अभिकल्प कार्यालय विवरण
DESIGN OFFICE REPORT
NO LG-3(f)/R-2/24/95

केन्द्रीय जल आयोग
CENTRAL WATER COMMISSION

निचली गोदावरी (उप अँचल–3 एफ)
का बाढ़ आँकलन विवरण
(परिशोधित)
FLOOD ESTIMATION REPORT FOR LOWER GODAVARI SUBZONE-3(f)
(REVISED)

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भूतल परिवहन मंत्रालय
का संयुक्त कार्य
A JOINT WORK OF
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INDIA METEOROLOGICAL DEPTT.
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STANDARDS ORGANISATION
MINISTRY OF TRANSPORT

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FLOOD ESTIMATION REPORT FOR LOWER GODAVARI

SUBZONE 3(f)

(REVISED)

A METHOD BASED ON UNIT HYDROGRAPH PRINCIPLE

DESIGN OFFICE REPORT NO. LG-3(f)/R-2/24/1995

HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
CENTRAL WATER COMMISSION
NEW DELHI

Flood Estimation Report for Lower Godavari subzone 3(f) (revised) was discussed and approved by the following Members of Flood Estimation Planning and Co-ordination Committee in its 53rd meeting held on 18th April, 1995 at Central Water Commission, New Delhi.

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FOREWORD

Estimation of flood of various return periods for design of waterways and foundations of bridges and culverts having small and medium catchments , where hydrological data are inadequate or totally absent , is extremely difficult. In such a situation, regional method based on Hydrometeorological approach involving use of synthetic unit hydrograph and design storm of specific return period has been adopted. For this purpose, the country has been divided into 26 Hydrometeorologicaly homogeneous subzones and 21 Flood estimation reports covering Hydrometeorological studies for 24 subzones have been published from time to time .

In addition to above, there is also periodic revision of such subzonal reports, whenever extra data sets become available and sophisticated analysis becomes due. The Flood estimation report of Lower Ganga Plains subzone 1(g) has been revised on these lines and published in 1995.

The present report is a revision of the Flood estimation report of Lower Godavari subzone 3(f),published in 1980 . The report gives the method to compute design flood of 25/50/100 year return period for ungauged catchments located in Lower Godavari subzone.

The report is a joint effort of Central Water Commission (CWC), India Meteorological Department (IMD) and Research Design and Standard Organisation (RDSO) of Ministry of Railways .

I would like to place on record my appreciation of the cooperative efforts of the officers and staff of the three organisations in bringing out this report.

New Delhi

29th May, 1995.

(A.B.Joshi)

Member (Designs & Research)

PREFACE

Design engineers essentially need the design flood of a specific return period for fixing the waterway vis-a-vis the design HFL and foundation depths of bridges, culverts and cross drainage structures depending on their life and importance to ensure safety as well as economy. A casual approach may lead to underestimation or overestimation of structure or uneconomic structure with problematic situation.

The use of empirical flood formulae like Dickens, Ryves, Inglis etc. has no such frequency concept, though has the simplicity of relating the maximum flood discharge to the power of catchment area with constants. These formulae do not take into account the basic meteorological factor of storm rainfall component and other physiography and hydraulic factors varying from catchment to catchment. Proper selection of constants in these empirical formulae is left to the discretion of design engineer, involving subjectivity.

Recognising the need to evolve a method for estimation of design flood peak of desired frequency, the committee of engineers headed by Dr. A.N. Khosla had recommended, in their report that the design discharge should be maximum flood on record for a period not less than 50 years. Where adequate records are available extending over a period of not much less than 50 years, the design flood should be 50 years flood determined from probability curve on the basis of recorded floods during the period. In case, where the requisite data as above are not available, the design flood should be decided on the ground and meteorological characteristics obtained on the basis of design storms necessitating the systematic and sustained collection of hydro-meteorological data at selected catchments in different climatic zones of India.

Economic constraints do not justify detailed hydrological and meteorological investigations at every new site on a large scale and on a long term basis for estimation of design flood with a desired return period. Regional flood estimation studies thus become necessary for hydro-meteorological regions in the country. Broadly, two main regional approaches namely flood frequency and hydrometeorological approaches are open for adoption depending on the availability of the storm rainfall and flood observations for the representative catchments for subjecting to statistical analysis to develop a regional flood frequency model. The other approach needs concurrent storm rainfall and run-off data of the representative catchments over a period of 5 to 10 years to develop representative Unit hydrographs of the catchments located in the region, so that synthetic unit hydrograph may be obtained for the region (subzones) and long term rainfall records at a large number of stations to develop design storm values. This approach has been adopted in the preparation of flood estimation reports under short term and long term plan.

Under short term plan, the report on estimation of design flood peak utilising hydromet data available for 60 bridge catchments, spread throughout the country, was brought out in 1973, wherein the method has been recommended for estimating the design flood peak for catchment areas ranging from 25 to 500 sq km. in the country.

Under long term plan, country has been divided into 26 hydro-meteorological homogenous subzones. For preparing the flood estimation reports for these subzones, systematic and sustained collection of hydrometeorological data at the representative catchments,numbering 10 to 30, for a period of 5 to 10 years in different subzones has been carried out in a phased manner by different zonal railways since 1965 under the supervision and guidance of Bridges and Flood Wing of Research Design and Standards Organisation of Ministry of Railways. Similarly, the Ministry of Transport had undertaken the collection of data for 45 catchments through Central Water Commission since 1979.

Regional Hydrology Studies Dte. CWC carries out analysis of selected concurrent rainfall and flood data for the gauged catchments to derive unit hydrographs of mostly one hour duration on the basis of rainfall data, gauge and discharge data collected during the monsoon season. Representative unit hydrographs are obtained for each of the gauged catchments. The characteristics of the catchments and their unit hydrographs, prepared for several catchments in a subzone are correlated by regression analysis and the equations for synthetic unit hydrograph for the subzone are derived for estimating design flood for ungauged catchments. Studies are also carried out by the CWC to arrive at suitable recommendations for estimating loss rate and base flow for ungauged catchments.

India Meteorological Department conducts depth-duration - frequency analysis of rainfall for each subzone to provide hydrometeorological input for estimation of design flood.

The subzonal reports incorporating studies carried out by CWC and IMD are prepared and published by CWC on approval of Flood Estimation Planning and Coordination Committee(FEPCC).

So far, following 21 flood estimation reports (FERs) covering 24 subzones have been published :

1.	Lower Ganga Plains subzone 1(g)*	(1978)
2.	Lower Godavari subzone 3(f)**	(1981)
3.	Lower Narmada & Tapi subzone 3(b)	(1982)
4.	Mahanadi subzone 3(d)	(1982)
5.	Upper Narmada & Tapi subzone 3(c)	(1983)
6.	Krishna & Penner subzone 3(h)	(1983)
7.	South Brahmaputra subzone 2(b)	(1984)
8.	Upper Indo-Ganga Plains subzone 1(e)	(1984)
9.	Middle Ganga Plains subzone 1(f)	(1985)
10.	Kaveri Basin subzone 3(i)	(1986)
11.	Upper Godavari subzone 3(e)	(1986)
12.	Mahi & Sabarmati subzone 3(a)	(1987)
13.	East Coast subzones 4(a), (b) & (c)	(1987)
14.	Sone subzone 1(d)	(1988)
15.	Chambal subzone 1(b)	(1989)
16.	Betwa subzone 1(c)	(1989)
17.	North Brahmaputra subzone 2(a)	(1991)
18.	West Coast Region subzone 5(a) & (b)	(1992)
19.	Luni subzone 1(a)	(1993)
20.	Indravati subzone 3(g)	(1993)
21.	Western Himalayas zone 7	(1994)

* Revised report published
** Present report is revision of this report

Hydrometeorological input in the FERs at serial number 1 to 7 were based on SRRG data alone and consisted of i) isopluvial maps for 24 hour and/ or shorter durations corresponding to 50 year return period ii) Time distribution of storm rainfall and iii) Point to areal rainfall ratios. However in the subsequent reports, IMD modified the methodology and prepared the hydrometeorological input based on conjuective use of ORG and SRRG data. The hydrometeorological components included i) isopluvial maps of 24-hour rainfall corresponding to 25, 50 and 100 year return periods ii) short duration ratios to convert 24-hour storm rainfall into rainfall of short duration storm iii) Time distribution of storm rainfall and iv) point to areal rainfall ratios. The FER for Lower Ganga Plains - subzone 1(g), published in 1974 has already been revised where the hydrometeorological input has been included as per revised methodology.

Present report is the revision of the flood estimation report of Lower Godavari subzone 3 f (report no LG/3/1980) and deals with the estimation of flood of 25 year, 50 year and 100 year return period for small and medium catchments in the subzone . It covers parts of area of the river Godavari in the States of Madhya Pradesh , Maharashtra, Andhra Pradesh and Orissa .

The rainfall-runoff data of 27 catchments for a period of 5 years during the period 1958 to 1978. was collected by the Railways . Data of 22 catchments for 132 bridge years found suitable was utilised in study carried out earlier. In the present study , additional of 22 bridge years for 5 catchments , collected subsequently alongwith the data of 132 bridge years has been used for UG study .

The storm study has been conducted by IMD. The rainfall data of 305 O.R.G. stations maintained by IMD and State Governments,41 S.R.R.G stations maintained by IMD in and around the subzone has been utilised in the study. Short duration data (hourly/ half hourly rainfall) of 65 stations in 13 bridge catchments of the subzone maintained by RDSO was not utilised for the storm studies because of fairly dense network of IMD"s SRRG data.

The report covers six parts. Part I of the report Introduction " gives the summary of the earlier and revised studies. Description of the subzone detailing river system, rainfall, temperature and types of the soil is given in Part II. Part III brings out the SUH relations to be used for ungauged catchments in the subzone. The storm studies carried out by the IMD are dealt in Part IV of the report. Criteria and standards in regard to design flood of structures and procedures to compute the design flood of ungauged catchments are described in Part V along with an illustrative example. Part VI highlights the limitations, assumptions and conclusions.

The report on subzone (3f)is recommended for estimation of design flood for small and medium catchments varying in areas from 25 to 1000 sq.km. This report may also be used for catchments having areas upto 5000 sq.km, judiciously after comparing the neighbouring catchments having more or less similar characteristics. For catchments of areas less than 25 sq.km., the method given in the Report No. RBF - 16 published by RDSO may be used.

The method adopted and conclusions arrived at, are subject to periodical review and revision in the light of adequate data being collected and analysed and also the advancements in theory and technique.

This report is a joint effort of Hydrology (Regional Studies) Dte., Central Water Commission of Ministry of Water Resources, India Meteorological Department of Ministry of Science and Technology and Research Design Standard Organisation, Ministry of Railways .

(R.V. GODBOLE)
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JAN,95

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SYMBOLS AND ABBREVIATIONS

SYMBOLS

As far as possible well recognised letter symbols in the hydrological science have been used in this report. The list of symbols adopted is given with the units.

A	Catchment Area in km^2.
ARF	Areal Reduction Factor.
C.G.	Centre of Gravity
Cumecs	Cubic metres per second
cms	Centimetres
D_{i-1}, D_i	Depths between the river bed profile (L-section) based on the levels of (i-1) and ith contours at the inter-section points and the level of the base line (datum) drawn at the point of study in metres.
E.R.	Effective Rainfall in cms.
Hr	Hour
H(RS),CWC	Hydrology (Region Studies) Directorate, Central Water Commission, New Delhi.
I.M.D.	India Meteorological Department
In	Inches
Km	Kilometres
L	Length of longest main stream along the river course in km
L_c	Length of the longest main stream from a point opposite to centroid of the catchment area to the gauging site along the main stream in km.
L_i	Length of the ith segment of L-section in km.
M.O.S.T.	Ministry of Surface Transport (Roads Wing).
M	Metres
Min	Minutes

mm	Millimetres
Q_p	Peak Discharge of Unit Hydrograph in cubic metres per second.
Q_{25}, Q_{50} and Q_{100}	Flood Discharge with return periods of 25-yr, 50-yr and 100-yr respectively in cumecs
q_p	Peak Discharge of Unit Hydrograph per unit area in cumecs per sq. km.
R_{25}, R_{50} and R_{100}	Point Storm Rainfall Values for 25-yr, 24-hour 50-yr 24-hour and 100-yr 24-hour return periods respectively in cm.
R.D.S.O	Research Designs & Standards Organisation (Ministry of Railways), Lucknow.
S	Equivalent stream slope in m/km.
S.U.G	Synthetic Unit Hydrograph
S.R.H	Surface Runoff Hydrograph
D.R.H	Direct Runoff Hydrograph
Sec	Seconds
Sq	Square
Sq.km	Square Kilometres, Km2
T	Time Duration of Rainfall in hours
T_B	Base Width of Unit Hydrograph in hours
T_D	Design Storm Duration in hours
T_m	Time from the start of rise to the peak of Unit Hydrograph in hours

PART - I

INTRODUCTION

Lower Godavari subzone 3(f) is one of the 26 hydrometeorological homogeneous subzones into which the country has been divided for developing the regional methodology for estimating the design flood of small and medium catchments. Annexure-1.1 shows various subzones into which the country has been divided. General description of the subzone is given in Part- II of the report.

The flood estimation report (FER) of Lower Godavari subzone (Design Office Report No. LG/3/1980) was published in 1981. The present report is the revision of the report.

The earlier report contained inputs for estimating the design flood of 50 year return period flood, whereas the present report provides inputs for estimating design flood of 25, 50 and 100 year return period.

1.1 Need for revision of report

Hydrometeorological input in 7 FERs viz.1(g) 2(b), 3(b), 3(c), 3(d), 3(f) and 3(h) were based on SRRG data alone and consisted of i) isopluvial maps for 24 hour and/or shorter durations corresponding to 50 year return period ii) Time distribution of storm rainfall and iii) Point to areal rainfall ratios. However, in the subsequent reports, IMD modified the methodology and prepared the hydrometeorological input based on conjunctive use of ORG and SRRG data.

FEPCC in its 51st meeting decided to revise these reports in a phased manner and include isopluvial maps of 24 hour rainfall corresponding to 25, 50, 100 year return periods ii) short duration ratios to convert 24 hours storm rainfall into rainfall of short duration storm iii) time distribution of storm rainfall and iv) point to areal rainfall ratios.

It was also decided by the FEPCC to review and revise the hydrological study contained in the reports utilizing additional rainfall-runoff data collected subsequent to the preparation of the reports.

The FER of Lower Ganga Plains subzone 1(g) has been revised and the revised report (No. LG-1(g)/R-1/23/94) has been published, as decided by the FEPCC. Present report is a revision of FER of Lower Godavari subzone 3(f), published in 1981 and includes hydrometeorological study as per the revised methodology and hydrological study with updated rainfall-runoff data .

1.2 Revised study

Hydrological and storm study contained in the earlier report and in the revised report are as under:-

1.2.1 Hydrological study

The hydrological study carried out earlier was based on rainfall-runoff data of 22 catchments for a period of 5 years during the period 1959 to 1978. Representative unit hydrographs of 1 hr duration were derived. The equations relating unit hydrograph parameters and basin parameters were developed for deriving 1-hr synthetic unit hydrograph.

Subsequent to the preparation of the earlier report, additional data in respect of 2 key gauging stations (875 and 15) for a period of 10 to 12 years from 1979 to 1992 and 3 sites (224, 161 and 65) for a period of 2 - 3 years was made available by RDSO. This data has been utilised in the present study .

Equivalent slope has been considered as one of the physiographic parameters in the revised study in place of statistical slope.

Recommendations regarding the suitable values of loss rate and base flow have also been revised considering additional data

The hydrological study carried out by CWC to derive relationships between physiographic parameters and unit hydrograph parameters for obtaining SUG for the ungauged catchments with the known physiographic parameters is given in Part-III of the report.

1.2.2 Storm study

The published report contained isopluvial maps of 50 year return period for different durations, time distribution curves and areal to point rainfall ratios.

The revised report includes the hydrometeorological components i) isopluvial maps of 24-hour rainfall corresponding to 25, 50 and 100 year return periods ii) short duration ratios to convert 24-hour storm rainfall into rainfall of short duration storm iii) time distribution of storm rainfall and iv) point to areal rainfall ratios.

The revised study is based on the rainfall data of 305 ORGs maintained by IMD and State Govts. and 41 SRRG stations maintained by IMD.

The storm studies carried out by IMD are given in Part-IV of the report.

1.3 Procedure to estimate design flood

The flood estimation report for subzone 3(f) may be used for estimation of design flood of 25 / 50/ 100 year return period of the structures in ungauged or inadequately gauged catchments in the subzone. Part- V explains procedure for obtaining the design flood of specified return period alongwith an illustrative example.The limitations, assumptions and conclusions have been explained in Part- VI of the report.

PART - II

GENERAL DESCRIPTION OF SUBZONE

2.1 Location

Lower Godavari subzone extends from Longitudes 76° to 83° east and Latitudes 17° to 23° north. The subzone is bounded by Upper Narmada and Tapi subzone 3(c) on the north and northwest, Upper Godavari subzone 3(e) on the west, Krishna and Pennar subzone 3(h) on the south, Upper eastern coast subzone 4(a) on the southeast, Mahanadi subzone 3(d) and Indravati subzone 3(g) on the east.

The region includes the States of Maharashtra, Madhya Pradesh, Andhra Pradesh and Orissa. Nagpur, Chandrapur, Wardha, Gondia, Nizamabad, Kazipet and Adilabad are some of the important cities and towns located in the subzone.

2.2 River system

Plate-1 depicts the river system in the subzone. The subzone is covered by the river Godavari (in its lower reaches) and its tributaries. The catchment area of the subzone is 1,74,201 km., which is 56% of the area of main Godavari basin. The subzone comprises of the sub basins of Muneru, Pengana, Wardha, Wainganga and Sabari.

The break-up of the area covered by above sub-basins and free drainage area is given below:

S.No.	Sub-basin	Area in sq.kms.
1.	Muneru	12,954
2.	Pengana	23,898
3.	Wardha	24,087
4.	Wainganga	61,093
5.	Sabari	20,457
6.	Free Drainage Area	31,712
	Total area	1,74,201

2.3 General topographical features

2.3.1 Topography and relief

Plate-2 depicts the general topography and relief of the subzone. The Lower Godavari subzone has a complex relief. Plains of medium heights upto 150 m exist near main Godavari river in its Lower reaches. Higher plains between heights of 150 to 300 m cover most of the upper reaches. The western part of the subzone and north of Nagpur is the zone of the low plateau in the range of 300 to 600 m. The southeast and northwest portions of the subzone cover high plateaus in the ranges of 600 to 900 m and there are hills and higher plateaus ranges from 900 to 1350 m in the southeastern part of the subzone.

2.3.2 Soils

Plate 3 shows the main soil classification in the subzone. The broad soil groups in the subzone are red soils and black soils. The red soils are of red sandy, red loamy and red yellow type. Black soils are of deep black, medium black and shallow black type. The black soils are clayey in texture. The texture of the red soils vary considerably from place to place.

2.3.3 Land use

Plate 4 gives the land use map of the subzone. More than 50% of the area is covered by forest. Arable land is of the order of 25%.

2.4 Climatological features (contributed by IMD)

2.4.1 Rainfall features

2.4.1.1 Annual normal rainfall

The isohyetal map of annual normal rainfall over the subzone is prepared (Plate-5) based on data of 291 stations of which 118 stations are inside and 173 stations outside the subzone. It may be seen from the map that the annual rainfall over major portions of the subzone is between 900 mm and 1600 mm. The annual rainfall is the lowest in the western and southwestern parts of the subzone and increases northeastwards and eastwards. The centres of low rainfall are around Chandur (809 mm) in district Amraoti of Maharashtra on the west and in around Siddipet in district Medak of Andhra Pradesh on the southwest. The centres of high rainfall are around Tamia (1787 mm) in district Chhindwara of M.P on the northwest, around Lanji(1857 mm) in district Balaghat of M.P.on the northeast and around Jeypore (1940 mm) in district Koraput of Orissa on the southeast.

2.4.1.2 Monthly rainfall distribution

Monthly rainfall distribution at six representative stations of the subzone viz. Lanji, Tamia, Jeypore, Wardha, Chandur and Siddipet is illustrated through bar charts appended to the annual normal rainfall map. In the bar charts alphabets along abscissa indicate names of months whereas heights of rectangles are proportional to normal rainfall of respective months. Figures at the top of each rectangle indicate the month's rainfall as percent of annual rainfall.

It can be seen from the bar charts that the main rainy season comprises of four months from June to September in the subzone. Total rainfall for monsoon season at Lanji, Tamia, Jeypore, Wardha, Chandur and Siddipet is respectively 91%, 90%, 86 %, 87%, 86% and 81% of the annual rainfall. Out of these four rainy months , the maximum rainfall is in the month of July at all the representative stations, except Jeypore where the maxium rainfall is in the month of August. The next rainiest month at these stations is August/July.

2.4.2 Temperature distribution

2.4.2.1 Mean daily temperature (annual)

Mean daily temperature distribution over the subzone (Plate - 6) has been prepared based on data of 27 stations (10 stations inside the subzone, 17 stations outside the subzone). The mean daily temperatures are worked out as average of mean maximum and mean minimum temperatures over the year. It may be seen from the map that mean daily temperatures are slightly below 23°c over southeastern parts of subzone in Koraput district in Orissa State and over northwestern parts adjoining Pachmarhi in M.P. The highest mean daily temperatures are slightly above 28°c over Karimnagar district of Andhra Pradesh. Major parts of the subzone experience mean daily temperatures between 25°c and 28°c.

2.4.2.2 Monthly temperature variation at selected stations

Monthly variations of maximum, minimum and mean daily temperatures for six representative stations viz., Chhindwara, Nagpur, Buldhana, Nizamabad, Ramagundam and Koraput are shown graphically in plate-6, below the map of mean daily temperatures. It may be seen from the diagram that the highest maximum temperatures are observed in the month of May at all the six stations viz., Nagpur (42.8° c), Ramagundam (42.8°c), Nizamabad (41.5°c), Chhindwara (39.4°c), Buldhana (38.3°c) and Koraput (34.1°c). Mean daily temperatures are also the highest in the month of May at all the six stations viz., Nagpur (35.6°c), Ramagundam (36.3°c), Nizamabad (34.6°c) Chhindwara (32.8°c), Buldhana (32.3°c) and Koraput (28.4°c). Minimum temperatures are observed in the month of December at all the six stations viz., Chhindwara (9.8°c), Koraput (11.3°c), Nagpur (12.1°c), Nizamabad (13.8°c), Ramagundam (15.0°c) and Buldhana (15.1°c).

2.5 Communications

2.5.1 Railway sections

The South Central, South Eastern and Central railway serve the area. Following Railway sections traverse through the subzone :

S.No.	Section	Gauge	Railway
1.	Bhilai-Nagpur	Broad Gauge	South-Eastern
2.	Nagpur- Basdnera	"	Central
3.	Nagpur- Amla	'	Central
4.	Wardha- Balharsha	"	South-Central
5.	Balharsha- Kazipet	"	South-Central
6.	Mukhed-Adilabad	Meter-gauge	South-Central

7.	Nainpur-Chindwara-Parasia	Narrow-gauge	South-Eastern
8.	Chindwara-Nagpur	"	South-Eastern
9.	Nagpur-Gondia-Chandrapur	"	South-Eastern

2.5.2 Road sections

The subzone is traversed by a dense network of State road ways.National Highway No. 7 connecting Hyderabad and Nagpur passes through the subzone.

PART-III

SYNTHETIC UNIT HYDROGRAPH STUDIES

3.1 Synthetic unit hydrograph (SUG)

Hydrometeorological approach has been adopted for developing a regional method for estimating design flood for small and medium catchments in various hydrometeorologically homogeneous subzones. In this approach, the design storm after converting it into effective rainfall (input) is applied to the unit hydrograph (transfer function) to obtain a design flood (basin response). It is possible to develop unit hydrograph if site specific concurrent rainfall runoff data is available for 3-4 years. Collection of adequate concurrent rainfall runoff data for every site, is however neither practicable nor economically feasible. In such a situation, the regional method for developing Synthetic unit hydrograph (SUG) is resorted to.

The SUG in the present study is a unit hydrograph of unit duration for a catchment developed from relations established between physiographic and unit hydrograph parameters of the representative gauged catchments in hydrometeorlolgically homogenous region (subzone). Data collected and analysed for obtaining subzonal SUG equations are discussed in succeeding paragraphs.

3.2 Data required

For conducting the unit hydrograph studies for development of equations for derivation of SUG, following concurrent rainfall and runoff data for a number of catchments of small and medium size, representatively located in a subzone are required for a period of 5 to 8 years during the monsoon season:

i) Hourly gauge data at the gauging site (bridge site)

ii) Gauge and discharge data observed 2 to 3 times a day at the gauging site.

iii) Hourly rainfall data of raingauge stations in the catchment. Raingauge stations may be self-recording and /or manually operated.

Following catchment details are also required.

iv) Catchment area plans showing the river network, location of raingauge stations and gauge and discharge sites, contours, roadway and railway network, natural and man made storages, habitations, forests, agricultural and irrigated areas, soils etc.

v) Cross-sections of the river at bridge site (gauging site), upstream and downstream of the bridge site.

vi) Longitudinal section of the river upstream and downstream of the bridge site.

3.3 Data collected

Southeastern, Central and Southcentral railways had observed and collected data for a period of 5 years at 27 railway bridge catchments during 1959-78. The data of 148 bridge years were available for hydrological studies contained in the earlier report.

Additional data for 22 bridge years for 5 bridge sites shown below were collected by RDSO subsequent to the preparation of the report and furnished to CWC .

No.	Site	Additional data	Bridge years
1.	224	1979	01
2.	65	1979	01
3.	161	1976-79	04
4.	875*	1982-92	11
5.	15*	1982-86	05

* Key gauging stations and rainfall and discharge observations are continued .

Annexure 3.1 shows the name of the stream, railway bridge No., railway section, catchment area, no.of rain gauge stations and period of availability of rainfall-runoff data of 27 bridge catchments. This also includes additional data of 5 catchments, collected subsequent to the preparation of the report. It can be seen from the Annexure 3.1 that the catchment area of gauge sites lie between 35 to 824 sq. km.

3.4 Derivation of synthetic unit hydrograph

procedure to obtain physiographic parameters and unit hydrograph parameters of the catchments and establishing relationships between these parameters to derive SUG is described in the following paragraphs.

3.4.1 Physiographic parameters

The physiographic parameters considered in the present study are catchment area (A) , length of main stream (L) , length of the main stream from a point near the centre of gravity of catchment to the bridge site (Lc) and equivalent slope (S) . These are indicated in Figure -1 and explained in the following paras.

