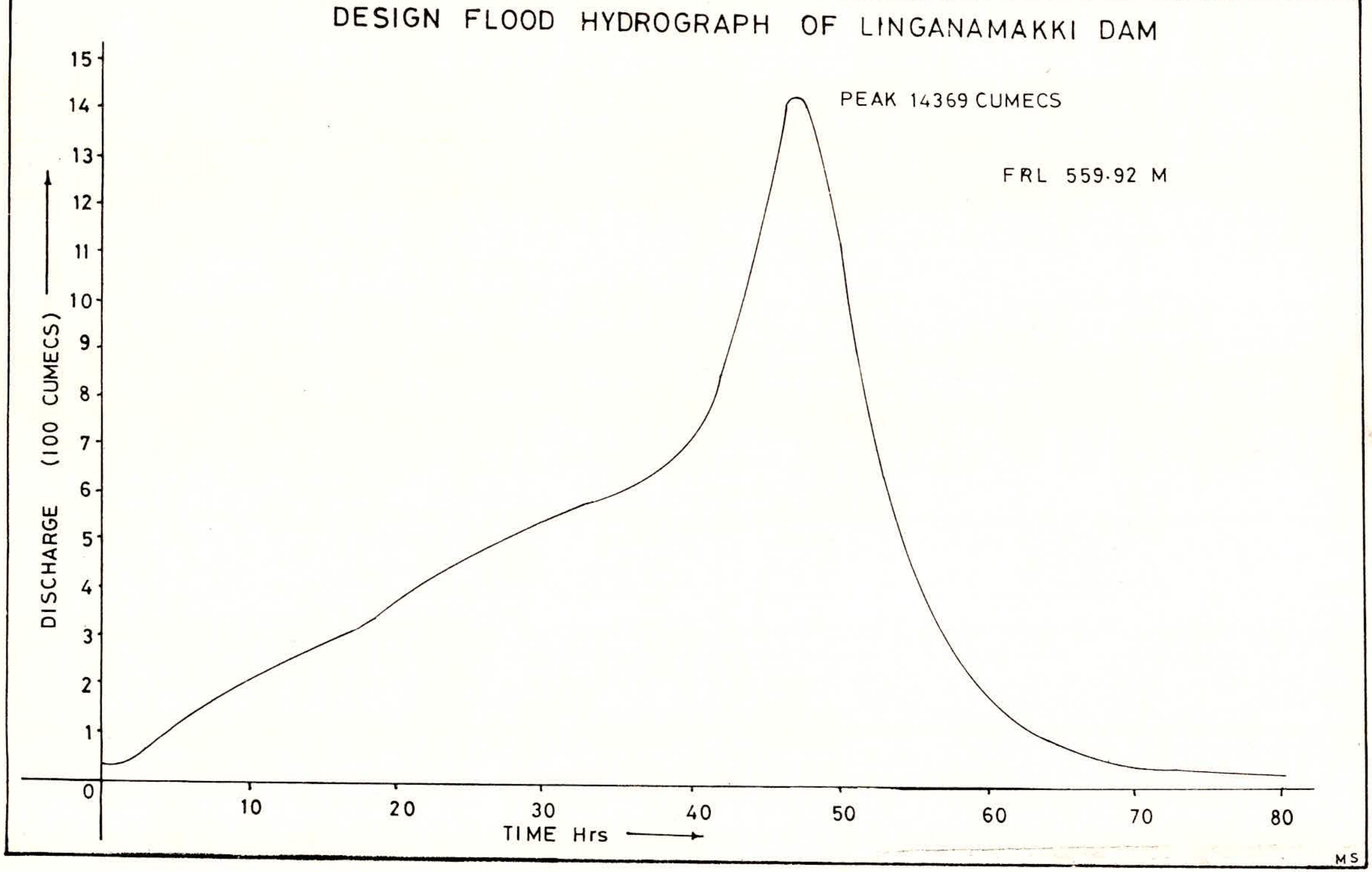

ONE HOUR HYDROGRAPH FOR LINGANAMAKKI
WITH RESERVOIR CONDITION
DISCHARGE (CUMECS)
TIME (Hrs)
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

PLATE - 3



DESIGN FLOOD HYDROGRAPH OF LINGANAMAKKI DAM
PEAK 14369 CUMECS
FRL 559·92 M
DISCHARGE (100 CUMECS)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
10
20
30
40
50
60
70
80
TIME Hrs
MS