3.4.1.1 Catchment area(A)

The gauging site is located on a toposheet and the watershed boundary is marked. The area enclosed in this boundary upto the gauging site may be referred to as the catchment area.(A)

3.4.1.2 Length of the main stream (L)

This implies the longest length of the main river from the farthest watershed boundary of the catchment area to the gauging site.

3.4.1.3 Length of the main stream from a point near the centre of gravity of catchment to the bridge site (Lc)

For finding the centre of gravity of the catchment, usually the boundary of the catchment is cut on a card board, which is then hung in three different directions in vertical planes and the plumb lines are drawn from the point of hanging. The point of intersection gives the centre of gravity of the catchment. The stream may or may not pass through the centre of gravity but the nearest point to the centre of gravity is considered to find the length of the main river from the centre of gravity to the point of study. (Lc)

3.4.1.4 Equivalent stream slope (S)

One of the physiographic parameters is slope. The slope may be equivalent or statistical . In the present study equivalent stream slope has been used for developing the SUG relations in place of statistical slope, used in the previous study, the statistical slope was considered. Equivalent slope can be computed by the following methods.

(a) Graphical method

Longitudinal section (L-section) of the main stream was prepared from the values of the contours across the stream or the spot levels near the banks with respect to their distances from the point of interest on the L-section such that the areas of the L-section (profile) above and below the line are equal. This line is called equivalent stream slope line.

(b) Analytical method

L-section is broadly divided into 3 to 4 segments representing the broad ranges of the slopes of the segments and the following formula is used to calculate the equivalent slope (S) :

$$S = \frac{\sum L_i \left(D_{i-1} + D_i\right)}{(L)^2}$$

Where Li = Length of the ith segment in km.

D_{i-1} D_i = Elevations of river bed at ith intersection points of contours reckoned from the bed elevation at points of interest considered as datum and D(i-1) and Di are the heights of successive bed location at contour and intersections.

L = Length of the longest stream as

Physiographic parameters A, L, Lc and S obtained for 22 catchments found suitable for analysis are shown in Annexure 3.2

3.4.2 Unit hydrograph parameters

3.4.2.1 Scrutiny of data and finalisation of gauge– discharge rating curve

Out of the 27 gauged catchments, data of 22 catchments (132 bridge years) were found suitable for the unit hydrograpph study contained in the earlier report.

The additional data of 5 catchments, viz. 875,15, 65, 161 and 224 for the period of 22 bridge years was available for revising the unit hydrograph study. These catchments are amongst 22 catchments, considered in the earlier study. The additional data of these catchments were scrutinized and gauge and discharge rating curve(s) were drawn on log-log scale. The hourly discharges for the duration of the selected floods were obtained from the rating curves.

3.4.2.2 Selection of floods and corresponding storm events

In Previous study, 200 flood events in 22 catchments were found suitable for UG study. 33 flood events shown in Table 3. were found suitable from the additional data collected for Bridge No. 875, 15, 224 and 161 on the basis of guidelines given below which were also followed in earlier study.

i) The flood should not have unduly stagnant water levels.

ii) The selected flood should result from significant rainfall excess not less than 1 cms.

No flood was found suitable in the additional data collected for Bridge No. 65.

Table 3.1
(Selected flood events from 4 catchments)

No.	Site	From data utilised earlier	From additional data	Total
1	2	3	4	5
1.	875	11	21	32
2.	224	12	03	15
3.	15	8	07	15 ~~07~~
5.	161	5	02	07

3.4.2.3 Computation of hourly catchment rainfall

As there is no change in raingauge net-work in the 4 catchments, the hourly rainfall values for these catchments for different flood events were obtained using station weights computed in the earlier study.

3.4.2.4 Computation of the hourly direct runoff depth

The selected flood events of 4 bridge catchments were plotted on the normal graph paper. The base flow was separated through the normal procedure to obtain direct surface runoff hydrographs and the hourly direct runoff depth over the catchment was computed for each flood event.

3.4.2.5 Computation of Infiltration loss (ϕ-index) and 1-hour effective rainfall units

With the known values of 1-hour catchment rainfall and the direct runoff depth for each flood event, the infiltration loss (constant loss rate) by trials was estimated for selected flood events of 4 Bridge catchments viz. 875,15,224 and 161.

3.4.2.6 Derivation of 1-hour unitgraph

1-hour unitgraphs were derived for each catchment for the selected flood events from rainfall excess hyetograph corresponding direct runoff hydrographs.

3.4.2.7 Drawing of representative unitgraphs and measuring their parameters

The representative unitgraphs (RUG) of 4 catchments were derived utilising UGs for flood events selected from earlier data and UGs obtained for flood events from the additional data as given in Col. 3 & 4 of Table 3.1 respectively. Integrated RUGs of 4 sites have been tested on observed floods. RUGs of remaining 18 sites developed earlier were utilised as such without any modifications.

Following parameters of RUGs of 22 catchments (shown in Fig.- 2) are furnished in Annexure 3.3.

a) Time from the centre of unit rainfall duration to the peak of unit hydrograph in hours (tp).

b Peak discharge of unit hydrograph in cubic meters per second (Qp). This is the product of peak discharge per sq km (qp) and catchment area (A).

c) Base width of unit hydrograph in hours (TB).

d) Width of unit hydrograph measured at discharge ordinate equal to 50% of Qp in hours (W50).

e) Width of the UG measured in hours at discharge ordinate equal to 75% of Qp (W75).

g) Width of the rising side of UG measured in hours at discharge ordinates equal to 50% of Qp (WR50).

h) Width of the rising side of UG measured in hours at discharge ordinate equal to 75% of Qp (WR75).

i) Time from the start of rise to the peak of the unit hydrograph (Tm). This is the summation of tp and 0.5 * tr.

3.4.3 Establishing relationships between physiographic and unit hydrograph parameters

Linear and non-linear equations were tried for establishing the relationship between UG parameters and physiographic parameters of the catchments and non-linear equation as described below was found to be the best fit.

$$Y = C * X^{P} \quad \text{.........................3.4.3.1}$$

where

Y = Dependent variable
X = Independent variable
C = Constant
P = Exponent

Various relationships attempted are shown in Annexure 3.4. The relationship between computed parameter L * Lc / $S^{0.5}$ and UG parameter tp was found to be significant. Unit peak discharge ofthe U.G.(qp) was related to tp. UG Parameters W50, W75, WR50, WR75 were related to qp . The UG parameter TB could be significantly correlated to tp.

The relationships derived are given in Table 3.2.

Table 3.2
(Derived relations)

Sl.No.	Relationship	Equation No.
1.	$tp = 0.348\ (L*Lc/S)^{0.454}$	3.4.3.2
2.	$qp = 1.842\ (tp)^{-0.804}$	3.4.3.3
3.	$W50 = 2.353\ (qp)^{-1.005}$	3.4.3.4
4.	$W75 = 1.351\ (qp)^{-0.992}$	3.4.3.5
5.	$WR50 = 0.936\ (qp)^{-1.047}$	3.4.3.6
6.	$WR75 = 0.579\ (qp)^{-1.004}$	3.4.3.7
7.	$TB = 4.589\ (tp)^{0.894}$	3.4.3.8
8.	Tm = tp + tr/2	3.4.3.9
10.	Qp = qp * A	3.4.3.10

Relations developed are shown in Figures 3 to 9. List of catchment and unit hydrograph parameters studied to establish relationships and co-efficients of correlations is given in Annexure-3.4.

The above relationships are recommended to estimate the parameters of 1-hour Synthetic unitgraph for an ungauged catchment with known physiographic characteristics A, L, Lc and S.

3.4.4 Derivation of 1-hour synthetic unit hydrograph for an ungauged catchment

Considering the hydro-meteorological homogeneity of subzone the relations established between physiographic and unitgraph parameters in section 3.4.3 are applicable for derivation of 1- hour Synthetic unitgraph for an ungauged catchment in the subzone.

The steps for derivation of 1-hour unitgraph are:

i) Physiographic parameters of the ungauged catchment viz A, L, Lc and S are determined from the catchment area plan.

ii) Obtain tp, qp , W50 , W75, WR50, WR75 and TB substituting appropriate basin / unit hydrograph parameters given in equation 3.4.3.2 to 3.4.3.10

iii) Plot the parameters of 1-hour unitgraph viz Tm, TB, Qp, W50, W75, WR50 and WR75 on a graph paper as shown in illustrative Figure 2 and sketch the unitgraph through these points.

Sum of discharge ordinates of tr-hr Unitgraph is obtained and compared with the value found by using the following equation

$$\sum Q_i = \frac{2.78\ A}{tr}$$

Where Q_i = discharge ordinates at 1-hour interval (cumecs)

A = Catchment duration in,sq.km.

tr = Unit duration in hours.

Suitable modifications can be made in falling limb upto W50 points, and a smooth Unitgraph be drawn.

3.5 Design loss rate

Direct surface runoff is the end product of storm rainfall after infiltration into surface soils, sub-surface and ground besides abstractions like evaporation, evapotranspiration, soil moisture and filling up of surface depressions. It is difficult, rather impossible , to record these various parameters at various representative locations in the catchment except by the analysis of observed storm rainfall and flood events. Conversion of gross storm rainfall units into effective rainfall units for application to unitgraph is normally done by subtraction of constant loss rate (Ø-index) for the catchment, even though the loss rates in the catchments, a complex phenomena, vary due to soil conditions, soil cover and topography alongwith temporal and spatial variations of storm rainfall.

· The loss rate (cm/hr) values computed for 233 flood events for 22 Bridge catchments including 33 flood events selected from additional data of 4 Bridge catchments are tabulated in Annexure 3.5. Loss rate is recommended as 0.2 cm/hour as loss rate value of 125 flood events lie in the range of 0.1 to 0.4 cm/hour. The designer can modify this value as per local conditions.

3.6 Design base flow

Base flow values for 182 flood events tabulated in different ranges are shown in Annexure 3.6. Out of 182 flood events,119 ·flood events fall under the range of 0.01-0.10 cumecs/sq Km. Base flow rate of 0.05 cumecs/sq..km. may be adopted for estimating base flow for a catchment. The designer may however any other suitable value as per site conditions.

PART- IV

RAINFALL STUDIES

4.1 Introduction

4.1.1 The India Meteorological Department (IMD) has conducted detailed rainfall studies for the subzone. The study covers Depth-Duration-Frequency analysis of available daily/Short duration rainfall data in and around the subzone. The Design Storm components have been derived in the form of (i) 25, 50 and 100-year 24-hour isopluvial maps, (ii) 24 hours to short duration (1 to 23 hours) rainfall ratios, (iii) Time distribution curves for storms of various durations (2 to 24 hours) and (iv) Point to areal rainfall ratios for specific durations (1, 3, 6, 12 and 24 hours). The methodology applied for analysis of each component and the procedure for design storm estimation is discussed in the subsequent paras.

4.1.2 The results of the study serve as basic input for design flood estimation for small and medium catchments.

4.2 Data collected

The following rainfall data for a large number of stations in and around the zone for as long a period as possible have been collected for the purpose of this study.

4.2.1 Ordinary raingauge (ORG) data (daily rainfall) of 305 stations, 16 maintained by IMD and 289 maintained by the State Governments, in 36 districts - 10 in Madhya Pradesh, 12 in Maharashtra, 12 in Andhra Pradesh and 2 in Orissa - covering the subzone with 30 districts partly/fully outside the subzone. Of these, 178, 64 and 63 stations have respectively 51-70 years', 31-50 years' and 11-30 years' record. This was necessary in order to cover the areas where the raingauge network is sparse.

4.2.2 Self recording raingauge (SRRG) data (hourly rainfall) of 41 stations maintained by IMD in 24 districts - 10 in Madhya Pradesh, 8 in Maharashtra and 6 in Andhra Pradesh. Of these 21,.12, 2 and 6 stations have respectively 14-20 years' (370 station years), 8-13 years' (125 station years), 5-7 years' (11 station years and 2-4 years' (17 station years) data. Of these 41 stations, 15 lie inside the subzone; 12 of them having data for 8 years or more.

4.2.3 Concurrent short duration (hourly/half-hourly) rainfall data, conforming to the requirement of 3 stations and 4 years in a bridge catchment, of 65 stations in 13 bridge catchments in the subzone, specially maintained by RDSO for varying periods during 1960-1992.

4.3 Data used

ORG data mentioned in para 4.2.1 above available from IMD's National Data Centre have been extensively utilised for preparation of 25, 50 and 100-year isopluvial maps.

SRRG data have been collected from 41 stations (523 station years) of which 15 fall inside and the remaining 26 lie outside the subzone within about half a degree of its boundary. The data available being vast, appropriate subsets of the data have been utilised for working out different components.

The bridge catchment data mentioned in para 4.2.3 procured from RDSO specifically for deriving point to areal rainfall ratios were not used because of fairly dense network of IMD's SRRG data was available which provides a better scientific method for this purpose than the RDSO data as was explained in Flood Estimation Report for subzone - 1(g).

4.4 Depth-Duration-Frequency Analysis

4.4.1 Isopluvial maps

For each of the 305 ORG stations in and around the subzone a series of annual maximum one-day rainfall was generated. The 305 station series thus formed were subjected to frequency analysis using Gumbel's extreme value distribution for computing one day rainfall estimates for 25, 50 and 100-year return periods. These daily rainfall estimates (305x3) were converted into any 24-hour rainfall estimates by using the conversion factor of 1.15. For each return period, the 24-hour estimates for 305 stations were plotted on a base map and isopluvials were drawn. The isopluvial maps of 25, 50 and 100-year 24-hour rainfall are shown in Plates 7, 8 and 9 respectively, which can be used to derive 24-hour rainfall estimates for specific return periods at any desired location in the subzone.

4.4.2 Short duration ratios

For each of the 12 SRRG stations inside the subzone having at least 8 years' record, the hourly rainfall data were subjected to frequency analysis using partial duration series for computing Tyear t-hour rainfall estimates for T = 2, 5, 10, 25 and 50 years and t = 1, 3, 6, 9, 12, 15, 18 and 24 hours. These estimates (12x8x5) were converted into ratios with respect to the corresponding 24-hour estimates. Average ratios (8x5) for the subzone as a whole (mean of 12 stations ratios) were then computed for each T-year t-hour pair. It was noticed that for a specified duration t, the average ratios beyond T=5 years were comparable in magnitude. As such the average ratios (8)

corresponding to 10-year t-hour rainfall have been recommended to be adopted uniformly for converting 24-hour rainfall into t-hour rainfall. The 8 conversion ratios for t=1, 3, 6, 9, 12, 15, 18, and 24 hours given below were plotted on a graph and a smooth curve was drawn as shown in graph at Fig. 10 which can be used to derive conversion ratios for any duration t in general, including the intermediate duration (see table alongside graph)

Rainfall Duration (t) in hours	Conversion ratio = 10-year t-hour rainfall / 10-year24-hour rainfall
1	0.320
3	0.520
6	0.650
9	0.730
12	0.790
15	0.850
18	0.910
24	1.000

Any 25, 50 or 100-year 24-hour point rainfall in the subzone as read from isopluvial maps in Plates 7, 8 and 9 can be converted into corresponding 25, 50 or 100-year t-hour rainfall by multiplying with t-hour ratio as read from the curve in Figure 10.

4.4.3 Time distribution curves

Based on hourly rainfall data of all the 15 SRRG stations inside the subzone a total of 2705 rainstorms of durations ranging from 2 to 24 hours were analysed and grouped stationwise into the following 5 categories :

1) rainstorms of 2 to 3-hour duration (518 of all stations)

2) rainstorms of 4 to 6-hour duration (722)

3) rainstorms of 7 to 12-hour duration (834)

4) rainstorms of 13 to 18-hour duration (343)

5) rainstorms of 19 to 24-hour duration (288)

For each station , 5 different graphs corresponding to each group of rainstorms were prepared by plotting the cumulative percentage of the total storm rainfall against percentage of the storm duration and the average time distribution curves (15x5) were drawn. Average time distribution curves (5) for the subzone as a whole were then drawn by plotting 15 station curves on the same graph and these are shown in Figure 11, which can be used to derive the time distribution coefficients of storm rainfall in the subzone for rainstorms of any duration (see Annexure 4.1).

4.4.4 Point to areal rainfall ratios

In the present study, the availability of a fairly dense SRRG network in the subzone and its surrounding area made it possible to adopt the best scientific procedure for deriving point to areal relationship based on SRRG data alone in preference to bridge data. The hourly rainfall records of 22 SRRG stations (5 inside the subzone and 17 outside) were scanned for short durations t =1, 3, 6, 12 and 24 hours to select t-hour representative storms based on consideration of maximum central value and concurrent surrounding data indicating an appreciable gradient. Isohytal maps of 5 representative storms described hereunder were then prepared using concurrent rainfall values of stations corresponding to the date and time of each representative storm.

Duration (hour)	Representative Storm			
	Station	Rainfall (mm)	Date & time of occurrence (clock hour)	concurrent data (No of stations)
1.	Harrai	59.8	25.7.79(18-19)	4
3.	Daryapur	31.0	28.8.77(15-18)	5
6.	Akola	40.5	2.9.81(15-21)	6
12.	Chikalda	80.2	3.10.77(3-15)	6
24.	Yeotmal	202.0	4-5.8.81(20-20)	7

By planimetering each isohyetal map around the storm centre and plotting the percentage ratios of areal rainfall depths to representative point rainfall against the areas, the best fit curves (5) were drawn as shown in graphs at Figure 12(a) and 12(b), which can be used to derive the percentage areal reduction factors for converting point rainfall of any duration in the subzone into corresponding areal rainfall for any particular small catchment in the subzone (Annexure 4.2).

4.5 Heaviest rainfall records

4.5.1 ORG data

The highest ever recorded one-day station rainfall (24 hours' rainfall ending 0830 hrs of date) along with date of occurrence in each of the 36 districts covering subzone- 3(f) have been compiled from the ORG data and presented in Annexure 4.3. However, in case of districts with stations recording > 35 cm. all such stations have been included.

4.5.2 SRRG data

The heaviest storm rainfall in durations of 24, 12, 6, 3 and 1 hour alongwith date and time of occurrence in each of the 24 districts covering all the 41 SRRG stations have been compiled from the available autographic records and are presented in Annexure 4.4.

4.6 Procedure for design storm rainfall estimation

For a specified design storm duration TD hour (time of concentration) for a particular bridge catchment in the subzone, the design storm rainfall and its temporal distribution in the catchment can be computed by adopting the following procedure :

Step-1 : Locate bridge catchment under study on the 50-year, 24-hour isopluvial map in Plate 8 and obtain the 50-year 24-hour point rainfall value in cm. For a catchment covering more than one isopluvial, compute the average point rainfall.

Step-2 : Read the conversion ratio for storm duration TD from Fig.10 and multiply the 50-year 24-hour point rainfall in Step-1 to obtain 50-year TD-hour point rainfall.

Step-3 : Read the areal reduction factor corresponding to storm duration TD and the given area of catchment from Fig.12(a)/12(b) or Annexure 4.2 and multiply the 50-year TD-hour point rainfall in Step-2 by this factor to obtain the 50-year TDhour areal rainfall over the catchment.

Step-4 : Read the time distribution co-efficients for 1,2,......(TD-1) hours corresponding to storm duration TD from relevant graph in Fig.11 or Annexure 4.1 and multiply the 50-year TD-hour areal rainfall in Step-3 by these co-efficients to obtain the cumulative depths of 1,2....(TD-1) hour catchment rainfall.

Step-5 : Obtain the depths of storm rainfall occurring every hour in the bridge catchment by subtraction of the successive cumulative depths of 1,2....(TD-1) and TD hours in Step-4.

PART-V

DESIGN FLOOD ESTIMATION

5.1 Criteria and standards in regard to design flood of Structures of small and medium catchments

The Khosla Committee of Engineers had recommended a design flood of 50-year return period for fixing the water way of the bridges. The committee had also recommended to design the foundation and protection work for larger discharge by increasing the design flood for waterways by 30% for small catchments up to 500 sq. km., 25 to 20% for medium catchments upto 500 to 5000 sq km., 20 to 10% for large catchments upto 5000 to 25000 sq. km. and less than 10% for very large catchments above 25000 sq. km.

Criteria and standards followed for design flood for bridges, cross drainage structures and small dams are given below:-

a) Indian Railway Standard Bridges substructures and foundation Code revised in 1985 stipulates that all bridges shall be designed with adequate waterway for design discharge. This shall normally be the computed flood with probable recurrence interval of 50 years. However, at discretion of Chief Engineer/Chief Bridge Engineer, if a bridge is likely to have severe consequences, it may be designed for floods with a probable recurrence interval of more than 50 years, while bridges on less important lines or sidings may be designed for floods with a probable recurrence interval of less than 50 years.

b) Indian Road Congress - IRC 5-1985, clause 103 of Section I "General Features of Design" Specifies that the water way of a bridge is to be designed for a maximum flood safety, the foundation and protection works should be designed for larger discharge. The recommended percentage increase over the design discharge specified in clause 103 is same as suggested by the committee of Engineers.

c) Indian Standard Code of "Practice for design of cross drainage works-IS: 7784 Part I 1975" recommends that the water way for cross drainage works should be designed for a 25 yr return period flood. To provide adequate margin of designed for larger discharges. The percentage increase over the design discharge recommended in the code is same as suggested by the committee of Engineers.

d) Central Water Commission's criteria of 1968 specifies that the diversion dams and weirs should be designed for floods of frequency of 50-100 yrs.

e) Indian Standards Guidelines for "fixing spillway capacity of dams under clauses 3.1.2 and 3.1.3 of IS; 11223-1985" recommends 100 yr return period flood as inflow design flood for small dams having either gross storage of the dam between 0.5 and 10mm or hydraulic head between 7.5m. and 12m.

5.2 Estimation of design flood

To obtain design flood of required return period the effective rainfall for design storm duration is to be applied to the unit hydrograph of a catchment. Procedure for computing design flood peak and design flood hydrograph for T year return period by SUG approach is as under:

a) Computation of design flood peak

Step-1 Synthetic unit hydrograph

Derive the synthetic Unit hydrograph as per section 3.4.4 and tabulate 1 hour U.G. ordinates.

Step-2 Design storm duration

The duration of storm, which causes maximum flow in a river at a specified location is called "Design Storm Duration". The SUG of 22 catchments have been derived using the parameters computed from recommended equations givenin Table-3.4. Annexure 5.1 shows the computed parameters . The excess rainfall increments for different storm durations TD=1.1*tp and TD= TB have been obtained for 25,50 and 100 year return period and applied on SUGs derived to obtain the flood peaks of 25,50 and 100 year return period. The computed flood peaks are shown in Annexure 5.2. It is seen from the Annexure 5.2 that maximum flood peak has been obtained using the storm duration as 1.1 * tp for nearly all the catchments.

It is therefore, recommended to adopt the value of TD as 1.1 * tp. The design engineer may adopt the value of TD as 1.1 * tp or any other value which gives the maximum value of discharge.

Step-3 Design storm rainfall.

i) Adopt suitable design storm duration(td) as explained in Step 2.

ii) Obtain design storm rainfall and hourly areal rainfall units vide section 4.6.

iii) Adopt design loss rate as recommended in section 3.5

iv) Obtain hourly effective rainfall increments by subtracting the design loss rate.

Step-4 Design flood peak:-

i) Arrange 1 hour effective areal rainfall values against the 1 hour U.G. ordinates such that the maximum value of effective rainfall against the maximum ordinate of U.G., the next lower U.G. ordinate and so on upto T hour duration.

ii) Obtain the base flow for the catchment area under study vide section 3.6 iii). Total surface runoff is obtained by summing the product of unit hydrograph ordinates as tabulated in Step 3 (iv).

iv) Obtain flood peak by adding base flow to total surface runoff as per step 4 (iii).

b) Design flood hydrograph

For computation of design flood hydrograph, carry out the steps from 1 to 3 and in addition, carry out the following steps.

Step-5 Reverse the sequence of effective rainfall units obtained in Step 4(i) to get the critical sequence of the effective rainfall units.

Step-6 Multiply the first 1 hr effective rainfall with the ordinates of U.G. to get the corresponding direct runoff ordinates. Likewise, repeat the procedure with the rest of the hourly effective rainfall values giving a lag of 1 hr to successive direct runoff ordinate.

Step-7 Add the direct runoff ordinates at 1 hour interval to get total direct runoff hydrograph.

Step-8 Add the base flow in Step 4(ii) to the direct runoff ordinates at 1 hour interval in Step 7 to get the 50 year flood hydrograph.

5.2.1 Illustrative example

An example, taking bridge number 269 as ungauged catchment has been worked out for illustrating the procedure to compute 50 year design flood. The catchment plan is enclosed at Fig. A-1.

The particulars of the catchment under study are as follow:

i)	Name of subzone	Lower Godavari
ii)	Name of Tributary	Wirur
iii)	Name of Rail section	Kazipet - Ballarshah
iv)	Shape of catchment	Leaf
v)	Location	Lat 19° - 39' Long 79° - 26'
vi)	Topography	Moderate slope

Procedure is explained stepwise.

Step-1 Physiographic parameters.

Physiographic parameters obtained are given below

1) Area (A) {refer Fig. A-1.1} 242 sq km

2) Length of the longest stream (L) 27.70 km

3) Length of the longest stream from a point opposite to C.G. of catchment to point of study (Lc) 11.2 km

4) Equivalent stream slope (S) (refer Annexure. 5.3) 3.87 m/ km

Step-2 1 hr synthetic unitgraph

Synthetic unitgraph parameters as given below were computed using equations in para 3.4.3.

---

tp = 3.50 hr

qp = 0.67 cum/km.

W50 = 3.50 hr

W75 = 2.00 hr

WR50= 1.42 hr

WR75= 0.86 hr

TB = 14. 06 hr

Qp = 162.81 cumecs

Estimated parameters of unitgraph in step 2 were plotted on a graph paper as shown in fig. A-2. The plotted points were joined to draw synthetic unitgraph. The discharge ordinates (Qi) of the unitgraph at ti=1 hr interval were summed up and multiplied by ti (=1) and compared with the volume of 1.00 cm direct runoff depth. over the catchment, computed from the runoff depth over the catchment, computed from the formula Q = A x d /ti x 0.36

Where A = Catchment area in Sq. km.

d = 1.0 cm depth

ti = 1 hr.

$$Q = \frac{A * d}{0.36 * ti} = \frac{242 * 1}{0.36 * 1} = 672 \ m^3/s$$

Note: (In case, <Qiti for the unitgraph drawn is higher or lower than the volume of 1 cm., the falling limb of hydrograph may be suitably modified without altering the points of synthetic parameters.)

Step-3 Estimation of design storm

(a) Design storm duration

The design storm duration (TD) has been adopted as 1.1 *tp as this value of storm duration gave higher value of flood peak (refer step 2, section 5.2). Rounding of the design storm duration to nearest hour, its value came as 4 hrs.

(b) Estimation of point rainfall and areal rainfall for storm duration

Catchment under study was located on Plate 8 showing 50 year 24 hr point rainfall. The point rainfall was found to be 24.00 cm. The conversion factor of 0.575 was read from Figure-10 to convert the 50 year -24 hour point rainfall to 50 year -24 hour areal rainfall (since TD = 4 hrs). 50 year-4 hr point rainfall was 13.80 cm.

Areal reduction factor of 0.813 corresponding to the catchment area of 242 sq. km. for TD = 4 hour was interpolated from Annex. 4.2 or Fig.12(a) for conversion of point rainfall to areal rainfall. 50 year-4 hr areal rainfall thus worked out to be 11.21 cm.

The 50 year-4 hour areal rainfall was split in to 1 hour rainfall increments using time distribution coefficients given in Annexure 4.1 or Figure 11.

A design loss rate of 0.20 cm/hr as recommended in para 3.5 was applied to get effective rainfall hyetograph.

The Table 1 given below gives the hourly effective rainfall increments.

Table — 1
(Hourly effective rainfall increments)

Duration	Distribution coefficient	Storm rainfall	Rainfall increments	Loss per hr	Effective rainfall increments
1	2	3 (cm)	4 (cm)	5 (cm)	6 (cm)
1	0.67	7.51	7.51	0.2	7.31
2	0.86	9.64	2.13	0.2	1.93
3	0.95	10.64	1.00	0.2	0.80
4	1.00	11.21	0.57	0.2	0.37

Step-4 Estimation of base flow

Taking design base flow of 0.05 cumecs per sq km as recommended in para 3.6, the base flow was estimated to be 12.10 cumecs for the catchment area of 242.00 sq. km.

Step-5 Estimation of 50 yr peak

(a) Computation of flood peak

For estimation of the peak discharge, the effective rainfall increments were re-arranged against ordinates such that the maximum effective rainfall is placed against the maximum U.G. ordinate, next lower value of effective rainfall against next lower value of U.G. ordinate and so on, as shown in col. (2) and (3) in Table 2. Sum of the product of U.G. ordinates and effective rainfall increments gives total direct surface runoff to which base flow is added to get total peak discharge.

Table-2

(50 year flood peak)

Time (hrs)	U.G. ordinate cumecs	1 hr. effec. rainfall (cms)	direct runoff (cumecs)
1	2	3	4
3	~~112.0~~ 110	0.81	89.10
4	~~161.7~~ 163	7.31	1191.53
5	~~126.6~~ 128	1.93	247.04
6	~~86.0~~ 84	0.37	31.08
		Total	1558.75
		Base flow	12.10
		Total	1570.85

(b) Computation of design flood hydrograph

Effective rainfall increments shown in col. (3) of Table 2 in Step 5 were reversed to obtain critical sequence as shown below:

Table-3
(Critical sequence of rainfall)

Time in hrs.	Critical 1-hr effective rainfall sequence in cms
1	0.37
2	1.93
3	7.31
4	0.81

For computation of design flood hydrograph, the U.G. ordinates were tabulated in col (2) of Annexure 5.4. The critical sequence of effective rainfall increments were entered in col.3 to 5 horizontally. Direct runoff resulting from each of the effective rainfall depths with the synthetic U.G. ordinate in col.(2) and direct runoff values were entered in columns against each unit with a successive lag of 1 hr since the unit duration of S.U.G. is 1 hr. Direct runoff values are shown in col (3) to (6). Direct runoff values were added horizontally and total direct runoff is shown in col. (7). Adding total base flow of 12.10 m3/sec. (col.8), design flood hydrograph ordinates (col 9) were obtained. Design Flood Hydrograph was plotted against time as shown in Fig. A-3. The peak obtained was ~~1560.85~~ 1570.85 m3/s which tallies with the peak shown in Table-2.

5.3 Computation of design H.F.L.

The Design engineer has to determine the design high flood Level corresponding to adopted design flood for the bridges and cross drainage structures under natural and constricted conditions. This elevation is very important in the analysis for foundations, scour, free board, formation levels, hydraulic forces etc.

Stage discharge relationship is represented by stage vs. discharge rating curve of a river at the point of study. The most acceptable method for establishing stage discharge rating curve is based on observed gauges and discharges covering satisfactorily the lower to upper elevation ranges. Stage discharge relation defines the complex interaction of channel characteristics including cross sectional areas, shape, slope and roughness of bed and banks. The permanent stage discharge relation is a straight line or a combination of straight lines on a logarithmic plotting depending on the channel configuration; a single straight line for a single well defined channel and a combination of two straight lines for the main channel with its firm portions. The stage discharge relation may be considered more accurate depending on the reliable and adequate observed gauge and discharge data of the river at the point of study. The gauge discharge rating curve so determined may be used for fixing the design HFL corresponding to design flood by extrapolation if necessary.

In the absence of observed gauge and discharge data at the point of study (bridge or cross-drainage structures location), synthetic gauge discharge rating curve has to be constructed by Area-Velocity Method, using the river cross section, slope data and nature of the cross-section. The velocity is computed by the Manning's formula.

Computation of HFL is generally done with the help of Manning's formula in which roughness coefficient ('N') is an important factor affecting the discharge of a river or Nalla. The value of N is highly variable and depends on a number of factors. viz, surface roughness, vegetation, channel irregularity, channel alignments, silting and scouring, obstruction, size and shape of channel, stage and discharge, seasonal change and suspended material and bed load.

The various values of the roughness co-efficient for different types of channel are given in Table 5.6 "Open Channel Hydraulics" by Ven-Te-Chow.

The above procedure pertains to determination of design HFL corresponding to design flood of a river under natural conditions. With the type of structures in position there will generally be a constriction in the waterway. The affect of the constriction by way of raising the design HFL under natural conditions. The difference between upstream and downstream water levels corresponding to design flood due to constriction in the waterway may be termed as afflux. There are hydraulic methods for working out the final design HFL due to constriction by the structure. The weir formula or orifice formula of hydraulics is generally used depending on the upstream and downstream depths to estimate the revised design HFL under constricted conditions.

Sometimes it happens that the cross section of river or nalla on the downstream side of a cross drainage structure may be narrow than the cross section at the location of a crossing site.

The flood levels at the proposed structure may also be affected by the high flood levels in the main river joining downstream in proximity of the stream. In such cases, there will be backwater effect due to the narrow gorge of the river as the design flood for the crossing site will not be able to pass through the narrow gorge in the downstream. There will, therefore, be heading up of water in its upstream side which ultimately affects HFL of the river at the crossing site. In the latter case the tributary/stream on which the bridge is located will be under the influence of the backwater effect of the main stream joining downstream. In such cases backwater study may be carried out.

In the absence of any observed levels of water profiles for computing hydraulic gradient, bed gradient of nalla may be considered, after verifying that local depressions are not accounted for and bed gradient is computed on a reasonable length of atleast 300m. upstream and downstream of the crossing site.

If the crossing site is located across the river/drainage in the unfavorable reach i.e. not complying with the usual requirements of gauge site, the design flood elevation may be computed in a straight reach downstream of the crossing and design flood elevation may be worked out by undertaking backwater studies.

PART-VI

ASSUMPTIONS, LIMITATIONS AND CONCLUSIONS

6.1 Assumptions

It is assumed that 50-year return period storm rainfall produces 50- year flood. Similar is the case for 25- year and and 100-year flood.

A generalised conclusion regarding the base flow and loss rate are assumed to hold good during the design flood event.

6.2 Limitations

The method would be applicable for reasonably free catchments with interception, if any, limited to 20% of the total catchment. For calculating the discharge the total area of the catchment has to be considered.

The generalised values of base flow and loss rate have been assumed to hold good for the whole subzone. The designer may adopt other suitable values of base flow and loss rate as per site conditions.

The data of 22 catchments have been considered for developing a generalised approach. However, for more reliable results , the data of more catchments uniformly distributed would be desirable.

6.3 Conclusions

The methodology for estimating the design flood of 50- yr return period incorporated in the body of the report is recommended for adoption, which also holds good for 25-yr flood and 100-yr flood.

The report also recommends the adoption of design flood of 25 year and 100 year return periods taking into account the type and relative importance of the structures.

The report is applicable for the catchment areas ranging from 25 sq. km. to 1000 sq. km. The report can also be used for large catchments upto 5000 sq km based on sound judgment and considering the data of neighbouring catchments also. However, individual site conditions may necesstiate special study. Engineer-in-charge at site is advised to take a pragmatic view while deciding the design discharge of a bridge.

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ANNEXURE I.1

LIST OF HYDRO-METEOROLOGICAL SUB-ZONE

SUBZONE	NAME OF SUBZONE (designated earlier)	Name of sub-zone (designated now)	River Basins included in the subzone
1(a)	Luni basin & thar (Luni & other rivers of Rajasthan and Kutch)	Luni	Luni river. Thar (Luni & Other rivers of Rajasthan and Kutch and Banas river)
1(b)	Chambal Basin	Chambal	Chambal river
1(c)	Betwa Basin & Other Tributaries	Betwa	Sind, Betwa and Ken rivers and other South Tributaries of Yamuna
1(d)	Sone Basin and Right Bank Tributaries.	Sone	Sone and Tons rivers and other South Bank Tributaries of Ganga.
1(e)	Punjab Plains including parts of Indus, Yamuna, Ganga and Ramganga Basins.	Upper Indo-Ganga Plains	Lower portion of Indus Ghaggar Sahibi Yamuna, Ganga and Upper portion of Sirsa, Ramganga, Gomti and Sai rivers.
1(f)	Ganga Plains including Gomti, Ghagra, Gandak, Kosi and other.	Middle Ganga Plains	Middle Portion of Ganga, Lower portion of Gomti, Ghagra, Gandak, Kosi and middle portion of Mahanadi
1(g)	Lower Ganga Plains including Subarnarekha and other east-flowing rivers between Ganga and Baitarani.	Lower Ganga Plains	Lower portion of Ganga, Hoogli river system and Subarnarekha.
2(a)	North Brahmaputra Basin	North Brahmaputra	North Bank Tributaries of Brahmaputra river and Balason river.
2(b)	South Brahmaputra Basin	South Brahmaputra	South Bank Tributaries of Brahmaputra river.
2(c)	Barak and others	Barak	Barak, Kalden and Manipur rivers.
3(a)	Mahi, including the dhadhar, Sabarmati and rivers of Saurashtra.	Mahi and Sabarmati	Mahi and Sabarmati including Rupen & Machha Bandar, Ozat Shetaranji rivers of Kathiawad Peninsula.

3(b)	Lower Narmada and Tapi Basin	Lower Narmada & Tapi	Lower portion of Narmada, Tapi and Dhadhar rivers.
3(c)	Upper Narmada and Tapi Basin	Upper Narmada & Tapi	Upper portion of Narmada and Tapi rivers.
3(d)	Mahanadi Basin including Brahmani and Baitarani rivers.	Mahanadi	Mahanadi, Baitarani and Brahmani rivers
3(e)	Upper Godavari Basin	Upper Godavari	Upper portion of Godavari Basin.
3(f)	Lower Godavari Basin except coastal region	Lower Godavari	Lower portion of Godavari Basin.
3(g)	Indravati Basin	Indravati	Indravati river.
3(h)	Krishna subzone including penner Basin except coastal region	Krishna	Krishna & Pennner rivers except coastal region.
3(i)	Kaveri & East flowing rivers except coastal region	kaveri	Kaveri, Palar and Ponnaiyar rivers (except coastal region).
4(a)	Circars including east flowing rivers between Mahanadi and Godavari	Upper Eastern Coast	East flowing coastal rivers between Deltas of Mahanadi & Godavari rivers.
4(b)	Coromandal Coast including east flowing rivers between Godavari and Kaveri	Lower Eastern Coast	East flowing coastal rivers, Manimukta, South Pennar, Cheyyar, Palar, North Pennar, Munneru, Palleru, Cundalakama and Krishna Delta.
4(c)	Sandy Coroman Belt (east flowing rivers between Cauvery & Kanyakumari).	South Eastern Coast	East flowing coastal rivers, Manimuther, Vaigani, Arjuna, Tamraparni.
5(a)	Konkan coast (west flowing river between Tapi and Panaji)	Konkan Coast	West flowing coastal rivers between Tapi and Maudavi rivers
5(b)	Malabar Coast (west flowing rivers between Kanyakumari and Panaji)	Malabar Coast	West flowing coastal rivers between Mandavi and Kanyakumari
6	Andaman and Nicobar	Andaman & Nicobar	
7	J & K Kumaon Hills (Indus Basin).	Western Himalayas	Jhelum, Upper portion of Indus, Ravi and Beas rivers

SUBZONE - 3(f)

LIST OF RAILWAY BRIDGE CATCHMENTS AND AVAILABILITY OF GAUGE & DISCHARGE AND RAINFALL DATA

Sl.No.	Name of Stream	Name of Section where bridge is located with Railway zone/Road Section	Railway bridge No./site No.	Gauging Site Location: Longitude Deg.	Longitude Min.	Latitude Deg.	Latitude Min.	Catchment area (sq.km)	No. of raingauge	Data avilability	No. of years
1	WUNNA	BADNERA-NAGPUR	807	20	54	79	01	824	5	1966-73	8
2	KAYADHU	AKOLA-PURNA	875*	19	40	77	10	750	6	1971-76,82-92+	17
3	WUNNA	BADNERA-NAGPUR	224	20	54	79	01	~~824~~ 750	5	1966-73,79+	8
4	NAHARA	NAINPUR-BALAGHAT	65	22	02	80	09	731	7	1975-78,79+	5
5		SAUSAR-SLONI	228	21	58	78	57	483	4	1966-73	8
6	MARUH	NAGPUR-NAGBHIR	15*	20	46	79	32	459	7	1966,68-74,82-86+	13
7	PANGOLI	RAIPUR-NAGPUR	184	21	28	80	14	364	4	1959-65	7
8	JAM	ITARSI-NAGPUR	604/973	21	20	78	34	341	9	1959-65	7
9	WIRUR	KAZIPET-BALLARSHAH	269	19	39	79	26	242	6	1959-60	2
10	KALD	WASHIM-PURNA	881	19	37	77	10	233	4	1969-73	5
11	KHADUKWAR	AMLA-NAGPUR	969	21	22	78	33	208	6	1968-74	7
12	BHAGI(N)	NAGPUR-GONDIA	57	21	14	79	23	163	8	1959,61-66	7
13	GORBDOHO	GONDIA-NAGBHIR	36	21	10	80	08	139	2	1974-78	5
14	WARDHA	ITARSI-NAGPUR	566/912	21	43	78	21	137	8	1958-65	8
15	KUMBHI	WARDHA-BALLARSHAH	494/795	20	30	78	51	120	2	1964-66	3
16	KHARKIM	RAIPUR-GONDIA	51	21	14	79	20	87	3	1965-74	10
17	BALLPHATA	TUMSAY-TIRODI	59	21	38	79	40	66	4	1961-64	4
18	KUIBAHERA	CHHINDWARA-BARKUHT	20	22	07	78	44	60	1	1961-67,69	8
19	PALAVAGU	KAZIPET-BALLARSHAH	161	18	57	79	28	54	2	1974-75,76-79+	6
20		NANDED-HIMAYAT NAGAR	4	19	09	77	33	50	1	1957-66	10
21			491	20	45	78	45	42		1959-62,64	5
22	Tri. of PEDDAVAGU	KAZIPET-BALLARSHAH	214	19	20	79	28	35	2	1964-69	6
23	WAINGANGA	NAINPUR-CHHINDWARA	28	22	23	79	25	3100	8	1966-71	8
24	JAM N.	ITARSI-NAGPUR	611	21	20	78	45	208	3	1966	1
25		MANMAD-SECUNDERABAD	500	19	33	78	25	106	1	1968-71	4
26	BEDDAMPET	KAZIPET-BALLAHARSHAH	230	19	33	79	25	93	4	1961-92	2
27	MADHAR	ITARSI-NAGPUR	595	21	30	78	30	71	1	1966	1

* Key gauging stations. + Additional data studied for revised studies. Data of bridges at Sl.no 23 to 27 not considered for UG analysis

SUBZONE - 3(f)

ANNEXURE - 3.2

PHYSIOGRAPHY PARAMETERS OF SELECTED CATCHMENTS

SL. No.	BRIDGE No.	AREA Sq.Km.	L Km.	Lc Km.	S M/Km.
1	807	824	61.08	22.54	1.24
2	875	750	60.00	29.00	1.77
3	224	750	61.00	23.80	1.19
4	65	731	57.36	23.35	6.99
5	228	483	41.80	17.70	3.68
6	15	459	33.10	8.40	1.28
7	184	364	35.20	12.90	0.67
8	604/973	341	45.95	20.40	1.84
9	269	242	27.70	11.20	3.87
10	881	233	24.10	10.10	1.53
11	969	208	25.00	6.80	2.96
12	57	163	29.00	15.30	1.23
13	36	139	23.00	8.50	~~3.34~~ 3.35
14	566/912	137	19.60	8.40	5.01
15	494/795	120	16.90	8.00	2.55
16	51	87	23.74	10.10	1.21
17	59	66	18.00	10.00	3.30
18	20	60	16.98	7.45	7.42
19	161	54	15.05	9.50	3.94
20	4	50	12.20	5.30	8.22
21	491	42	14.70	7.70	5.40
22	214	35	14.00	7.90	9.03

1- HOUR RUG PARAMETERS OF SELECTED CATCHMENTS

Sl.No.	BRIDGE No.	tp hr.	Qp cumecs	qp cumec/km	TB hr.	W50 hr.	W75 hr.	WR50 hr.	WR75 hr.
1	807	4.50	650.00	0.79	17.00	2.90	1.70	1.20	0.60
2	875	7.50	315.98	0.42	30.00	5.63	3.17	2.27	1.30
3	224	9.50	214.00	0.29	40.00	7.50	4.00	3.80	1.80
4	65	10.50	184.00	0.25	40.00	9.20	5.50	5.90	3.50
5	228	4.50	280.00	0.58	20.00	3.30	2.00	1.30	1.00
6	15	4.50	189.00	0.41	20.00	5.70	3.20	2.30	1.40
7	184	11.50	60.00	0.16	44.00	15.30	7.00	7.20	3.40
8	604/973	3.50	228.70	0.67	12.00	3.60	2.30	1.60	1.00
9	269	3.50	140.80	0.58	14.00	4.40	3.10	1.20	1.00
10	881	3.50	190.00	0.82	14.00	2.40	1.10	1.10	0.50
11	969	2.50	179.00	0.86	12.00	2.80	1.70	1.10	0.70
12	57	6.50	65.00	0.40	24.00	5.50	3.00	1.80	1.00
13	36	4.50	80.00	0.58	15.00	3.90	2.30	1.50	1.00
14	566/912	2.50	190.50	1.39	9.00	1.50	0.80	0.70	0.40
15	494/795	3.50	65.10	0.54	13.00	4.80	3.40	1.80	1.30
16	51	3.50	65.80	0.76	11.00	4.40	2.10	1.10	0.70
17	59	2.50	66.50	1.02	6.50	2.10	1.30	1.10	0.80
18	20	2.00	60.80	1.01	10.00	3.40	1.80	1.00	0.90
19	161	3.50	29.79	0.55	13.00	4.50	3.00	1.60	1.10
20	4	1.50	71.40	1.41	8.00	1.60	0.90	0.90	0.50
21	491	1.50	43.50	1.04	8.00	2.30	1.30	0.80	0.40
22	214	1.20	55.80	1.59	6.00	1.30	0.70	0.60	0.30

SUBZONE 3(f) ANNEXURE - 3.4

PHYSIOGRAPHIC AND UNIT HYDROGRAPH PARAMETERS STUDIED

Sl. No.	No. of samples	X	Y	A	B	r
1	22	$L*Lc/S^{0.5}$	tp	0.401	0.426	0.71
2	do	do	qp	3.578	-0.331	0.76
3 *	18	do	tp	0.348	0.454	0.93
4	do	do	qp	4.026	-0.332	0.83
5	22	L/S	tp	1.452	0.419	0.68
6	18	do	do	1.326	0.450	0.89
7	22	do	qp	1.345	-0.335	0.71
8	18	do	do	1.430	-0.349	0.76
9	22	$L/S^{0.5}$	tp	1.377	0.416	0.71
10	18	do	do	1.352	0.417	0.87
11	22	do	qp	2.207	-0.454	0.66
12	18	do	do	2.045	-0.406	0.67
13 *	18	tp	qp	1.842	-0.804	0.90
14	22	tp	W50	1.206	0.856	0.90
15 *	22	qp	do	2.353	-1.005	0.99
16	do	tp	W75	0.710	0.832	0.88
17 *	do	qp	do	1.351	-0.992	0.94
18	do	tp	WR50	0.449	0.922	0.86
19 *	do	qp	WR50	0.936	-1.047	0.95
20	do	tp	WR75	0.293	0.864	0.85
21 *	do	qp	WR75	0.579	-1.004	0.93
22 *	do	tp	TB	4.589	0.894	0.98

Note:
1. Equation is of the form of $Y = A * X^B$
2. Recommended relations for derivation of SUG are marked as " *"

SUBZONE - 3(f)

ANNEXURE-3.5

LOSS RATE RANGES (Cm/hr) OF OBSERVREVD FLOOD EVENTS

S.N.BR.NO.			807	875	224	65	228	15	184	604	269	881	969	57	36	566	494	51	59	20	161	4	491	214	
C.A. sq.km.			824.00	750.00	750.00	731.00	483.00	~~451.00~~ 459	364.00	341.00	242.00	233.00	208.00	163.00	139.00	137.00	120.00	87.00	~~65.00~~ 66	60.00	54.00	50.00	42.00	35.00	
LOSSRATE RANGES Cm/hr	LB	UB	NUMBER OF OBSERVED FLOODS																						TOTAL
1	0.00	0.20	-	16	7	11	-	3	2	-	1	1	-	-	-	-	2	-	1	2	-	15	5	9	71
2	0.20	0.40	6	11	1	1	2	1	3	3	1	1	1	2	1	-	4	2	3	3	4	-	-	-	50
3	0.40	0.60	-	2	2	-	2	3	-	2	-	2	1	2	2	-	1	1	2	3	-	-	-	-	25
4	0.60	0.80	-	2	-	-	2	3	3	2	1	-	-	2	2	-	1	-	-	1	1	-	-	-	20
5	0.80	1.00	2	1	1	-	2	2	-	1	-	-	-	1	2	2	-	1	1	-	-	-	-	-	16
6	1.00	1.20	1	-	2	-	1	1	1	-	2	-	-	-	-	1	1	-	-	-	-	-	-	-	10
7	1.20	1.40	1	-	-	-	-	1	2	1	-	-	1	-	4	-	-	1	-	1	-	-	-	-	12
8	1.40	1.60	-	-	-	-	-	-	-	-	-	1	-	1	1	-	1	1	-	1	1	-	-	-	7
9	1.60	and above	1	-	2	-	2	1	-	4	1	-	1	1	2	2	-	-	-	-	1	-	-	-	18

SUBZONE - 3(f)

BASE FLOW RANGES (CUMECS/ SQ KM) OF OBSERVED FLOOD EVENTS

BR.NO.			807	875	224	65	228	15	184	604	269	881	969	57	36	566	494	51	59	20	161	4	491	214	
C.A. sq.km.			824	750	750	731	483	~~451~~ 459	364	341	242	233	208	163	139	137	120	87	~~65~~ 66	60	54	50	42	35	
S.No	BASE FLOW RANGES Cumecs/sq.km. LB	UB	NUMBER OF OBSERVED FLOODS																						TOTAL
1	0.000	0.005	0	8	3	0	0	6	11	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	31
2	0.005	0.010	1	5	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	13
3	0.010	0.100	10	10	12	11	4	3	0	11	3	5	3	7	12	4	6	5	6	7	0	0	0	0	119
4	0.100	0.200	0	0	0	0	0	0	0	1	3	1	1	1	1	0	0	1	1	0	1	0	0	0	11
5	0.200	& Above	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	6	0	0	0	8
		Total	11	23	15	11	6	9	11	13	7	6	4	9	14	5	7	6	7	11	7	0	0	0	182

TIME DISTRIBUTION CO-EFFICIENTS (PERCENTAGE) OF CUMULATIVE HOURLY RAINFALL

INTER-MEDIATE HOURS	DESIGN STORM DURATION (HOURS)																							INTER-MEDIATE HOURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	100	89	78	68	62	57	48	44	40	38	37	35	31	28	27	26	25	24	23	22	21	20	19	18	1
2		100	94	87	81	76	67	64	60	57	55	50	45	43	41	39	38	37	34	33	32	31	30	29	2
3			100	96	92	87	80	75	72	69	66	64	56	53	51	49	48	46	44	42	41	40	38	37	3
4				100	97	94	88	85	80	77	74	72	65	62	59	58	57	55	52	50	49	48	46	44	4
5					100	98	94	91	87	84	81	79	73	70	67	65	63	62	59	58	56	55	53	51	5
6						100	97	95	92	90	87	85	78	75	73	70	69	67	65	63	62	61	59	58	6
7							100	98	96	93	91	89	83	80	78	75	74	72	69	68	66	65	64	62	7
8								100	98	96	94	92	87	85	83	80	78	76	73	72	70	69	68	66	8
9									100	98	96	95	91	88	86	84	82	80	77	76	74	73	71	70	9
10										100	98	97	94	91	89	87	85	84	81	79	77	76	74	73	10
11											100	99	97	94	92	90	88	87	84	82	80	79	77	76	11
12												100	99	97	95	93	91	90	87	85	83	82	80	79	12
13													100	99	97	95	93	92	89	88	86	85	83	81	13
14														100	99	97	95	94	91	90	88	87	85	84	14
15															100	99	97	96	93	92	90	89	87	86	15
16																100	99	98	95	94	92	91	89	88	16
17																	100	99	97	96	94	93	91	90	17
18																		100	99	98	96	95	93	92	18
19																			100	99	98	97	95	94	19
20																				100	99	98	97	96	20
21																					100	99	98	97	21
22																						100	99	98	22
23																							100	99	23
24																								100	24

AREAL REDUCTION FACTORS (%) FOR CONVERTING POINT RAINFALL TO AREAL RAINFALL

SUBZONE - 3(f)

CATCHMENT AREA (Sq.Km)	DESIGN STORM DURATION (HOURS) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	CATCHMENT AREA (Sq.Km.)
00	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	00
50	90.00	91.50	93.00	93.67	94.33	95.00	95.33	95.67	96.00	96.33	96.67	97.00	97.12	97.25	97.38	97.50	97.62	97.75	97.88	98.00	98.12	98.25	98.37	98.50	50
100	84.50	86.25	88.00	89.00	90.00	91.00	91.54	92.08	92.62	93.17	93.71	94.25	94.50	94.75	95.00	95.25	95.50	95.75	96.00	96.25	96.50	96.75	97.00	97.25	100
150	81.00	82.75	84.50	85.67	86.83	88.00	88.67	89.33	90.00	90.67	91.33	92.00	92.33	92.67	93.00	93.33	93.67	94.00	94.33	94.67	95.00	95.33	95.67	96.00	150
200	78.25	80.00	81.75	83.08	84.42	85.75	86.50	87.25	88.00	88.75	89.50	90.25	90.62	91.00	91.37	91.75	92.12	92.50	92.87	93.25	93.62	94.00	94.37	94.75	200
250	76.00	77.88	79.75	81.08	82.42	83.75	84.54	85.33	86.12	86.92	87.71	88.50	88.94	89.38	89.81	90.25	90.69	91.12	91.56	92.00	92.44	92.87	93.31	93.75	250
300	74.50	76.25	78.00	79.42	80.83	82.25	83.04	83.83	84.62	85.42	86.21	87.00	87.48	87.96	88.44	88.92	89.40	89.87	90.35	90.83	91.31	91.79	92.27	92.75	300
350			76.50	78.00	79.50	81.00	81.79	82.58	83.37	84.17	84.96	85.75	86.25	86.75	87.25	87.75	88.25	88.75	89.25	89.75	90.25	90.75	91.25	91.75	350
400			75.00	76.67	78.33	80.00	80.75	81.50	82.25	83.00	83.75	84.50	85.04	85.58	86.12	86.67	87.21	87.75	88.29	88.83	89.37	89.92	90.46	91.00	400
450			73.50	75.33	77.17	79.00	79.75	80.50	81.25	82.00	82.75	83.50	84.06	84.62	85.19	85.75	86.31	86.87	87.44	88.00	88.56	89.12	89.69	90.25	450
500			72.50	74.50	76.50	78.50	79.17	79.83	80.50	81.17	81.83	82.50	83.08	83.67	84.25	84.83	85.42	86.00	86.58	87.17	87.75	88.33	88.92	89.50	500
600												81.00	81.60	82.21	82.81	83.42	84.02	84.62	85.23	85.83	86.44	87.04	87.65	88.25	600
700												79.50	80.12	80.75	81.37	82.00	82.62	83.25	83.87	84.50	85.12	85.75	86.37	87.00	700
800												78.00	78.67	79.33	80.00	80.67	81.33	82.00	82.67	83.33	84.00	84.67	85.33	86.00	800
900												77.00	77.67	78.33	79.00	79.67	80.33	81.00	81.67	82.33	83.00	83.67	84.33	85.00	900
1000												76.00	76.69	77.37	78.06	78.75	79.44	80.12	80.81	81.50	82.19	82.87	83.56	84.25	1000
1100												75.00	75.71	76.42	77.12	77.83	78.54	79.25	79.96	80.67	81.37	82.08	82.79	83.50	1100
1200												74.00	74.73	75.46	76.19	76.92	77.65	78.37	79.10	79.83	80.56	81.29	82.02	82.75	1200
1300																								82.00	1300
1400																								81.40	1400
1500																								80.80	1500
2000																								78.00	2000

Statistics of heaviest daily rainfall & annual normal rainfall
(Recorded at 52 ORG stations)

	State/	Station	Heaviest ≥35 cm	Rainfall < 35cm	Date of occurrence	Annual normal Rainfall in cm
	1	2	3	4	5	6
	Orissa					
1.	Koraput	1. Pottangi	54.6	--	14.10.1931	160.1
2.	Kalahandi*	2. Bhawanipatna	--	31.1	02.07.1930	145.7
	Andhra Pradesh					
3.	Srikalulam*	3. Cheepurupalli	46.5	--	22.10.1870	106.3
		4. Salur	41.7	--	22.10.1870	112.0
		5. Itchapuram	35.1	--	19.11.1923	117.2
4.	East Godavari	6. Biccarole	43.2	--	20.10.1958	108.5
		7. Coringa	39.8	--	30.10.1902	115.1
		8. Alamuru	38.8	--	26.09.1908	108.9
		9. Ramachandrapuram	36.9	--	27.09.1908	108.1
5.	Vishakapatnam	10.Konada	38.7	--	18.11.1923	94.0
		11.Pallavaram	35.9	--	20.10.1958	91.5
		12.Viziagram	35.8	--	14.10.1931	105.5
		13.Yellamanchilli	35.6	--	22.10.1928	95.9
6.	West Godavari*	14.Talepalligudem	--	34.4	10.07.1954	104.9
7.	Adilabad	15.Asifabad	--	32.6	27.09.1891	100.3
8.	Karimnagar	16.Jactial	--	30.8	24.10.1939	95.6
9.	Medak	17.Sangareddy	--	30.7	27.09.1908	86.6
10.	Warangal	18.Hanamkonda	--	30.5	27.09.1908	99.8
11.	Khammam	19.Khammam	--	30.0	10.07.1954	95.9
12.	Nizamabad	20.Chintakunta	--	29.6	05.07.1958	115.7
13.	Nalgonda*	21.Nalgonda	--	20.5	27.08.1949	77.4
14.	Hyderabad*	22.Bolaram	--	18.7	28.09.1908	77.6
	Madhya Pradesh					
15.	Hoshangabad*	23.Pachmarhi	45.9	--	02.08.1913	207.5
		24.Seoni	37.6	--	03.07.1930	128.7
		25Makrai	36.7	--	03.07.1930	143.1
16.	Narsinghpur*	26.Narsinghpur	42.2	--	07.09.1891	121.3
		27.Mohpani	35.0	--	02.08.1913	138.0

1	2	3	4	5	6
17. Chindwara	28.Tamia	39.5	--	12.07.1942	178.7
18. Jabalpur*	29.Pariat	39.1	--	25.08.1952	146.2
	30.Jabalpur	--	34.3	30.07.1915	138.0
19. Balaghat	31.Palhera	36.8	--	22.08.1931	155.8
	32.Soletaka	35.0	--	16.07.1939	136.9
20. Mandla	33.Bichhia	35.9	--	21.09.1926	159.8
21. Durg	34.Donagarh	35.9	--	01.08.1959	130.6
22. Bastar	35.Kanker	--	30.5	05.08.1911	134.8
23. Betul	36.Shahpur	--	29.0	03.07.1930	109.8
24. Seoni	37.Seoni	--	28.2	02.08.1913	139.0
Maharashtra					
25. Amraoti	38.Chikalada	43.1	--	19.08.1886	171.5
26. Parbhani	39.Parbhani	40.1	--	27.06.1914	90.0
27. Chanda	40.Ghorajheri	40.0	--	19.07.1959	135.2
28. Bhandara	41.Pangree	39.5	--	25.07.1937	143.0
	42.Sakoli	38.4	--	26.06.1908	155.7
29. Akola	43.Telhara	39.2	--	14.09.1959	74.3
	44.Akola	36.5	--	15.09.1959	77.5
	45.Washim	35.6	--	26.06.1914	96.7
30. Yeotmal	46.Yeotmal	--	33.8	21.07.1937	109.7
31. Buldana	47.Buldana	--	33.8	09.09.1930	87.7
32. Nagpur	48.Umrer	--	33.0	14.08.1953	127.4
33. Wardha	49.Hinganghat	--	31.3	18.07.1913	113.3
34. Nanded	50.Nanded	--	25.4	20.08.1903	95.1
35. Osmanabad*	51.Osmanabad	--	24.7	07.09.1895	84.3
36. Aurangabad*	52.Aurangabad	--	24.5	02.09.1891	73.4

Note: Col.(1) Districts Underlined/asterisked(*) are partly/fully outside the subzone.

Heaviest 24 hrs & shorter durations rainfall
(Recorded at 28 SRRG Stations)

	State District		SRRG Station	Highest Storm Rainfall (mm) & Duration (hrs.)	Date & Time of Occurence (Clock hr.)
	(1)		(2)	(3)	(4)
	MADHYA PRADESH				
1.	Hoshangabad* (3)	1.	Pachmarhi	448 (24)	18-19.8.74 (03-03)
				269 (12)	18.8.74 (06-18)
		2.	Bagratawa	222 (6)	27.8.87 (08-14)
				175 (3)	27.8.87 (11-14)
				81 (1)	2.7.73 (9-10)
2.	Betul (3)	3.	Sarni Dam	329 (24)	6- 7.8.89 (13-13)
				237 (12)	13. 9.77 (9-21)
				213 (6)	13.9.77 (10-16)
				183 (3)	13.9.77 (12-15)
				84 (1)	13.9.77 (13-14)
3.	Bastar (4)	4.	Paralkote	316 (24)	19-20.7.76 (15-15)
				223 (12)	19-20.7.76 (21-09)
				75 (1)	19.6.78 (09-10)
		5.	Bhopalpatnam	167 (6)	8-9.8.74 (19-01)
				147 (3)	8.8.74 (19-22)
4.	Jabalpur* (2)	6.	Jabalpur	268 (24)	29-30.8.74 (02-02)
				221 (12)	14-15.8.72 (21-09)
				197 (6)	14-15.8.72 (22-04)
				146 (3)	15.8.72 (00-03)
				100 (1)	18.6.80 (16-17)
5.	Narsinghpur* (1)	7.	Narsinghpur	226 (24)	26-27.6.77 (08-08)
				189 (12)	5-6.8.89 (22-10)
				132 (6)	11.7.76 (02-08)
				102 (3)	30.7.82 (07-10)
				100 (1)	30.7.82 (07-08)
6.	Chindwara (2)	8.	Chindwara	210 (24)	1-2.7.70 (21-21)
				64 (01)	3.10.77 (22-23)
		9.	Harrai	170 (12)	29-30.8.90 (14-02)
				168 (6)	29.8.90 (14-20)
				153 (3)	18.8.90 (02-05)
7.	Mandla (1)	10.	Mandla	193 (24)	6- 7.8.74 (23-23)
				178 (12)	7.8.74 (07-19)
				173 (6)	7.8.74 (11-17)
				151 (3)	7.8.74 (14-17)
				100 (01)	1.4.71 (00-01)
8.	Durg (2)	11.	Kawardha	164 (24)	16-17.8.74 (23-23)
				144 (12)	19-20.7.70 (17-04)
				142 (6)	19-20.7.70 (21-03)
				70 (1)	5.8.70 (15-16)

(1)		(2)	(3)	(4)
9.	Seoni (1)	13. Lakhna Dam*	107 (24)	23-24.6.81 (04-04)
			84 (12)	23.6.81 (10-22)
			58 (6)	23.6.81 (10-16)
			49 (3)	25.7.77 (16-19)
			43 (1)	25.7.77 (18-19)
10.	Balaghat (2)	14. Paraswada*	88 (24)	18-19.8.90 (01-01)
			76 (12)	27.6.90 (03-15)
			74 (6)	27.6.90 (03-09)
			64 (3)	27.6.90 (03-06)
			51 (1)	27.6.90 (03-04)
	MAHARASHTRA			
11.	Chanda (2)	15. Chanda	417 (24)	13.8.86 (00-24)
			229 (12)	13-14.8.86 (13-01)
			178 (6)	18.7.88 (05-11)
			161 (3)	18.7.88 (07-10)
			90 (1)	8.8.77 (23-24)
12.	Amraoti (4)	16. Chikalda	349 (24)	21.7.76 (00-24)
			319 (12)	21-22.7.76 (16-04)
			300 (6)	21-22-7.76 (20-02)
			200 (3)	21-22.7.76 (22-01)
			100 (1)	21.7.76 (23-24)
13.	Akola (1)	17. Akola	329 (24)	17-18.7.86 (17-17)
			283 (12)	17-18.7.86 (20-08)
			207 (6)	18.7.86 (00-06)
			128 (3)	18.7.86 (03-06)
			63 (1)	25.9.70 (03-04)
14.	Bhandara (2)	18. Gondia	268 (24)	29-30.8.71 (19-19)
			235 (12)	30.8.71 (00-12)
			206 (6)	30.8.71 (03-09)
			135 (3)	30.8.71 (04-07)
			69 (1)	6.7.73 (21-22)
15.	Yeotmal (1)	19. Yeotmal	227 (24)	20-21.9.81 (06-06)
			213 (12)	20-21.9.81 (19-07)
			205 (6)	20-21.9.81 (22-04)
			163 (3)	21.9.81 (00-03)
			85 (1)	18.7.88 (14-15)
16.	Nagpur (1)	20. Nagpur	226 (24)	3- 4.8.79 (10.10)
			181 (12)	3- 4.8.79 (20-08)
			148 (6)	11-12.10.85 (22-04)
			104 (3)	3.9.76 (01-04)
			64 (1)	14.8.85 (14-15)
17.	Parbhani (1)	21. Hingoli	193 (24)	1- 2.9.77 (04-04)
			140 (12)	1- 2.9.77 (20-08)
			131 (6)	1- 2.9.77 (21-03)
			101 (3)	1- 2.9.77 (23-02)
			45 (1)	1.8.75 (16-17)

(1)	(2)	(3)	(4)
18. Buldana (1)	22. Buldana	161 (24)	17-18.6.88 (17-17)
		161 (12)	17-18.6.88 (17-05)
		157 (6)	17.6.88 (17-23)
		130 (3)	17.6.88 (19-22)
		100 (1)	16.12.71(00-01)
ANDHRA PRADESH			
19. Nizamabad (1)	23. Nizamabad	363 (24)	5-6.10.83 (14-14)
		313 (12)	5-6.10.83 (17-05)
		202 (6)	5-6.10.83 (23-05)
		121 (3)	6.10.83 (01-04)
		53 (1)	29.9.75 (22-23)
20. Karimnagar (1)	24. Ramagundam	240 (24)	16-17.7.86 (23-23)
		217 (12)	23-24.10.73(20-08)
		175 (6)	20.8.83 (02-08)
		168 (3)	20.8.83 (04-07)
		96 (1)	25.9.79 (16-17)
21. Warangal (1)	25. Hanamkonda	236 (24)	21-22.6.81 (23-23)
		231 (12)	21-22.6.81 (23-11)
		231 (6)	21-22.6.81 (23-02)
		177 (3)	22.6.81 (01-04)
		99 (1)	22.6.81 (02-03)
22. Khammam (2)	26. Bhadrachalam	217 (24)	3- 4.8.81 (03-03)
		183 (12)	19-20.11.77(16-04)
		166 (6)	19-20.11.77(22-04)
		127 (3)	20.11.77(00-03)
		100 (1)	5.9.77 (00-03)
23. Hyderabad* (1)	27. Hyderabad	151 (24)	24-25.9.71 (18-18)
		116 (12)	8- 9.9.75 (13-01)
		101 (6)	21-22.9.70 (21-03)
		80 (3)	21-22.9.70 (22-01)
		60 (1)	23.5.78 (19-20)
24. Adilabad (1)	28. Adilabad*	127 (24)	13-14.8.86 (07-07)
		82 (12)	13-14.8.86 (19-07)
		69 (6)	14.9.83 (17-23)
		64 (3)	14.9.83 (17-20)
		41 (1)	17.6.86 (15-16)

Note :

Col. (1) Districts underlined/asterisked(*) are partly/fully outside the subzone and figures in parentheses indicate total number of SRRG stations in the district.

Col. (2) Stations asterisked(*) have data for less than five years.

SUBZONE - 3(f)

ANNEXURE - 5.1

List of SUG parameters obtained from equations

SL.No.	BRIDGE No.	CA sq.km.	L Km.	Lc Km.	S M/Km.	S^0.5	LLc/S^0.5	tp hrs.	tp(r)	qp Cumec/sq.km.	W50 hrs.	W75 hrs.	WR50 hrs.	WR75 hrs.	TB hrs.	QP Cumecs
1	807	824.00	61.08	22.54	1.24	1.11	1236.35	8.82	8.50	0.33	7.18	4.06	2.99	1.76	31.09	271.62
2	875	750.00	60.01	29.00	1.77	1.33	1308.08	9.05	9.50	0.30	7.85	4.44	3.29	1.93	34.34	226.08
3	224	750.00	61.00	23.80	1.19	1.09	1330.86	9.12	9.50	0.30	7.85	4.44	3.29	1.93	34.34	226.08
4	65	731.00	57.36	23.35	6.99	2.64	506.59	5.88	5.50	0.47	5.05	2.87	2.07	1.24	21.07	341.94
5	228	483.00	41.80	17.70	3.68	1.92	385.68	5.20	5.50	0.47	5.05	2.87	2.07	1.24	21.07	225.94
6	15	459.00	33.10	8.40	1.28	1.13	245.75	4.24	4.50	0.55	4.29	2.45	1.75	1.06	17.61	252.30
7	184	364.00	35.20	12.90	0.67	0.82	554.75	6.13	6.50	0.41	5.78	3.28	2.39	1.42	24.46	148.87
8	604/973	341.00	45.95	20.40	1.84	1.36	691.05	6.77	6.50	0.41	5.78	3.28	2.39	1.42	24.46	139.46
9	269	242.00	27.70	11.20	3.87	1.97	157.70	3.46	3.50	0.67	3.50	2.00	1.42	0.86	14.06	162.81
10	881	233.00	24.10	10.10	1.53	1.24	196.79	3.81	3.50	0.67	3.50	2.00	1.42	0.86	14.06	156.75
11	969	208.00	25.00	6.80	2.96	1.72	98.81	2.80	2.50	0.88	2.67	1.53	1.07	0.66	10.41	183.40
12	57	163.00	29.00	15.30	1.23	1.11	400.07	5.28	5.50	0.47	5.05	2.87	2.07	1.24	21.07	76.25
13	36	139.90	23.00	8.50	3.35	1.83	106.81	2.90	2.50	0.88	2.67	1.53	1.07	0.66	10.41	122.56
14	566/912	137.00	19.60	8.40	5.01	2.24	73.56	2.45	2.50	0.88	2.67	1.53	1.07	0.66	10.41	120.80
15	494/795	120.00	16.90	8.00	2.55	1.60	84.67	2.61	2.50	0.88	2.67	1.53	1.07	0.66	10.41	105.81
16	51	87.00	21.74	10.10	1.21	1.10	217.98	4.01	4.50	0.55	4.29	2.45	1.75	1.06	17.61	47.82
17	59	66.00	18.00	10.00	3.30	1.82	99.09	2.80	2.50	0.88	2.67	1.53	1.07	0.66	10.41	58.20
18	20	60.00	16.98	7.45	7.42	2.72	46.44	1.99	1.50	1.33	1.77	1.02	0.69	0.43	6.59	79.77
19	161	54.00	15.05	9.50	3.94	1.98	72.03	2.43	2.50	0.88	2.67	1.53	1.07	0.66	10.41	47.61
20	4	50.00	12.20	5.30	8.22	2.87	22.55	1.43	1.50	1.33	1.77	1.02	0.69	0.43	6.59	66.48
21	491	42.00	14.70	7.70	5.40	2.32	48.71	2.03	2.50	0.88	2.67	1.53	1.07	0.66	10.41	37.03
22	214	35.00	14.00	7.90	9.03	3.00	36.81	1.79	1.50	1.33	1.77	1.02	0.69	0.43	6.59	46.54

SUBZONE - 3(f) ANNEXURE - 5.2

COMPUTED FLOOD PEAKS(CUMECS) USING TD=1.1*tp AND TD=TB

SL.NO.	BRIDGE No.	TD = 1.1 * tp			TD = TB		
		Q25	Q50	Q100	Q25	Q50	Q100
1	807	2204	2795	3320	2056	2644	3167
2	875	1936	2445	2920	1809	2315	2786
3	224	2686	3101	3594	2573	2989	3483
4	65	3561	4171	4888	3160	3727	4394
5	228	1795	2197	2550	1580	1957	2287
6	15	2854	3272	3701	2575	2967	3368
7	184	2084	2330	2625	1909	2143	2423
8	604/973	939	1238	1503	829	1114	1367
9	269	1282	1571	1872	1149	1418	1701
10	881	989	1290	1592	873	1154	1435
11	969	1257	1534	1827	1213	1489	1780
12	57	784	929	1099	702	837	996
13	36	1555	1759	1972	1518	1720	1932
14	566/912	926	1132	1333	893	1098	1297
15	494/795	998	1178	1368	973	1153	1342
16	51	515	591	692	470	543	638
17	59	521	618	725	507	605	713
18	20	802	902	1034	829	973	1116
19	161	477	574	660	464	561	646
20	4	470	579	688	504	621	739
21	491	454	522	582	445	513	573
22	214	450	513	594	450	512	594

SUBZONE - 3(f)

ANNEXURE-53

COMPUTAION OF EQUIVALENT SLOPE OF BRIDGE CATCHMENT NO 269

SL. No.	REDUCED DISTANCE RD KM	REDUCED LEVEL RL M	LENGTHOF EACH SEGMENT Li KM	HEIGHT ABOVE DATUM Di M	(Di-1+Di) M	Li*(Di-1+Di) KM*M
1	0.00	165.20	0.00	0.00	0.00	0.00
2	2.01	167.64	2.01	2.44	2.44	4.90
3	6.84	182.88	4.83	17.68	20.12	97.18
4	13.28	198.12	6.44	32.92	50.60	325.86
5	18.11	213.36	4.83	48.16	81.08	391.62
6	20.92	228.60	2.81	63.40	111.56	313.48
7	22.53	243.84	1.61	78.64	142.04	228.68
8	24.14	259.08	1.61	93.88	172.52	277.76
9	24.94	274.32	0.80	109.12	203.00	162.40
10	25.74	381.00	0.80	215.80	324.92	259.94
11	26.54	396.24	0.80	231.04	446.84	357.47
12	27.70	411.46	1.16	246.26	477.30	553.67
					Sum =	2972.97

$$S = \frac{\text{Sum } Li*(Di\text{-}1+Di)}{L^2} = \frac{2972.97}{767.29} = 3.87 \text{ MT/KM.}$$

DATUM = 100.00 M, i.e. R.L. of river bed at point of study.

SUBZONE - 3(f)

ANNEXURE - 5.4

COMPUTAT.ION OF DESIGN FLOOD HYDROGRAPH OF BRIDGE CATCHMENT NO 269

TIME HRS.	S.U.H ORDINATES CUMECS	RAINFALL EXCESS IN CMS 0.37	1.93	7.31	0.81	TOTAL D.S.R.O. IN CUMECS	BASE FLOW IN CUMECS	TOTAL FLOW IN CUMECS	
		DIRECT RUNOFF (CUMECS)							
1	2	3	4	5	6	7	8	9	
0	0.00	0.00				0.00	12.10	12.10	
1	11.00	4.07	0.00			4.07	12.10	16.17	
2	44.00	16.28	21.23	0.00		37.51	12.10	49.61	
3	110.00	40.70	84.92	80.41	0.00	206.03	12.10	218.13	
4	163.00	60.31	212.30	321.64	8.91	603.16	12.10	615.26	
5	128.00	47.36	314.59	804.10	35.64	1201.69	12.10	1213.79	
6	84.00	31.08	247.04	1191.53	89.10	1558.75	12.10	1570.85	-----) PEAK
7	49.00	18.13	162.12	935.68	132.03	1247.96	12.10	1260.06	
8	32.00	11.84	94.57	614.04	103.68	824.13	12.10	836.23	
9	21.00	7.77	61.76	358.19	68.04	495.76	12.10	507.86	
10	13.50	5.00	40.53	233.92	39.69	319.14	12.10	331.24	
11	9.00	3.33	26.06	153.51	25.92	208.82	12.10	220.92	
12	5.50	2.04	17.37	98.69	17.01	135.10	12.10	147.20	
13	2.00	0.74	10.62	65.79	10.94	88.08	12.10	100.18	
14	0.00	0.00	3.86	40.21	7.29	51.36	12.10	63.46	
15			0.00	14.62	4.46	19.08	12.10	31.18	
16				0.00	1.62	1.62	12.10	13.72	
17					0.00	0.00	12.10	12.10	

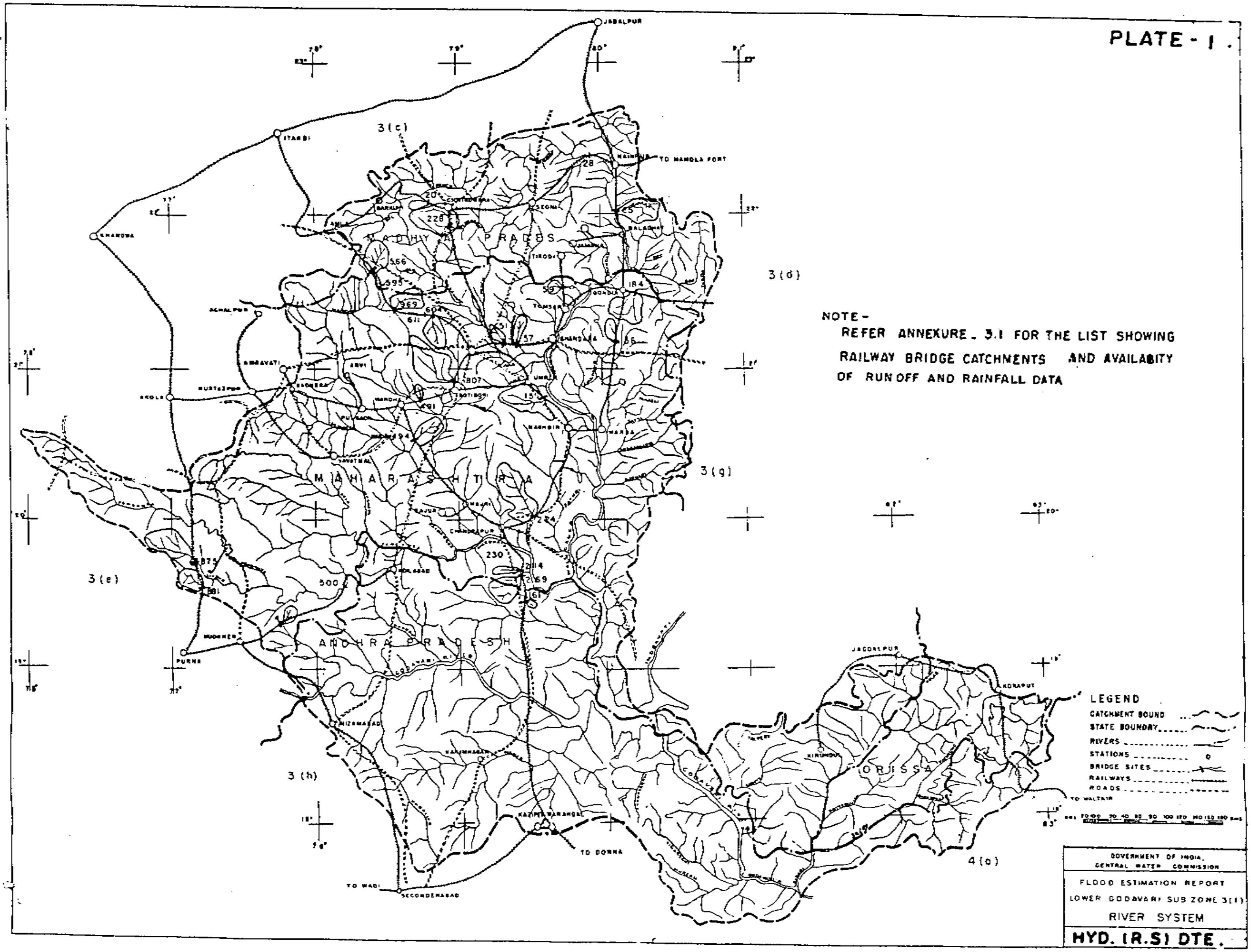
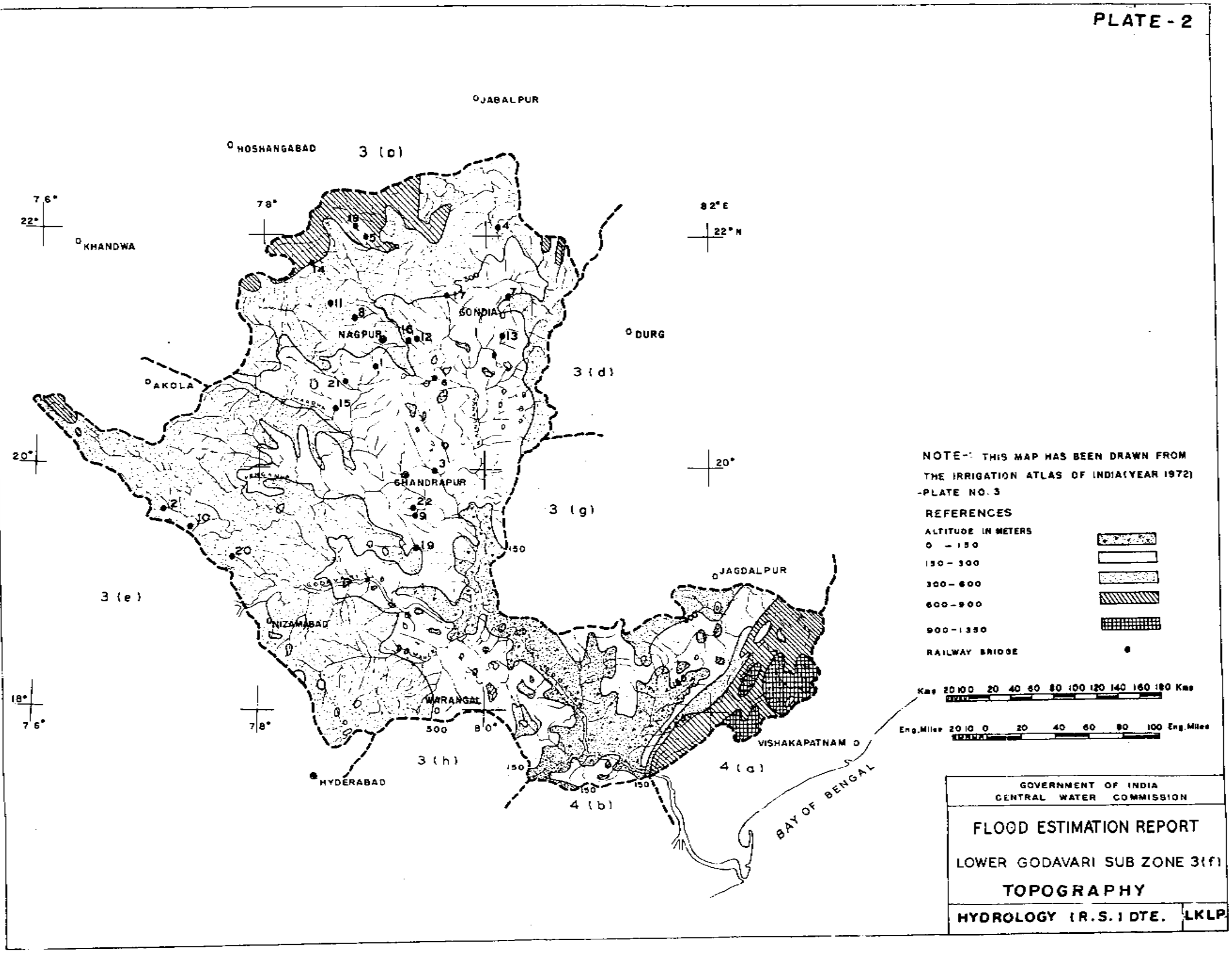


PLATE - I .
NOTE -
REFER ANNEXURE - 3.1 FOR THE LIST SHOWING
RAILWAY BRIDGE CATCHMENTS AND AVAILABITY
OF RUN OFF AND RAINFALL DATA
3(c)
3(d)
3(g)
3(e)
3(h)
4(a)
MADHYA PRADESH
MAHARASHTRA
ANDHRA PRADESH
ORISSA
JABALPUR
ITARSI
KHANDWA
TO MANDLA FORT
ACHALPUR
AMRAVATI
AKOLA
PURNA
SECONDERABAD
TO WADI
TO DORNA
TO WALTAIR
JAGDALPUR
KORAPUT
LEGEND
CATCHMENT BOUND
STATE BOUNDARY
RIVERS
STATIONS
BRIDGE SITES
RAILWAYS
ROADS
GOVERNMENT OF INDIA,
CENTRAL WATER COMMISSION
FLOOD ESTIMATION REPORT
LOWER GODAVARI SUB ZONE 3(f)
RIVER SYSTEM
HYD. (R.S) DTE.

PLATE - 2


JABALPUR
HOSHANGABAD
3 (a)
KHANDWA
AKOLA
DURG
3 (d)
3 (g)
3 (e)
3 (h)
4 (a)
4 (b)
NAGPUR
GONDIA
CHANDRAPUR
NIZAMABAD
WARANGAL
HYDERABAD
JAGDALPUR
VISHAKAPATNAM
BAY OF BENGAL
76°
22°
78°
82°E
22°N
20°
18°
80°
500
150
NOTE-: THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA(YEAR 1972) -PLATE NO. 3
REFERENCES
ALTITUDE IN METERS
0 - 150
150 - 300
300 - 600
600 - 900
900 - 1350
RAILWAY BRIDGE
Kms 20 10 0 20 40 60 80 100 120 140 160 180 Kms
Eng.Miles 20 10 0 20 40 60 80 100 Eng.Miles
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
FLOOD ESTIMATION REPORT
LOWER GODAVARI SUB ZONE 3(f)
TOPOGRAPHY
HYDROLOGY (R.S.) DTE.
LKLP

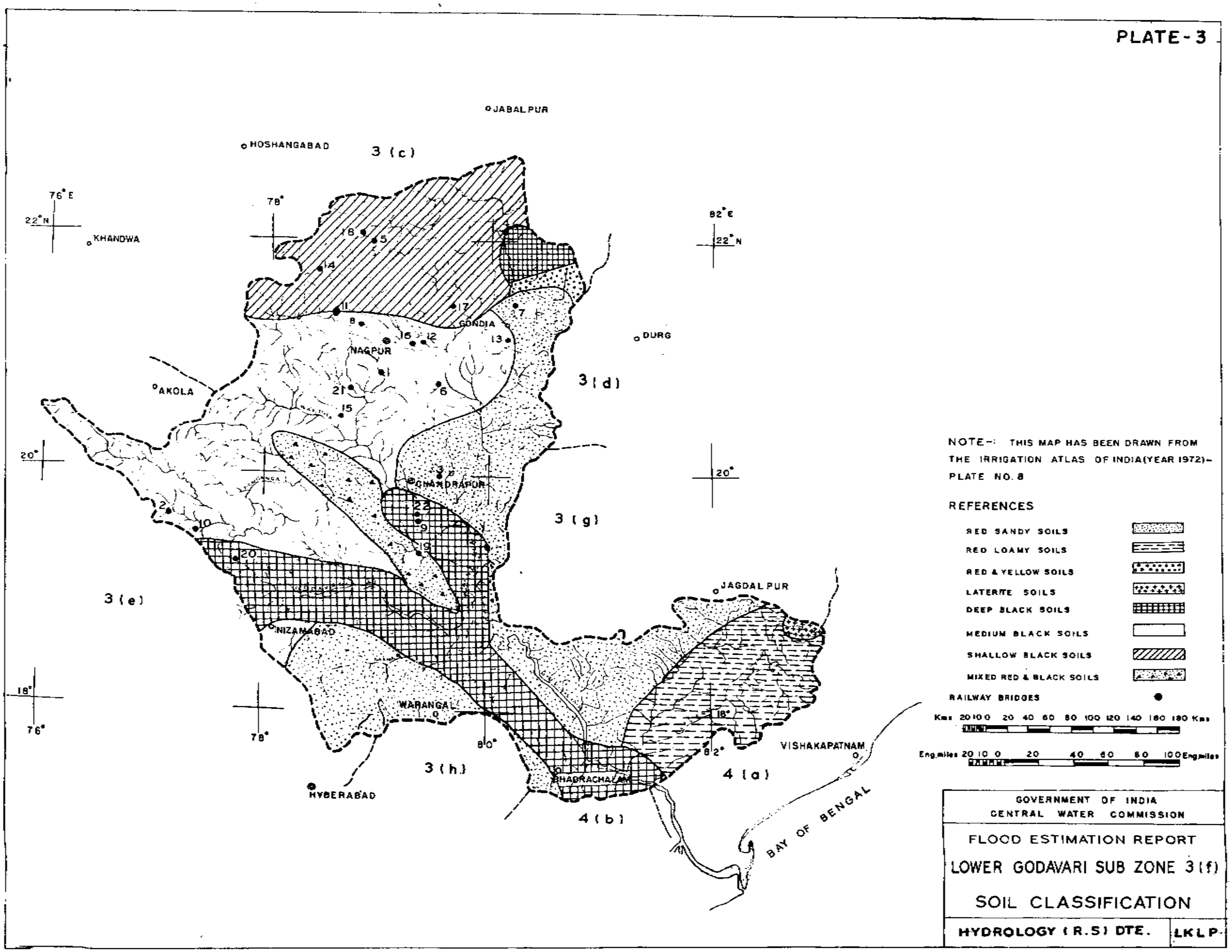
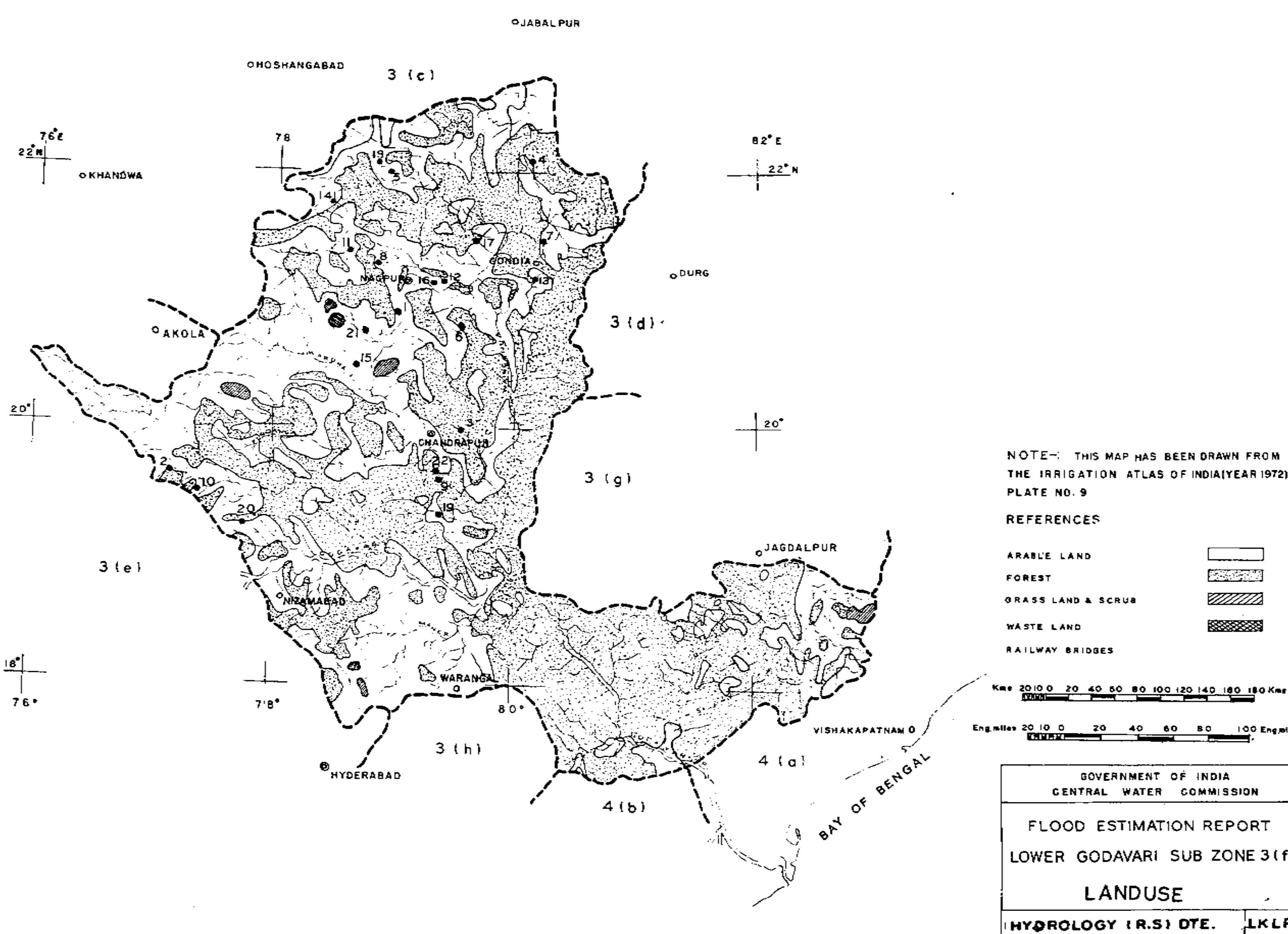


PLATE - 3
JABALPUR
HOSHANGABAD
3 (c)
KHANDWA
AKOLA
NAGPUR
GONDIA
DURG
3 (d)
CHANDRAPUR
3 (g)
3 (e)
NIZAMABAD
WARANGAL
HYBERABAD
3 (h)
BHADRACHALAM
JAGDALPUR
VISHAKAPATNAM
4 (a)
4 (b)
BAY OF BENGAL
76° E
22° N
78°
82° E
20°
18°
80°
82°
NOTE-: THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA(YEAR 1972)-PLATE NO. 8
REFERENCES
RED SANDY SOILS
RED LOAMY SOILS
RED & YELLOW SOILS
LATERITE SOILS
DEEP BLACK SOILS
MEDIUM BLACK SOILS
SHALLOW BLACK SOILS
MIXED RED & BLACK SOILS
RAILWAY BRIDGES
Kms 20 10 0 20 40 60 80 100 120 140 160 180 Kms
Eng.miles 20 10 0 20 40 60 80 100 Eng.miles
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
FLOOD ESTIMATION REPORT
LOWER GODAVARI SUB ZONE 3(f)
SOIL CLASSIFICATION
HYDROLOGY (R.S) DTE.
LKLP

PLATE - 4



NOTE-: THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA(YEAR 1972)-PLATE NO. 9

REFERENCES

ARABLE LAND
FOREST
GRASS LAND & SCRUB
WASTE LAND
RAILWAY BRIDGES

Kms 20 10 0 20 40 60 80 100 120 140 160 180 Kms

Eng.miles 20 10 0 20 40 60 80 100 Eng.miles

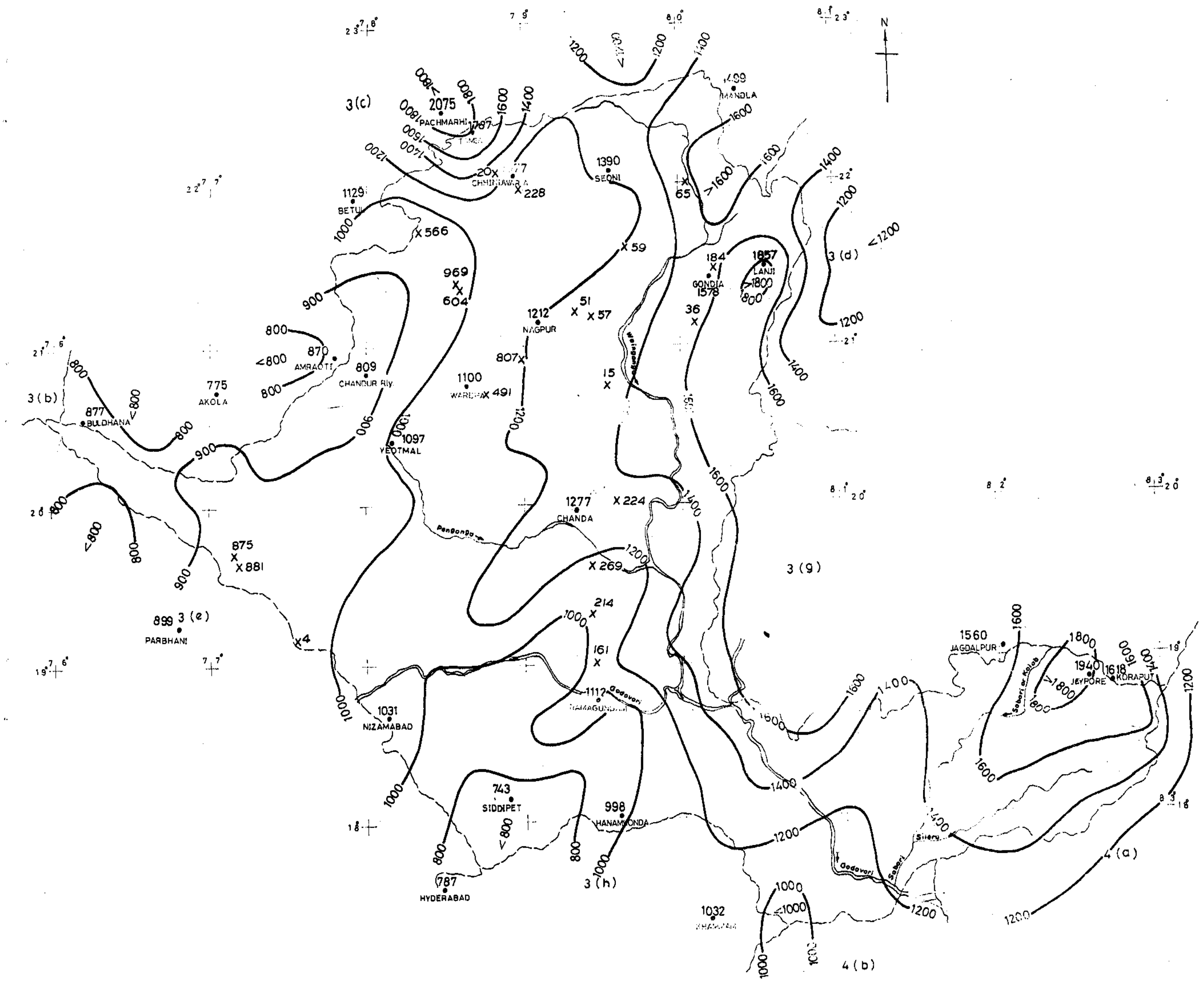
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION

FLOOD ESTIMATION REPORT
LOWER GODAVARI SUB ZONE 3(f)

LANDUSE

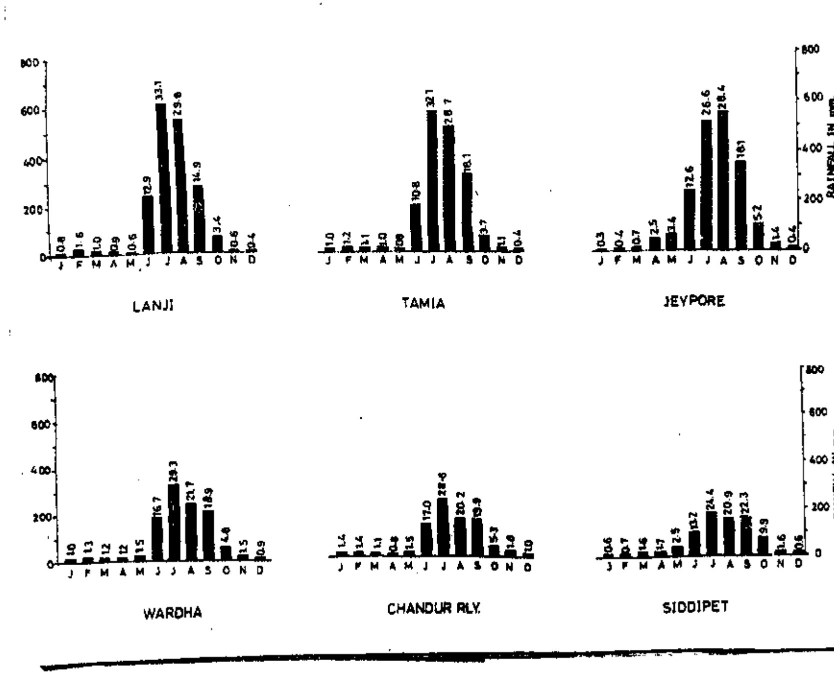
HYDROLOGY (R.S) DTE. | LKLP.

PLATE - 5.



MAP SUPPLIED BY I.M.D

MONTHLY RAINFALL DISTRIBUTION



REFERENCES

1. ISOHYETES IN mm.(ANNUAL NORMAL RAINFALL) (1400)
2. SUBZONE BOUNDARY
3. TOWNS
4. RIVERS
5. BRIDGE SITE X 214

NOTES

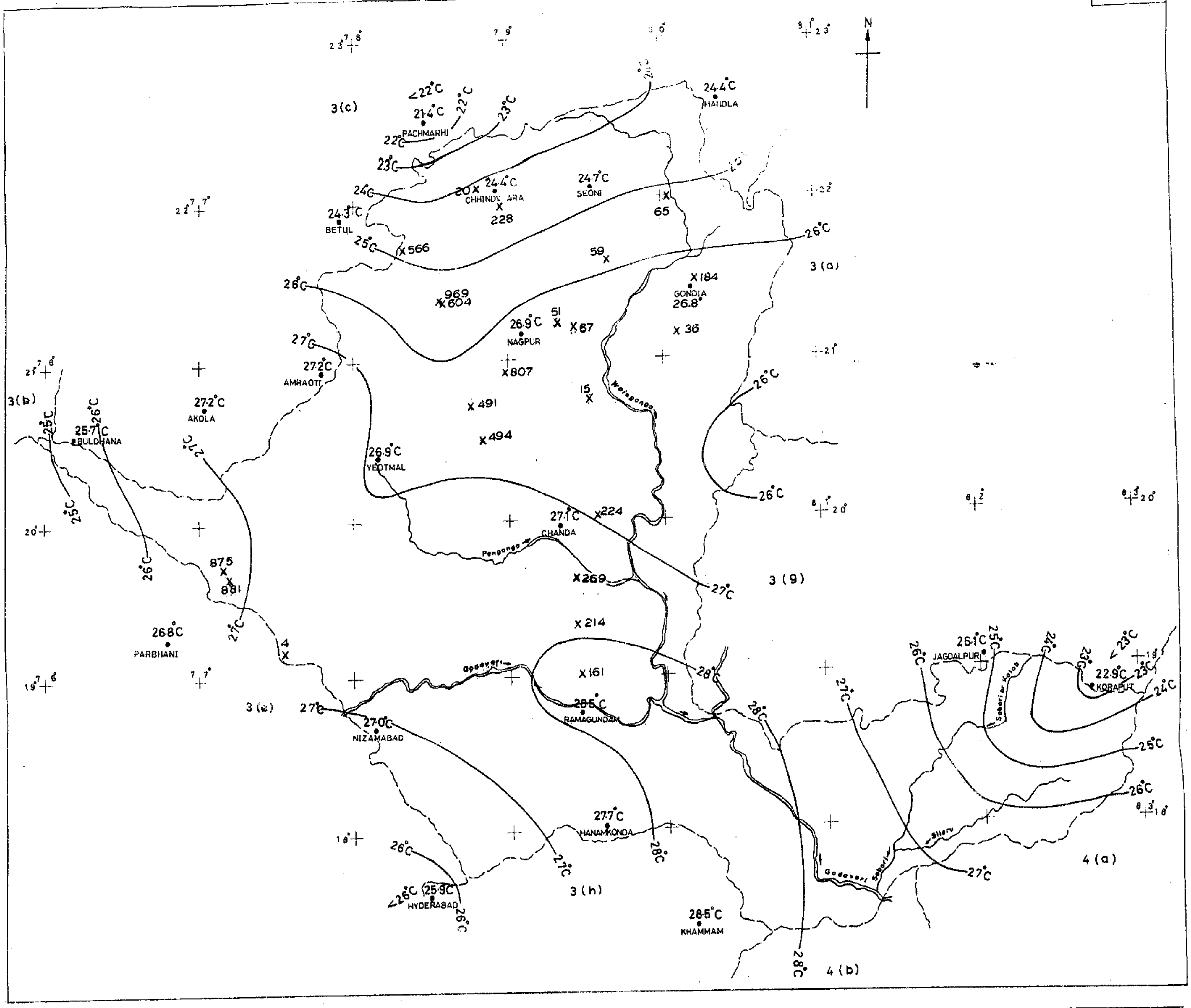
1. THE ALPHABETS ALONG ABCISSA INDICATE NAME OF MONTHS.
2. COLUMN HEIGHTS REPRESENT RAINFALL IN mm.
3. FIGURES ABOVE COLUMN INDICATE MONTHLY RAINFALL AS PERCENT OF ANNUAL RAINFALL.
4. REFER ANNEXURE 3.1 FOR LOCATION OF BRIDGES

SCALE

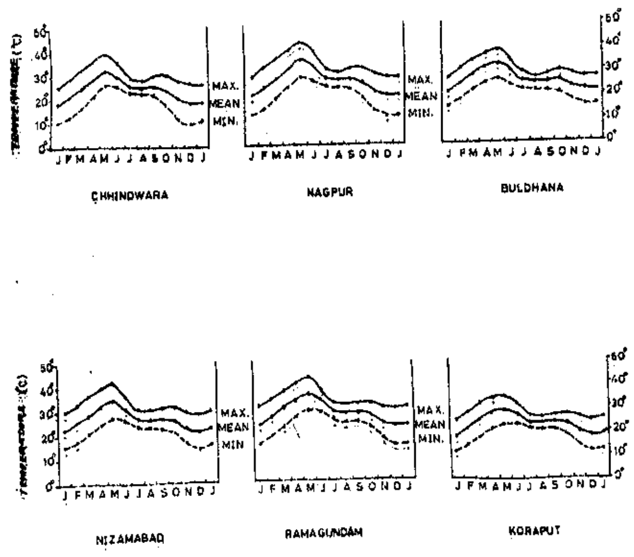
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S.) DIRECTORATE

LOWER GODAVARI
SUB ZONE - 3 (f)
ANNUAL NORMAL RAINFALL (m.m)

DRAWN BY - L. P. NAUTIYAL	CHECKED BY - VINOD KAUL



MONTHLY TEMPERATURE VARIATIONS



REFERENCES

1. ISOTHERMS (DEGREES CELSIUS) — 26°C
2. SUBZONE BOUNDARY
3. TOWNS
4. RIVERS
5. BRIDGE SITE — X 51

NOTE.- REFER ANNEXURE 3.1 FOR LOCATION OF BRIDGES

MAP SUPPLIED BY I.M.D

SCALE

10 5 0 10 20 30 40 50 60 70 80 Kms.

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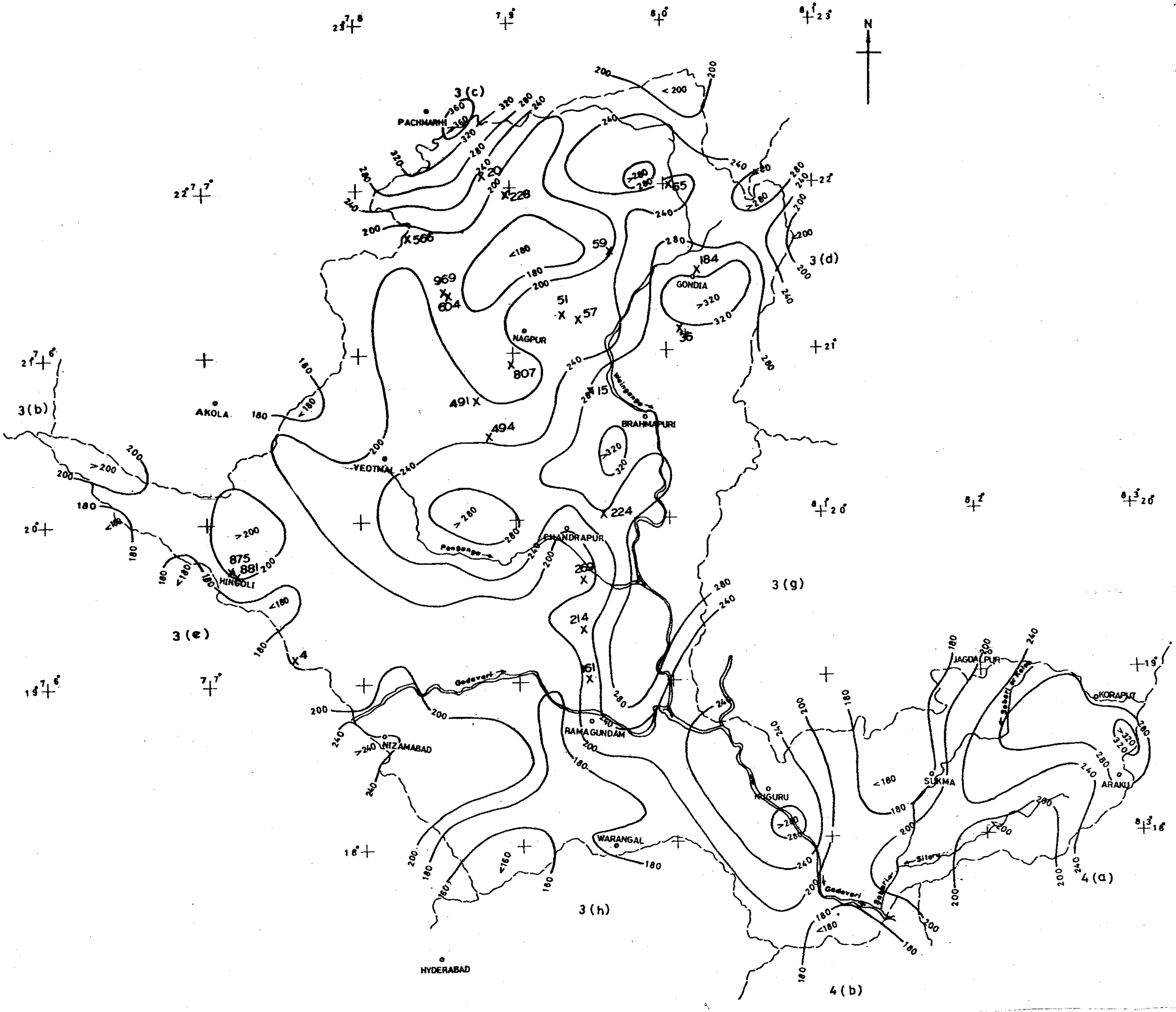
CENTRAL WATER COMMISSION
HYDROLOGY (R.S) DIRECTORATE

LOWER GODAVARI
SUB ZONE - 3 (f)
MEAN DAILY TEMPERATURE (0°C)
(ANNUAL)

DRAWN BY —	CHECKED BY —
L. K. PANT	VINOD KAUL



REFERENCES:

1. SUB ZONE BOUNDARY
2. TOWNS
3. ISOPLUVIALS
4. RIVER
5. BRIDGE SITE X 214

NOTES.

1. REFER ANNEXURE 5.1 FOR LOCATION OF BRIDGES.
2. INDICATED VALUE AGAINST THIS SYMBOL <> TO BE DECREASED OR INCREASED BY 10 mm. RAINFALL
3. PHYSICAL ATTRIBUTES OF THIS MAP BASED ON MAP NOS. NE. 45 & 44, NF-45 & 44.

SCALE

Kms 10 5 0 10 20 30 40 50 60 70 80 Kms.

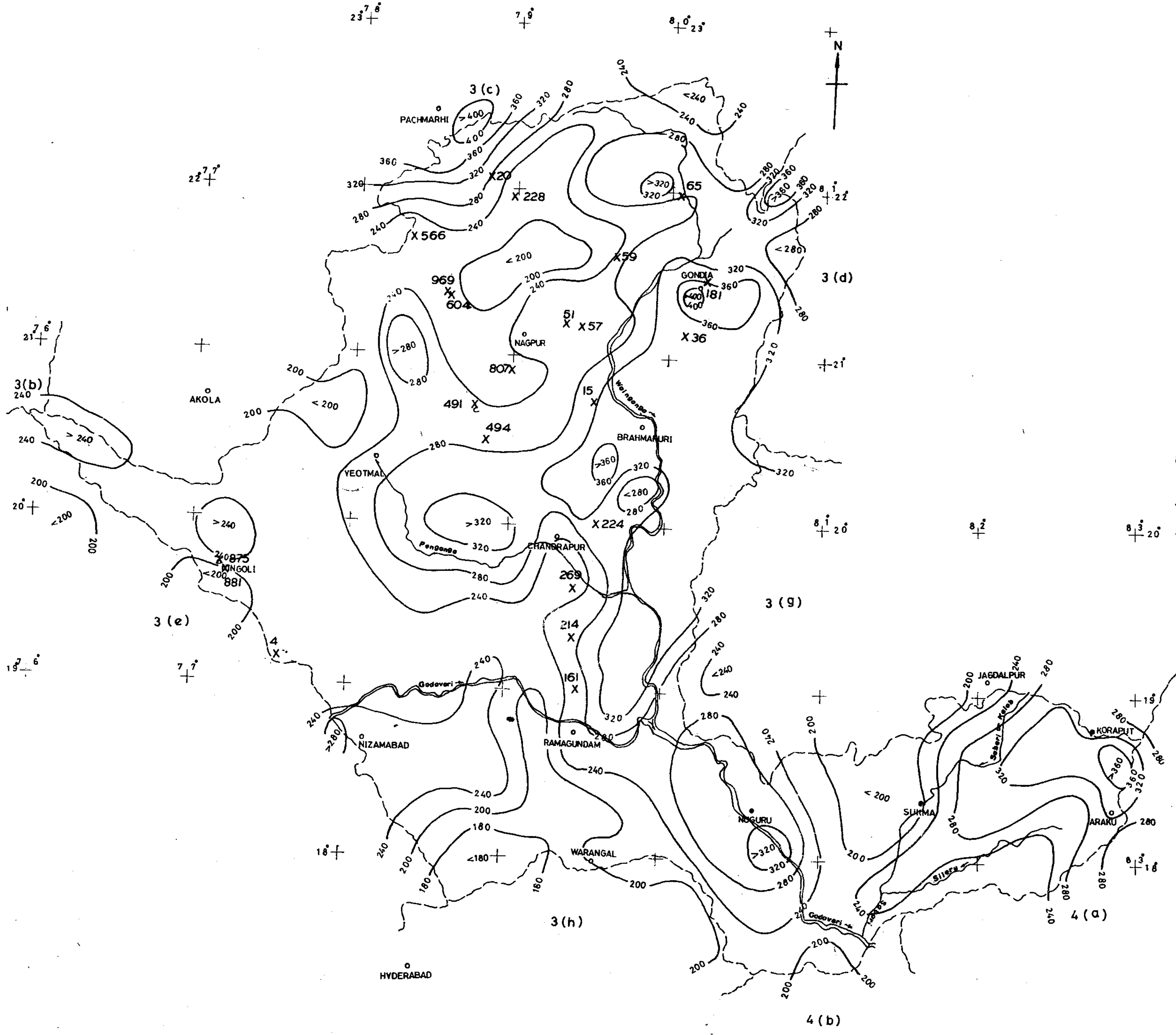
MAP SUPPLIED BY IMD.

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S) DIRECTORATE

LOWER GODAVARI
SUB ZONE - 3 (f)
25 YEAR 24. HOUR RAINFALL (mm)

DRAWN BY -	CHECKED BY -
L. P. NAUTIYAL	C. S. AGARWAL

PLATE- 8



NOTES -

1. REFER ANNEXURE 3.1 FOR LOCATION OF BRIDGES
2. INDICATED VALUE AGAINST THIS SYMBOL < > TO BE DECREASED OR INCREASED BY 10 mm. RAINFALL.
3. PHYSICAL ATTRIBUTES OF THIS MAP BASED ON MAP NOS. NE.43 & 44, NF-43 & 44.

REFERENCES

1. SUB ZONE BOUNDARY
2. TOWNS
3. ISOPLUVIALS (360)
4. BRIDGE SITE X 269
5. RIVERS

SCALE

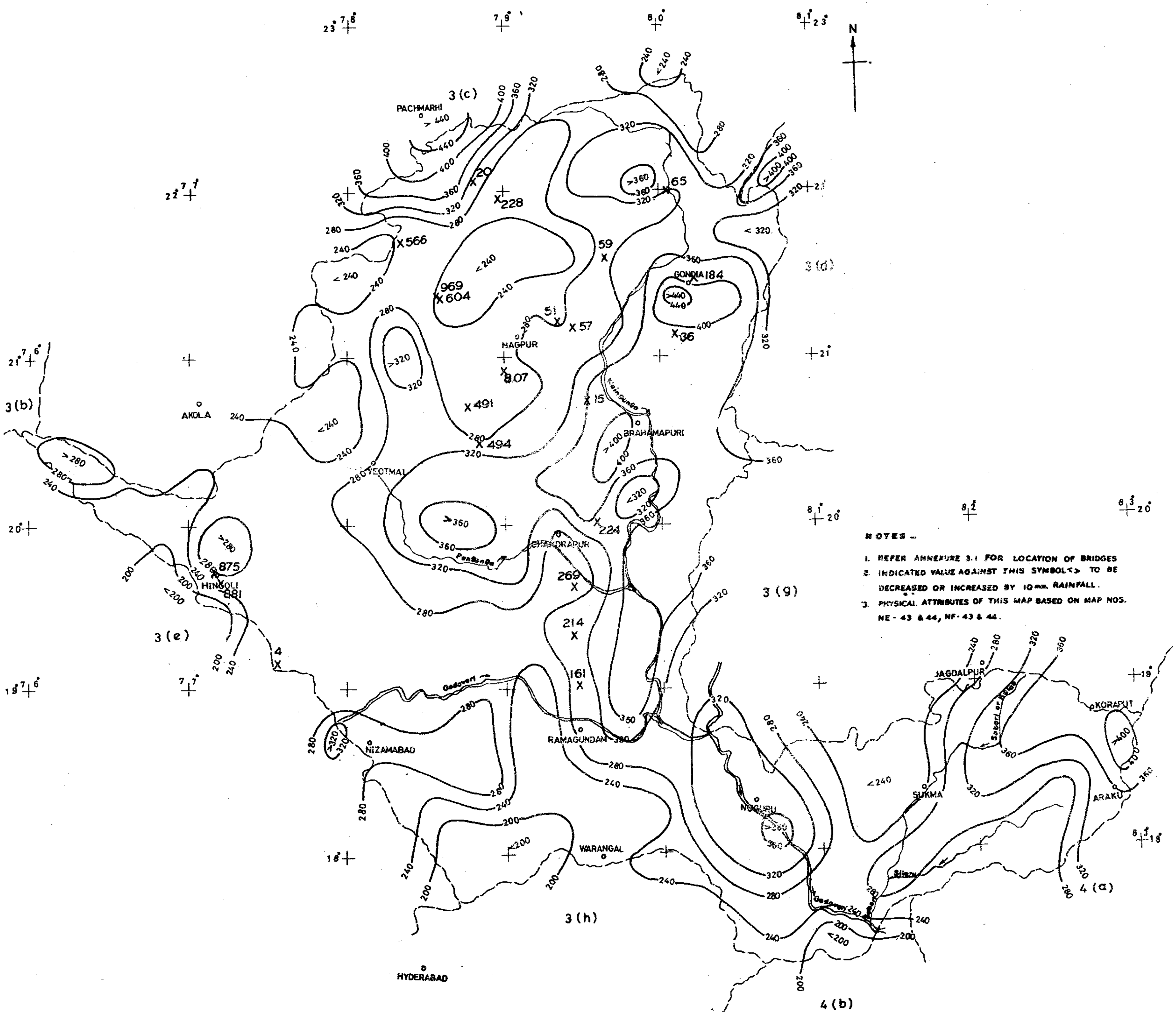
Kms 10 5 0 10 20 30 40 50 60 70 80 Kms.

MAP SUPPLIED BY IMD.

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S) DIRECTORATE

LOWER GODAVARI
SUB ZONE - 3 (f)
50-YEAR 24-HOUR RAINFALL
(mm.)

PLATE - 9



REFERENCES:

1. SUB ZONE BOUNDARY
2. TOWNS
3. ISOPLUVIALS
4. BRIDGE SITE X 57
5. RIVERS

NOTES -

1. REFER ANNEXURE 3.1 FOR LOCATION OF BRIDGES
2. INDICATED VALUE AGAINST THIS SYMBOL <> TO BE DECREASED OR INCREASED BY 10 mm. RAINFALL.
3. PHYSICAL ATTRIBUTES OF THIS MAP BASED ON MAP NOS. NE - 43 & 44, NF - 43 & 44.

MAP SUPPLIED BY IMD.

SCALE

Kms. 10 5 0 10 20 30 40 50 60 70 80 Kms.

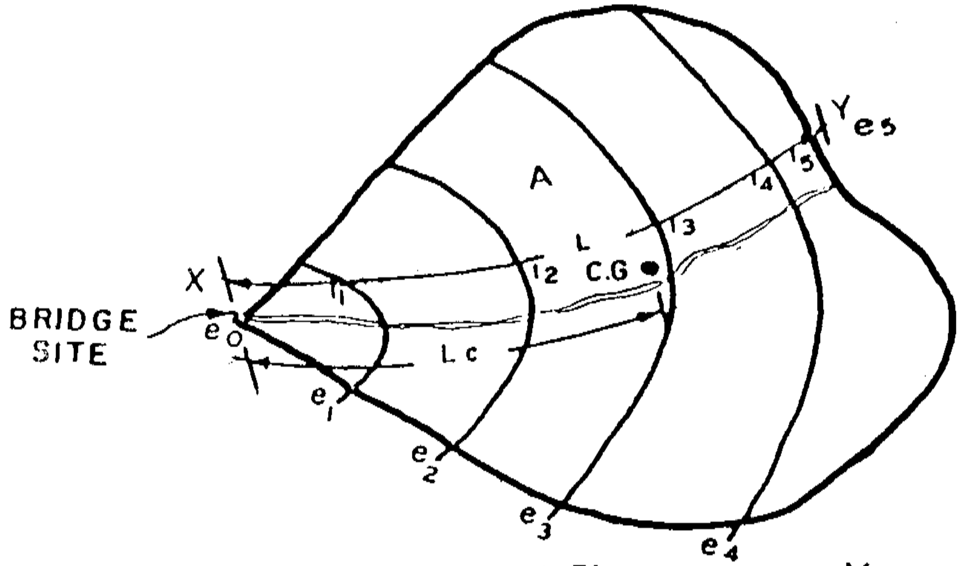
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S) DIRECTORATE

LOWER GODAVARI
SUB ZONE - 3 (f)
100 YEAR 24 - HOUR RAINFALL (mm.)

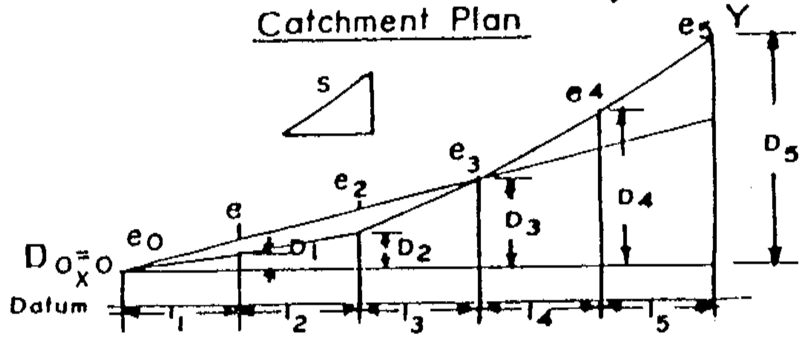
DRAWN BY -	CHECKED BY -
L.K. PANT	C.S. AGARWAL

-57-

FIG.1



Catchment Plan



L- Section

$$S = \frac{\sum_{1}^{n}(D_i + D_{i-1})\, l_i}{L^2}$$

Where: S = Equivalent stream slope (m/km)

L = Length of longest stream course (km)

$l_i = l_1, l_2, l_3, \ldots\ldots l_n$ = Segment lengths (km)

$e_i = e_1, e_2, \ldots\ldots\ldots e_n$ = contour elevation (m)

$D_i = D_0, D_1, D_2, \cdots D_n$

$= (e_0 - e_0), (e_1 - e_0), (e_2 - e_0) \cdots (e_n - e_0)$ (m)

A = Catchment area (km^2)

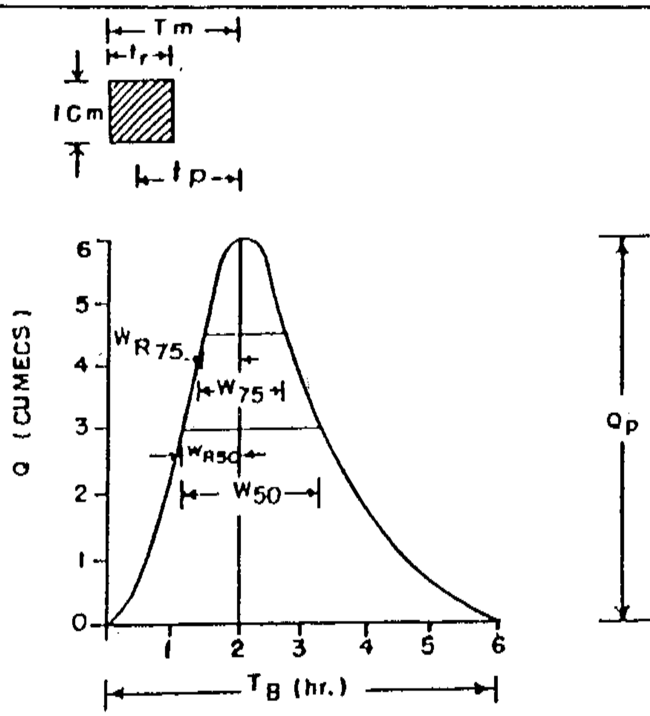
Lc = Length of longest stream course from a point opposit the centre of gravity of the catchment to the point of study (Km.)

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

PHYSIOGRAPHIC PARAMETERS

DRAWN	CHECKED
L. P. NAUTIYAL	C.S. AGARWAL

FIG. – 2



U.G. = Unit Graph

t_r = Unit Rainfall Duration adopted in a specific study (hr.)

Tm = Time from the start of rise to the peak of the U.G (hr.)

Qp = Peak Discharge of Unit Hydrograph (cumecs)

t_p = Time from the centre of effective rainfall duration to the U.G peak (hr.)

W_{50} = Width of the U.G. measured at 50% of peak discharge ordinate (hr.)

W_{75} = Width of the U.G measured at 75% of peak discharge ordinate (hr.)

W_{R50} = Width of the rising limb of U.G. measured at 50% of peak discharge ordinate (hr.)

W_{R75} = Width of the rising limb of U.G. measured at 75% of peak discharge ordinate (hr.)

T_B = Base width of Unit Hydrograph (hr.)

A = Catchment Area (Sq. km.)

$q_p = Q_p / A$ = Cumec per sq. km.

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HYDROLOGY (SMALL CATCHMENT) DTE.

UNIT GRAPH PARAMETERS

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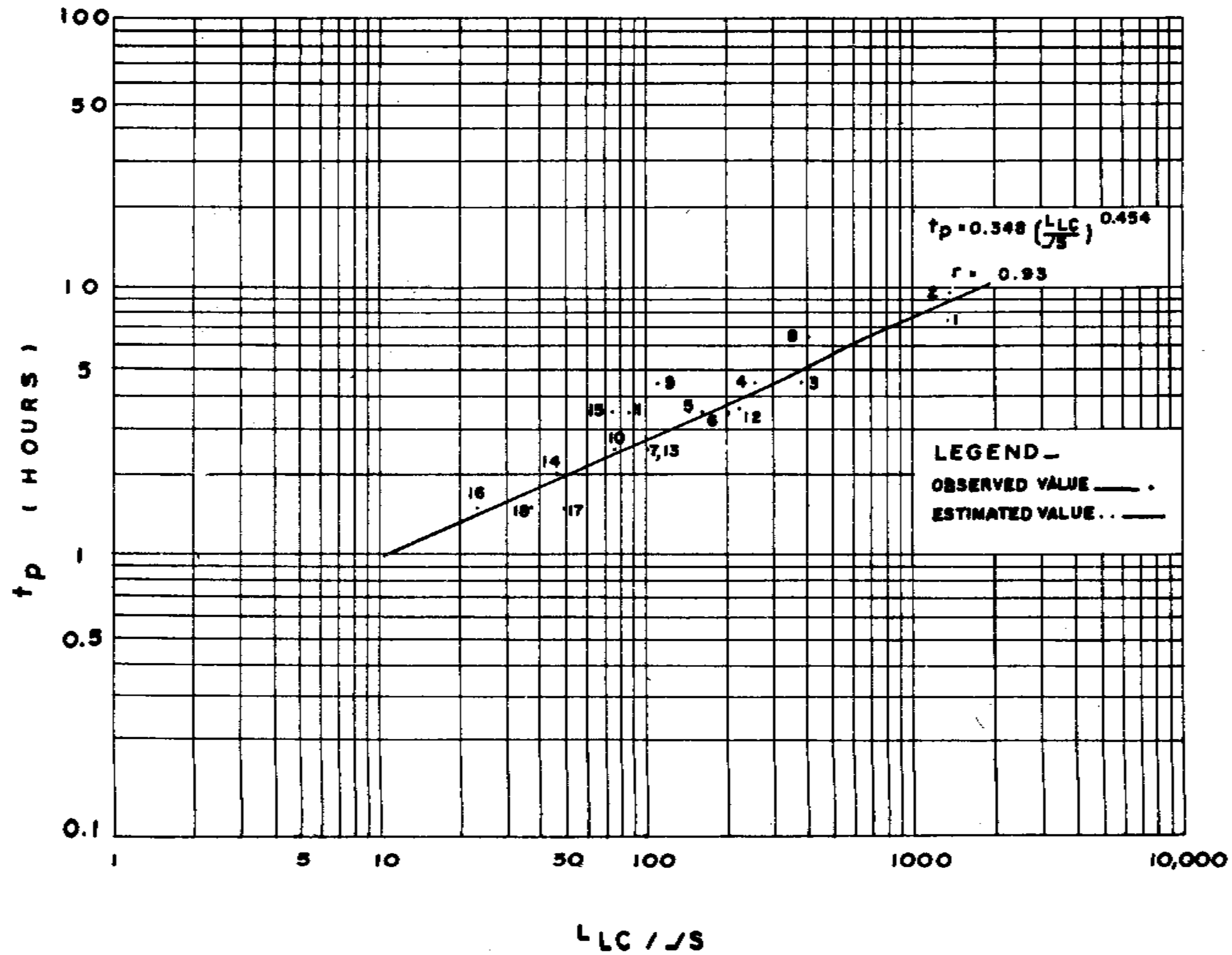
L.K. PANT	C.S. AGARWAL

FIG. — 3.

SCALE - LOG. X LOG.



SL. NO.	BRIDGE NO.	$L_{LC}/\sqrt{S}$	t_p (HOURS) OBS. VALUE	t_p (HOURS) ESTI VALUE
1	875	1308	7.50	9.05
2	224	1332	9.50	9.13
3	228	386	4.50	5.20
4	15	246	4.50	4.24
5	269	158	3.50	3.46
6	881	197	3.50	3.83
7	969	99	2.50	2.80
8	57	400	6.50	5.29
9	36	107	4.50	2.90
10	566	74	2.50	2.45
11	494	85	3.50	2.61
12	51	218	3.50	4.01
13	59	99	2.50	2.80
14	20	46	2.00	1.98
15	161	72	3.50	2.43
16	4	23	1.50	1.43
17	491	49	1.50	2.03
18	214	37	1.50	1.79

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

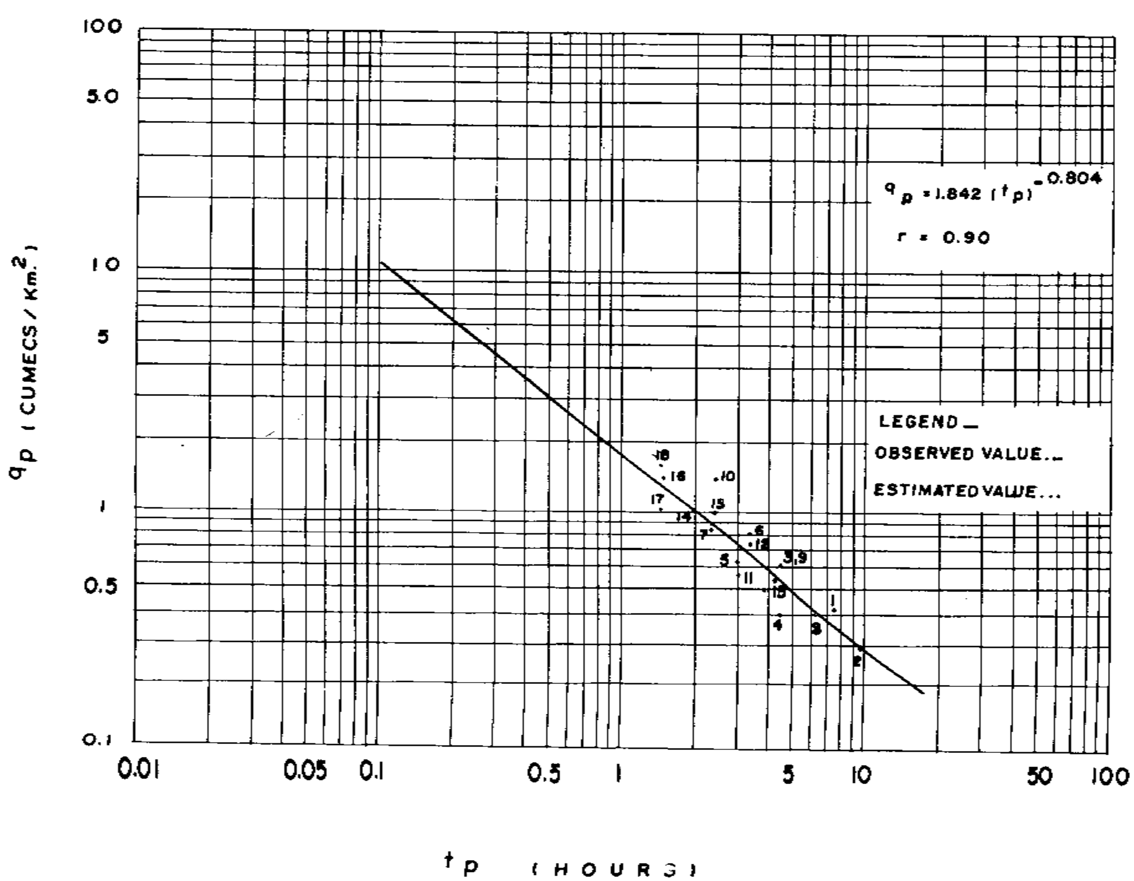
LOWER GODAVARI
SUB ZONE-3(f)
RELATION BETWEEN
LLC/√S AND t_p

DRAWN BY— L. K. PANT

CHECKED BY— C.S. AGARWAL.

FIG. – 4

SCALE – LOG. X LOG.



Sl. No.	Bridge No.	t_p Hours	q_p Cumecs / Km.^{2} Observed Value	q_p Cumecs / Km.^{2} Estimated Value
1	875	7.50	0.42	0.36
2	224	9.50	0.29	0.30
3	228	4.50	0.58	0.55
4	15	4.50	0.41	0.55
5	269	3.50	0.58	0.67
6	881	3.50	0.82	0.67
7	969	2.50	0.86	0.88
8	57	6.50	0.40	0.41
9	36	4.50	0.58	0.55
10	566	2.50	1.39	0.88
11	494	3.50	0.54	0.67
12	51	3.50	0.76	0.67
13	59	2.50	1.02	0.88
14	20	2.00	1.01	1.05
15	161	3.50	0.55	0.67
16	4	1.50	1.41	1.33
17	491	1.50	1.04	1.33
18	214	1.50	1.59	1.33

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

LOWER GODAVARI

SUB ZONE – 3 (f)

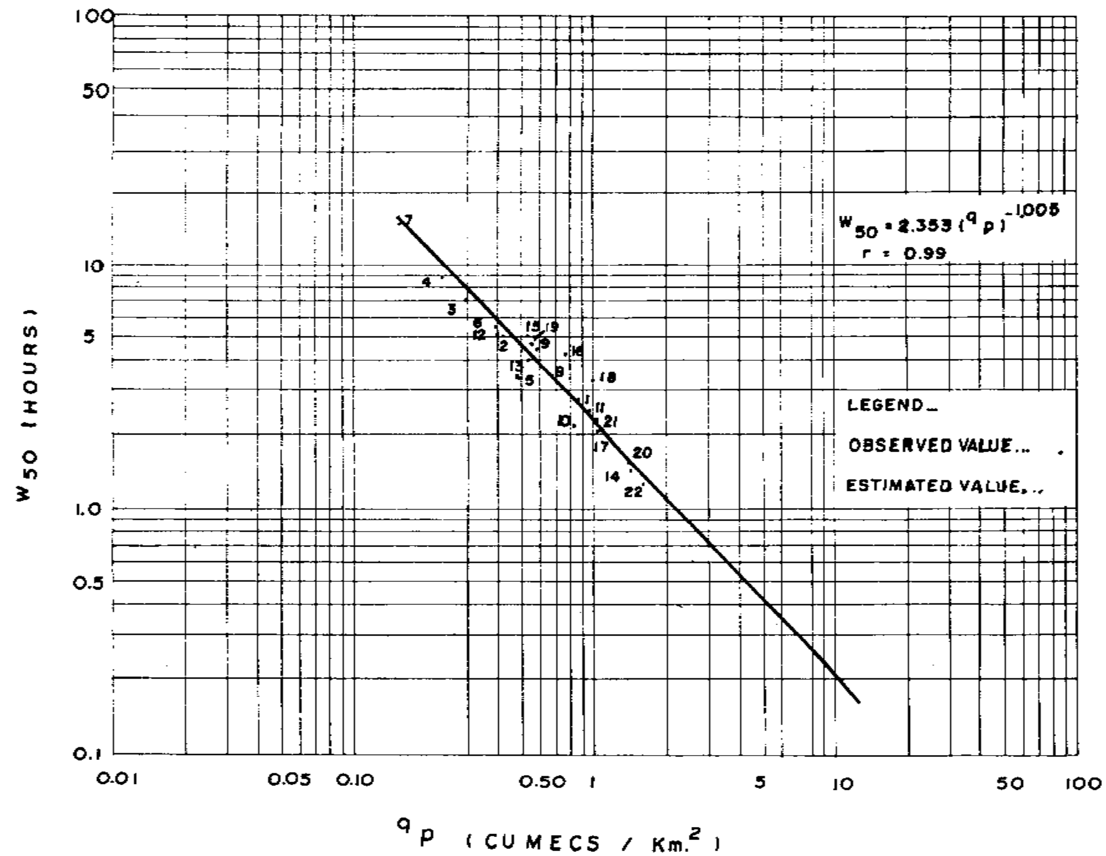
RELATION BETWEEN t_p AND q_p

DRAWN BY — L. K. PANT.

CHECKED BY — C. S. AGARWAL

FIG. _ 5.

SCALE _ LOG. X LOG.



Sl. NO.	BR. NO	q_p Cum./Km.²	W_{50} HOURS Obs. Value	W_{50} HOURS Esti. Value
1	807	0.79	2.90	2.98
2	875	0.42	5.63	5.63
3	224	0.29	7.50	8.17
4	65	0.25	9.20	9.48
5	228	0.58	3.30	4.07
6	15	0.41	5.70	5.77
7	184	0.16	15.30	14.85
8	604	0.57	3.60	3.52
9	269	0.58	4.40	4.07
10	881	0.82	2.40	2.87
11	969	0.86	2.80	2.74
12	57	0.40	5.50	5.91
13	36	0.58	3.90	4.07
14	566	1.39	1.50	4.60
15	494	0.54	4.80	4.37
16	51	0.76	4.40	3.10
17	59	1.02	2.10	2.31
18	20	1.01	3.40	2.33
19	161	0.55	4.50	4.29
20	4	1.41	1.60	1.67
21	491	1.04	2.30	2.26
22	214	1.59	1.30	1.48

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

LOWER GODAVARI

SUB ZONE - 3 (f)

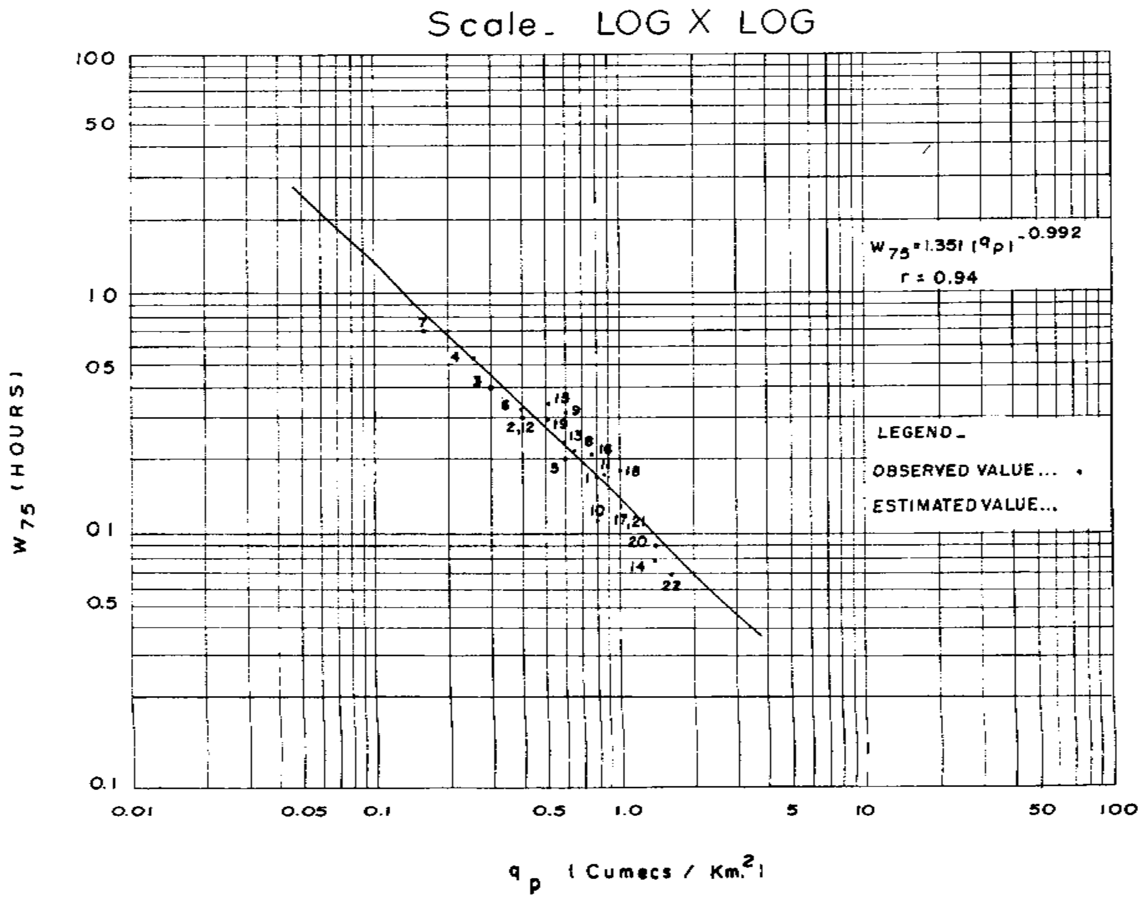
RELATION BETWEEN

q_p AND W_{50}

DRAWN BY _ L.P. NAUTIYAL

CHECKED BY _ VINOD KAUL

FIG._ 6



Sl.	BR. NO.	q_p cum./km.^{2}	W_{75} HOURS Obs. value	Est. value
1	807	0.79	1.70	1.71
2	875	0.42	3.17	3.20
3	224	0.29	4.00	4.62
4	65	0.25	5.50	5.35
5	228	0.58	2.00	2.32
6	15	0.41	3.20	3.28
7	184	0.16	7.00	8.34
8	604	0.67	2.30	2.01
9	269	0.58	3.10	2.32
10	881	0.82	1.10	1.65
11	969	0.86	1.70	1.57
12	57	0.40	3.00	3.36
13	36	0.58	2.30	2.32
14	566	1.39	0.80	0.97
15	494	0.54	3.40	2.49
16	51	0.76	2.10	1.77
17	59	1.02	1.30	1.33
18	20	1.01	1.80	1.34
19	161	0.55	3.00	2.45
20	14	1.41	0.90	0.96
21	491	1.04	1.30	1.30
22	214	1.59	0.70	0.85

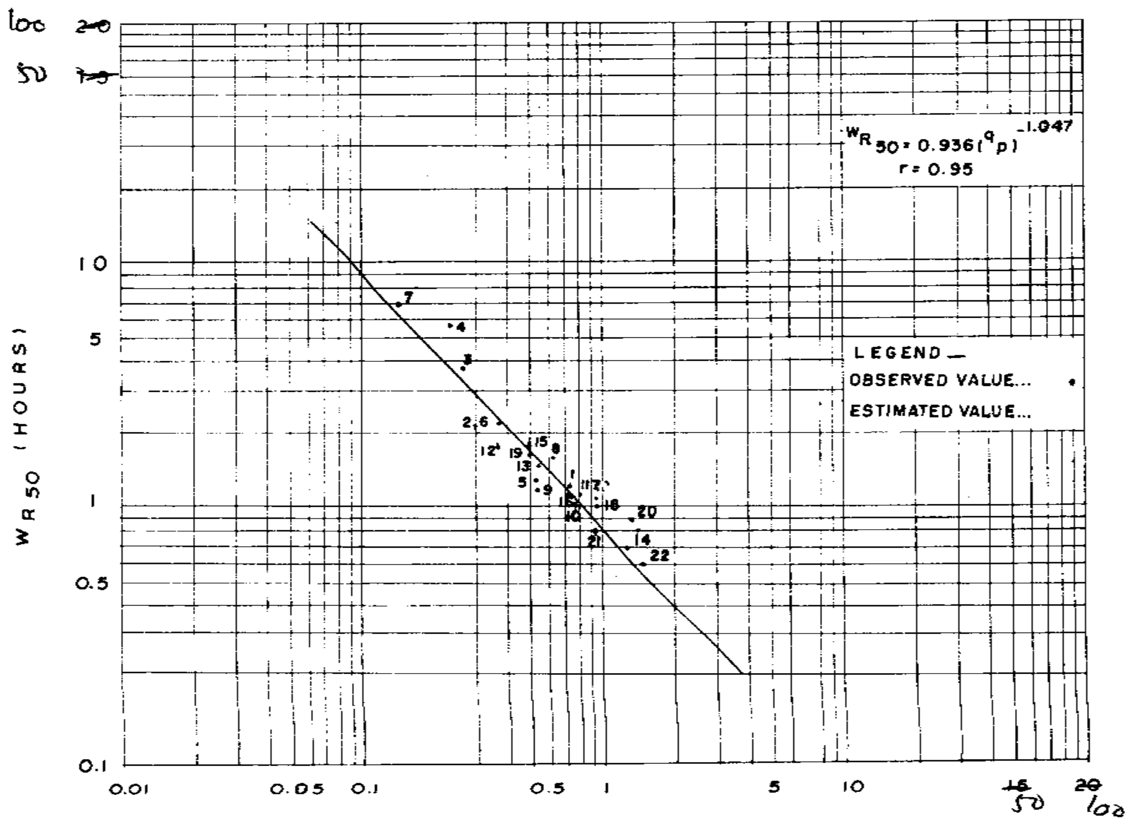
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

LOWER GODAVARI
SUB ZONE - 3 (f)
RELATION BETWEEN
q_p AND W_{75}

DRAWN BY_ L. K. PANT
CHECKED BY_ C. S. AGARWAL.

FIG. - 7

SCALE - LOG. X LOG



SL. NO.	BR. NO.	q_p Cum./Km.^{2}	W_{R50} HOURS OBS. VALUE	ESTI. VALUE
1	807	0.79	1.20	1.20
2	875	0.42	2.27	2.32
3	224	0.29	3.80	3.42
4	65	0.25	5.90	4.00
5	228	0.58	1.30	1.66
6	15	0.41	2.30	2.38
7	184	0.16	7.20	6.38
8	604	0.67	1.60	1.42
9	269	0.58	1.20	1.66
10	881	0.82	1.10	1.15
11	969	0.86	1.10	1.10
12	57	0.40	1.80	2.45
13	36	0.58	1.50	1.66
14	566	1.39	0.70	0.66
15	494	0.54	1.80	1.79
16	51	0.76	1.10	1.25
17	59	1.02	1.10	0.92
18	20	1.01	1.00	0.93
19	161	0.55	1.60	1.75
20	4	1.41	0.90	0.65
21	491	1.04	0.80	0.90
22	214	1.59	0.60	0.58

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE

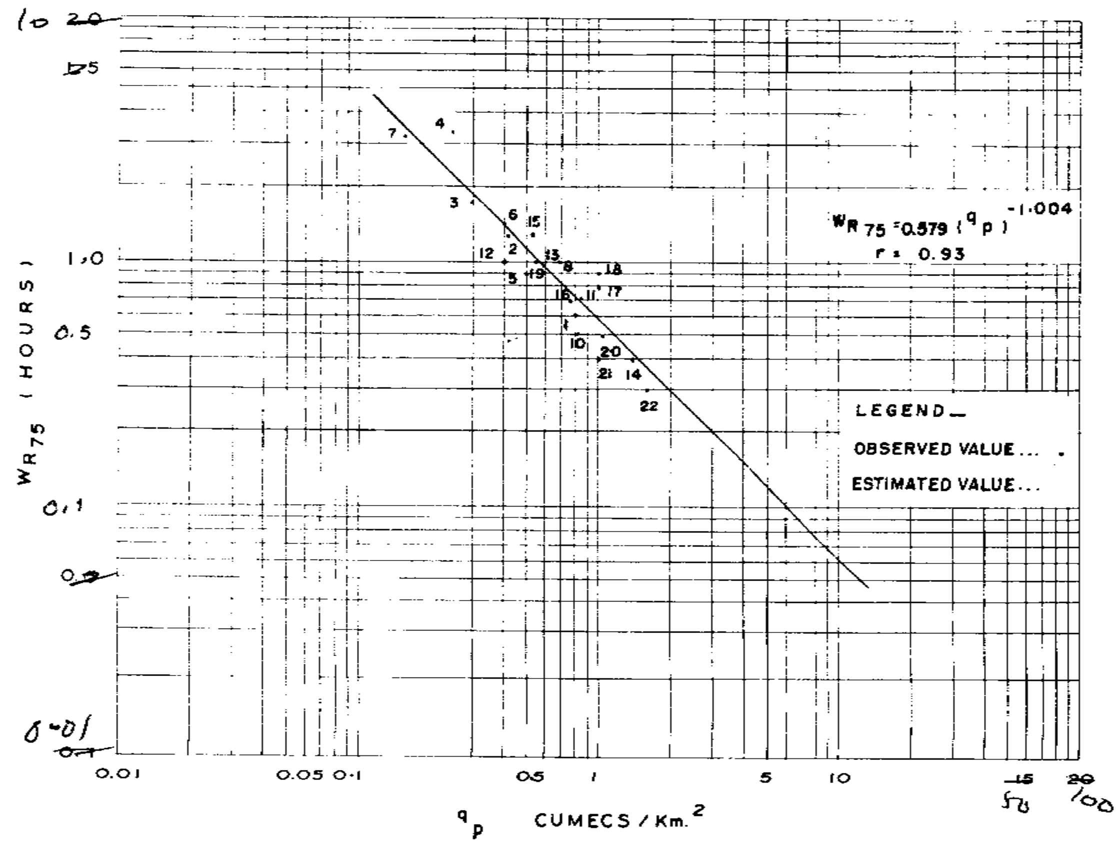
LOWER GODAVARI
SUB ZONE - 3 (f)
RELATION BETWEEN
q_p AND W_{R50}

DRAWN BY— L. K. PANT

CHECKED BY — C. S. AGARWAL

FIG. – 8

SCALE - LOG X LOG



SL. NO.	BR. NO.	q_p CUM./Km.^{2}	$W_{R_{75}}$ HOURS OBS. VALUE	$W_{R_{75}}$ HOURS ESTI. VALUE
1	807	0.79	0.60	0.73
2	875	0.42	1.30	1.38
3	224	0.29	1.80	2.01
4	65	0.25	3.50	2.33
5	228	0.58	1.00	1.00
6	15	0.41	1.40	1.42
7	114	0.16	3.40	3.64
8	604	0.67	1.00	0.87
9	269	0.58	1.00	1.00
10	881	0.82	0.50	0.71
11	969	0.86	0.70	0.67
12	57	0.40	1.00	1.45
13	36	0.58	1.00	1.00
14	566	1.39	0.40	0.42
15	494	0.54	1.30	1.07
16	51	0.76	0.70	0.76
17	59	1.02	0.80	0.57
18	20	1.01	0.80	0.57
19	161	0.55	1.00	1.05
20	4	1.41	0.50	0.41
21	491	1.04	0.40	0.56
22	214	1.59	0.30	0.30

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

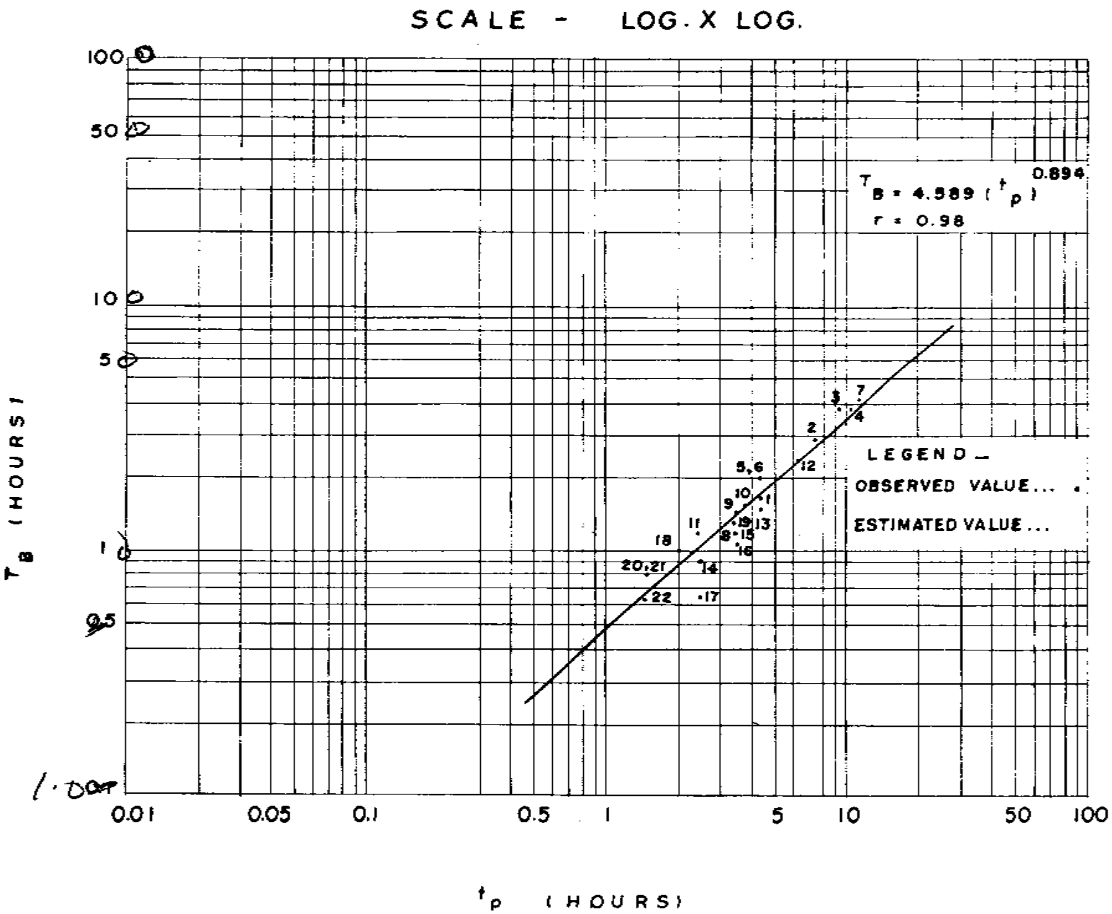
LOWER GODAVARI

SUB ZONE - 3 (f)

RELATION BETWEEN q_p AND $W_{R_{75}}$

DRAWN BY —	CHECKED BY —
L.P. NAUTIYAL	VINOD KAUL

FIG. – 9



Sl. No.	BR. NO.	t_p HOURS	T_B HOURS OBS. VALUE	T_B HOURS ESTI. VALUE
1	807	4.50	17.00	17.62
2	875	7.50	30.00	27.83
3	224	9.50	40.00	34.38
4	65	10.50	40.00	37.60
5	228	4.50	20.00	17.62
6	15	4.50	20.00	17.62
7	184	11.50	44.00	40.79
8	604	3.50	12.00	14.07
9	269	3.50	14.00	14.07
10	881	3.50	14.00	14.07
11	969	2.50	12.00	10.42
12	57	6.50	24.00	24.48
13	36	4.50	15.00	17.62
14	566	2.50	9.00	10.42
15	494	3.50	13.00	14.07
16	51	3.50	11.00	14.07
17	59	2.50	6.50	10.42
18	20	2.00	10.00	8.53
19	161	3.50	13.00	14.07
20	14	1.50	8.00	6.60
21	494	1.50	8.00	6.60
22	214	1.50	6.00	6.60

GOVERNMENT OF INDIA

CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE

LOWER GODAVARI

SUB ZONES - 3 (f)

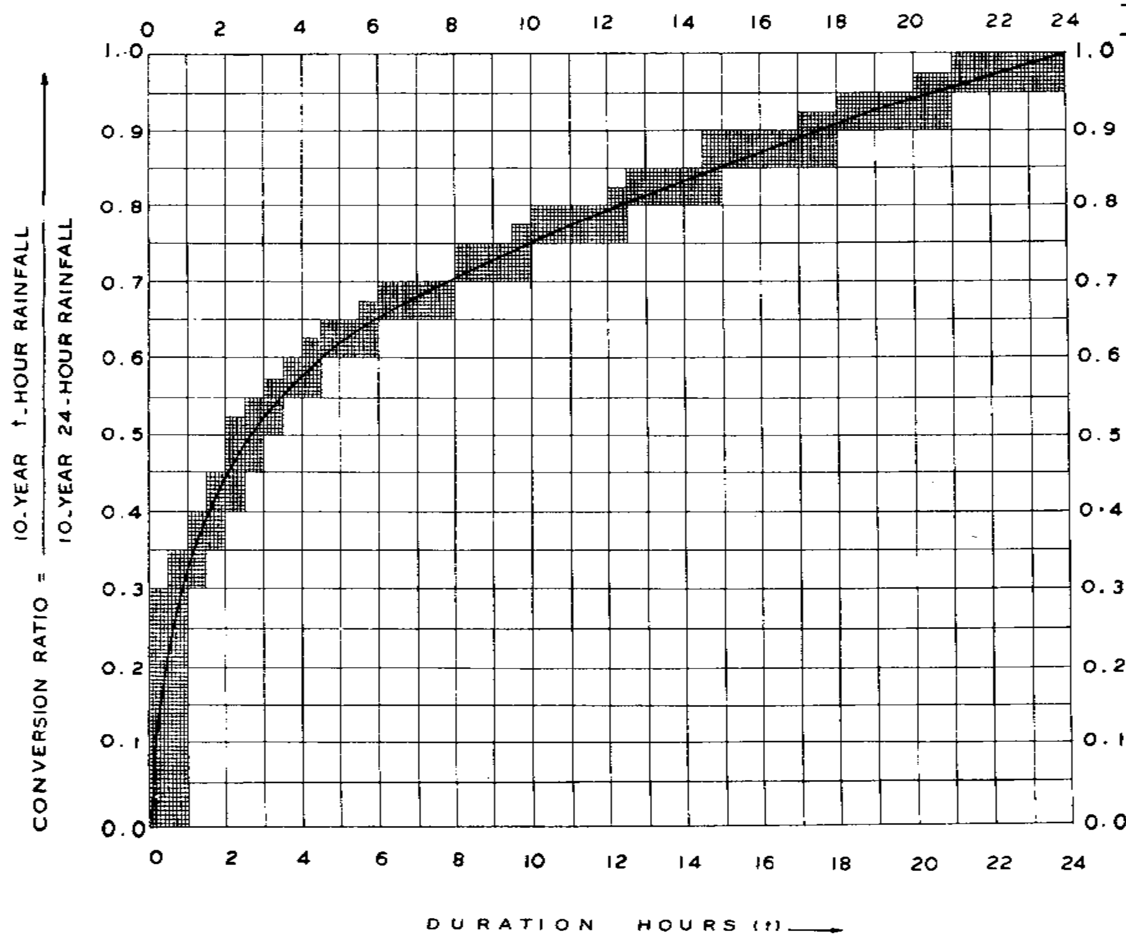
RELATION BETWEEN

t_p AND T_B

DRAWN BY – L.P. NAUTIYAL

CHECKED BY – C. S. AGARWAL.

FIG.-10



CURVE SUPPLIED BY I.M.D

RATIOS TO CONVERT 24-HOUR POINT RAINFALL TO SHORT DURATION RAINFALL

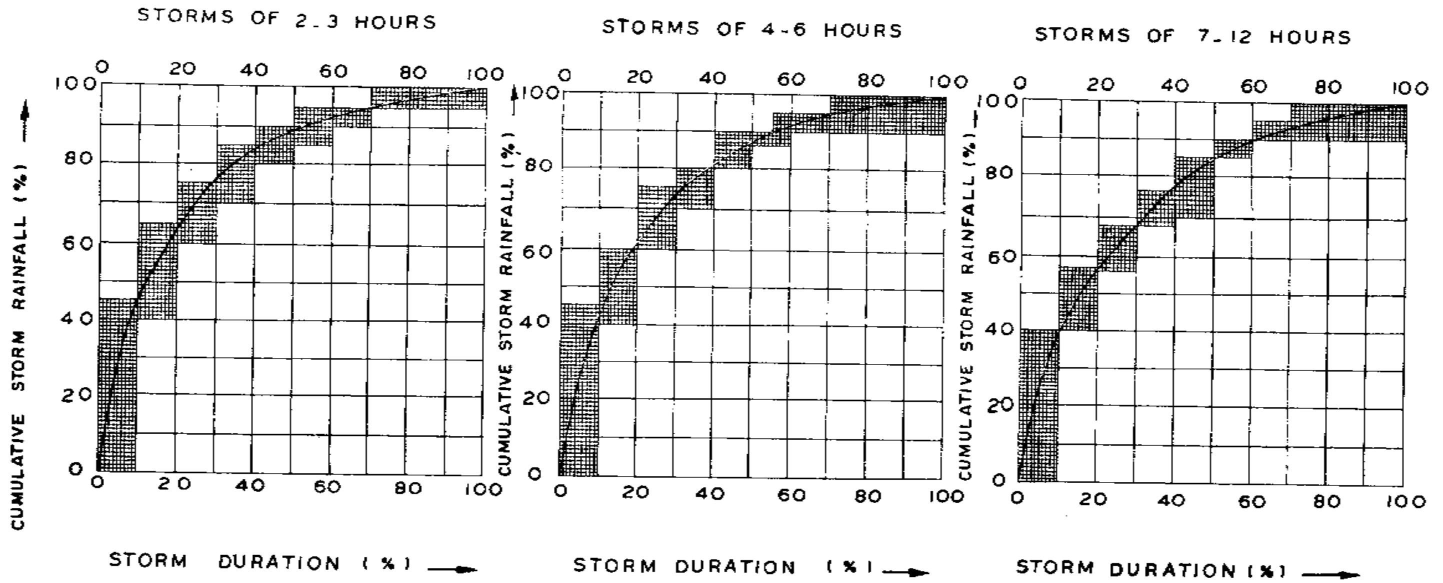
DURATION (HOURS)	RATIOS
1	0.320
2	0.445
3	0.520
4	0.575
5	0.620
6	0.650
7	0.680
8	0.705
9	0.730
10	0.750
11	0.770
12	0.790
13	0.815
14	0.835
15	0.850
16	0.870
17	0.890
18	0.910
19	0.925
20	0.945
21	0.960
22	0.970
23	0.985
24	1.000

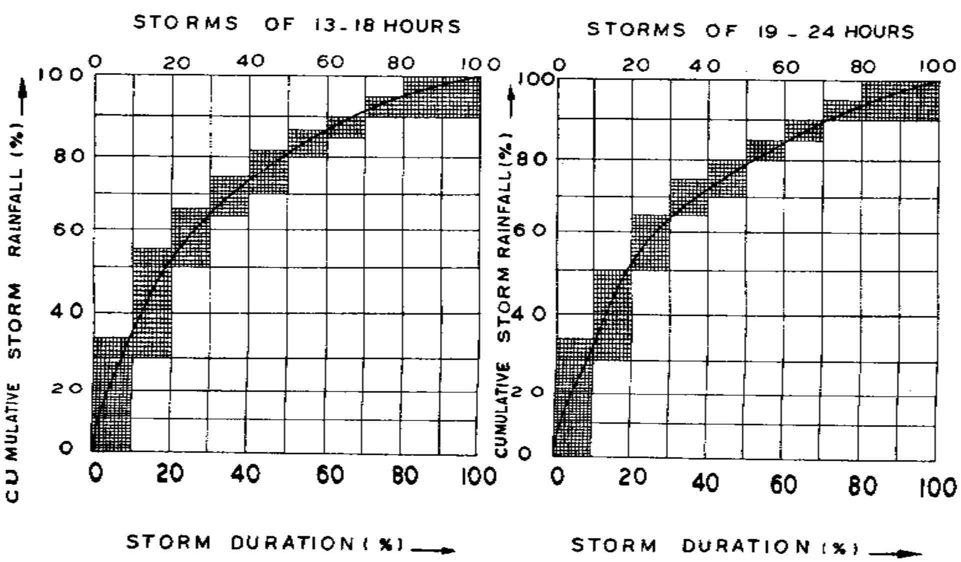
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

LOWER GODAVARI
SUB ZONE - 3 (f)
DURATION VS. CONVERSION RATIO

DRAWN BY - L. K. PANT
CHECKED BY - C.S. AGARWAL

FIG._ 11.





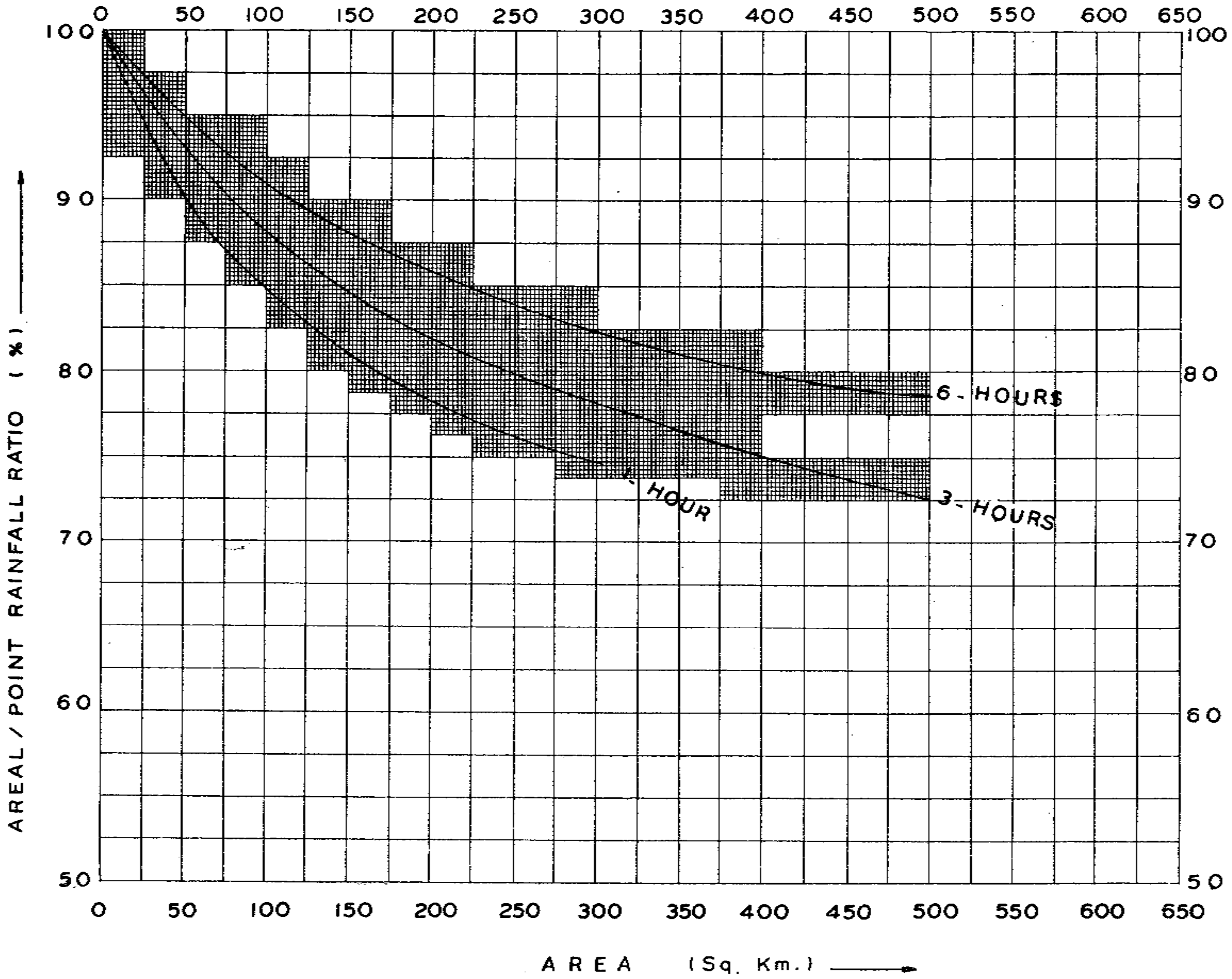
NOTE _

REFER ANNEXURE 4·1 FOR TIME DISTRIBUTAON CO.EFFICIENTS (%) OF CUMULATIVE HOURLY RAINFALL FOR STORMS OF DURATICNS 2, 3, 4 .... 23, 24 HOURS.

CURVES SUPPLIED BY I.M.D

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (REGIONAL STUDIES) DTE.	
LOWER GODAVARI SUB ZONE - 3 (f) MEAN AVERAGE TIME DISTRIBUTION CURVES OF STORMS OF VARIOUS DURATION	
DRAWN BY_ L. P. NAUTIYAL	CHECKED BY- L. EMMANUEL

FIG.-12(a).



NOTE –

i) REFER ANNEXURE 4.2 FOR AREAL REDUCTION FACTORS (%) FOR POINT TO AREAL RAINFALL FROM 1 TO 24 HOURS FOR CATCHMENT AREA FROM 50 TO 2000 SQ. KM.

ii) REFER FIG.-12(b) FOR AREAL TO POINT RAINFALL RATIOS FOR DURATIONS 12-HOURS AND 24-HOURS

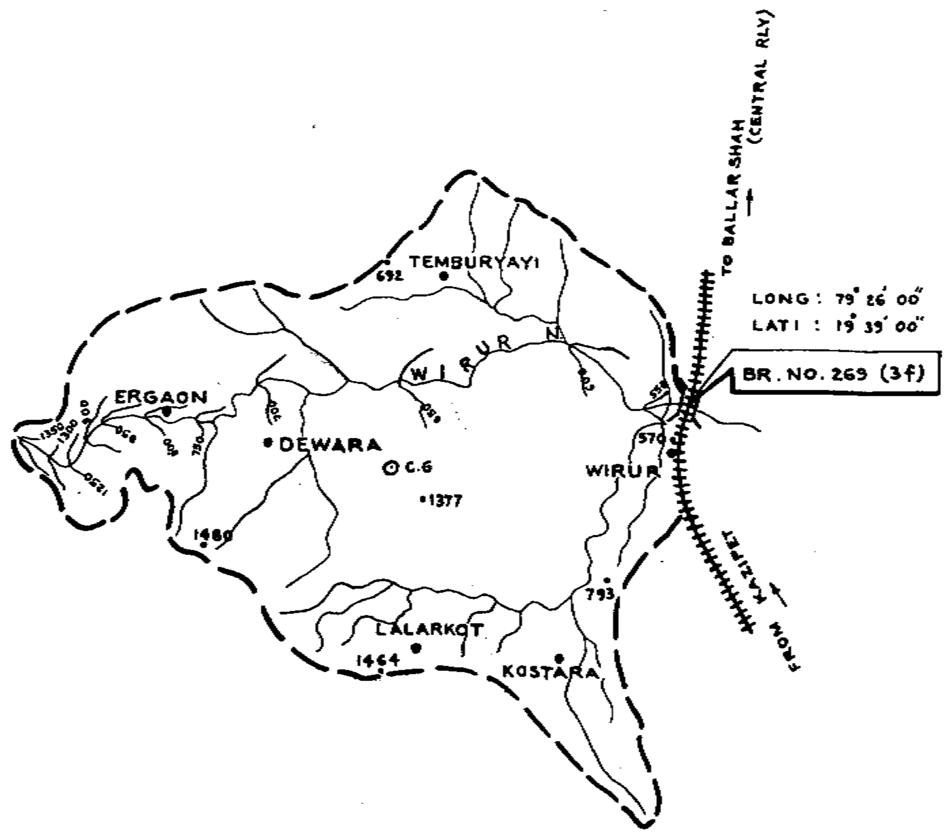
CURVE SUPPLIED BY I.M.D

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

LOWER GODAVARI
SUB ZONE – 3 (f)
POINT TO AREAL RAINFALL RATIO
FOR 1-Hr, 3-Hrs. & 6-Hrs.
(%)

DRAWN BY –	CHECKED BY –
L.P. NAUTIYAL	VINOD KAUL

FIG. - A.1.



NOTE

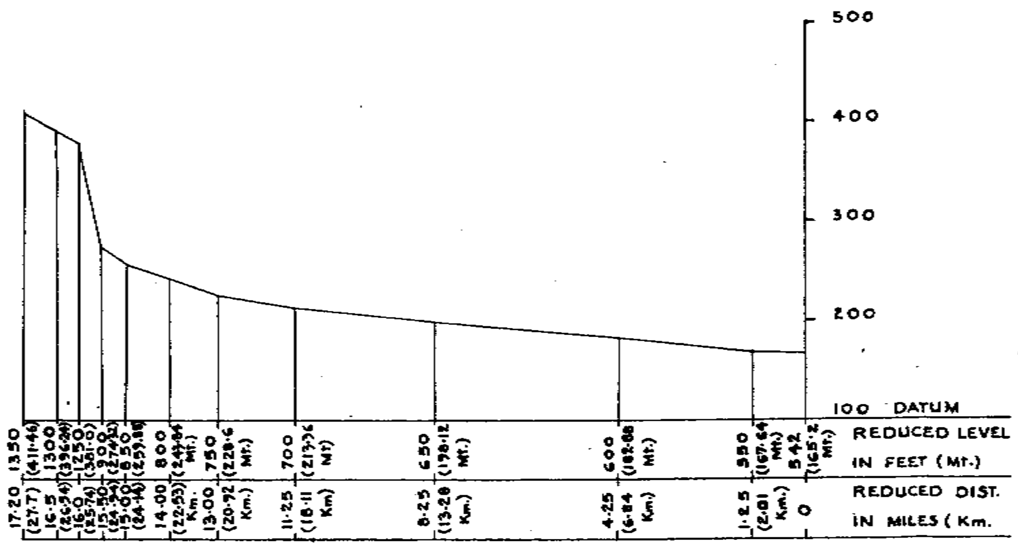
1. ALL LEVELS CORRESPOND TO G.T.S. DATUM.

LEGEND

1. CATCHMENT BOUNDARY
2. RAILWAY LINE
3. RIVERS
4. RAINGAUGE STATIONS
5. SPOT LEVELS IN FEET — • 570
6. CENTRE OF GRAVITY — C.G
7. CONTOURS — 1200

DETAILS OF CATCHMENT AREA

1. AREA OF THE CATCHMENT ---- 242·00 SQ. Km.
2. SHAPE OF THE CATCHMENT -- FAN.
3. L ---------------- 27·70 Km.
4. L_c ---------------- 11·20 Km.
5. W_c ---------------- 14·10 Km.
6. Seq. ------------ 3·87 Mt/Km.



LONGITUDINAL SECTION OF WIRUR NALLA

SCALE

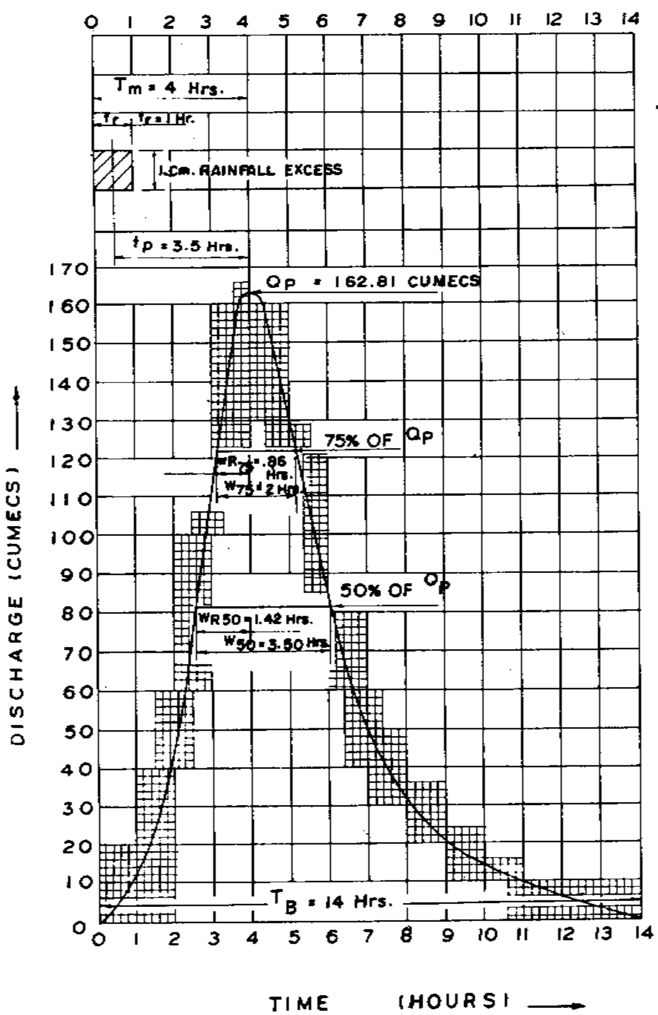
NOT TO THE SCALE.

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DIRECTORATE

CATCHMENT AREA PLAN OF BR. NO. 269 AT MILE 331/1-2 ON KAZIPET - BALLARSHAH SECTION CENTRAL RAILWAY (SUB ZONE - 3f)

DRAWN BY:	CHECKED BY:
L. K. PANT	VINOD KAUL

FIG._ A. 2



SYNTHETIC U. G. PARAMETERS

1. C. AREA 242.00 Km^2
2. t_r = 1.00 HOUR
3. Q_p = 162.81 CUMECS
4. q_p = 0.67 CUMECS
5. t_p = 3.50 HOURS
6. T_m = 4.00 HOUR
7. T_B = 14 HOURS
8. W_{50} = 3.50 HOURS
9. W_{75} 2.00 HOURS
10. $W_{R_{50}}$ = 1.42 HOURS
11. $W_{R_{75}}$ = 0.86 HOURS
12. d = 1.00 Cm.

$$\Sigma Q_i = \frac{A \times d}{t_r \times 0.36}$$

$$= \frac{242 \times 1.00}{1.00 \times 0.36}$$

$$= 672 \text{ CUMECS}$$

1. HOUR SYNTHETIC U.G PARAMETERS

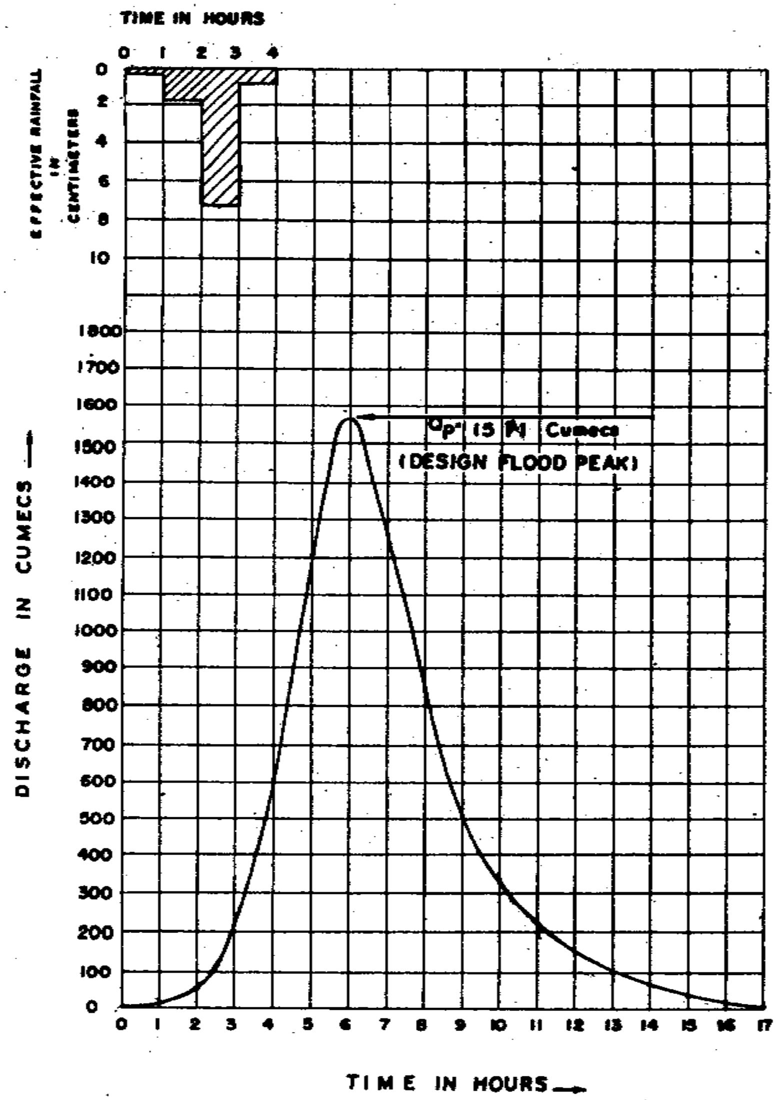
0	0
1	11.00
2	44.00
3	110.00
4	163.00
5	128.00
6	84.00
7	49.00
8	32.00
9	21.00
10	13.50
11	9.00
12	5.50
13	2.00
0	0
	672.00 CUMECS

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

LOWER GODAVARI
SUB ZONE - 3 (f)
SYNTHETIC UNIT HYDROGRAPH
OF BRIDGE NO.-269

DRAWN BY_ L.P. NAUTIYAL
CHECKED BY_ VINOD KAUL.

FIG. A.3



NOTE –

REFER ANNEXURE 5.4 FOR COMPUTATION OF DESIGN FLOOD HYDROGRAPH.

CATCHMENT AREA = 242 Sq. Km.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (REGIONAL STUDIES) DTE.	
LOWER GODAVARI SUB ZONE - 3 (f) DESIGN FLOOD HYDROGRAPH OF BRIDGE NO. - 269	
DRAWN BY — L. K. PANT	CHECKED BY — VINOD KAUL

NAMES OF THE OFFICIALS ASSOCIATED

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(Storm studies)

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3.	Sh. C.S. Jha	Asst. Meteorologist
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6.	Sh. P.K. Sharma	S.A.
7.	Sh. Greesh Kumar	S.A.
8.	Sh. J.D. Mahato	Admn. Asstt.
9.	Sh. Raju Bhargav	Draughtsman

b) Research Design and Standards Organization
(Guidance and supervision in data collection)

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(Hydrological studies and preparation of report)

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10.	Sh. L.P. Nautiyal	-------do-------
11.	Sh. L.K. Pant	-------do-------
12.	Smt. Shashi Gupta	Personal Assistant

LIST OF FLOOD ESTIMATION REPORTS PUBLISHED

A. UNDER SHORT TERM PLAN

1.	Estimation of Design Flood Peak	(1973)

B. UNDER LONG TERM PLAN

1.	Lower Ganga Plains subzone-1(g)	(1978)
2.	Lower Godavari subzone-3(f)	(1981)
3.	Lower Narmada & Tapi subzone-3(b)	(1982)
4.	Mahanadi subzone-3(d)	(1982)
5.	Upper Narmada & Tapi subzone-3(c)	(1983)
6.	Krishna & Penner subzone-3(h)	(1983)
7.	South Brahmaputra subzone-2(b)	(1984)
8.	Upper Indo-Ganga Plains subzone-1(e)	(1984)
9.	Middle Ganga Plains subzone-1(f)	(1985)
10.	Kaveri Basin subzone-3(i)	(1986)
11.	Upper Godavari subzone-3(e)	(1986)
12.	Mahi & Sabarmati subzone-3(a)	(1987)
13.	East Coast subzone-4(a), (b) & (c)	(1987)
14.	Sone subzone-1(d)	(1988)
15.	Chambal subzone 1(b)	(1989)
16.	Betwa subzone 1(c)	(1989)
17.	North Brahmaputra subzone 2(a)	(1991)
18.	West Coast Region subzone 5(a) & (b)	(1992)
19.	Luni subzone 1(a)	(1993)
20.	Indravati subzone 3(g)	(1993)
21.	Western Himalayas. zone-7	(1994)

C. REVISED UNDER LONG TERM PLAN

1.	Lower Ganga Plains subzone-1(g)	(1994)
2.	Lower Godavari subzone-3(f)	(1995)