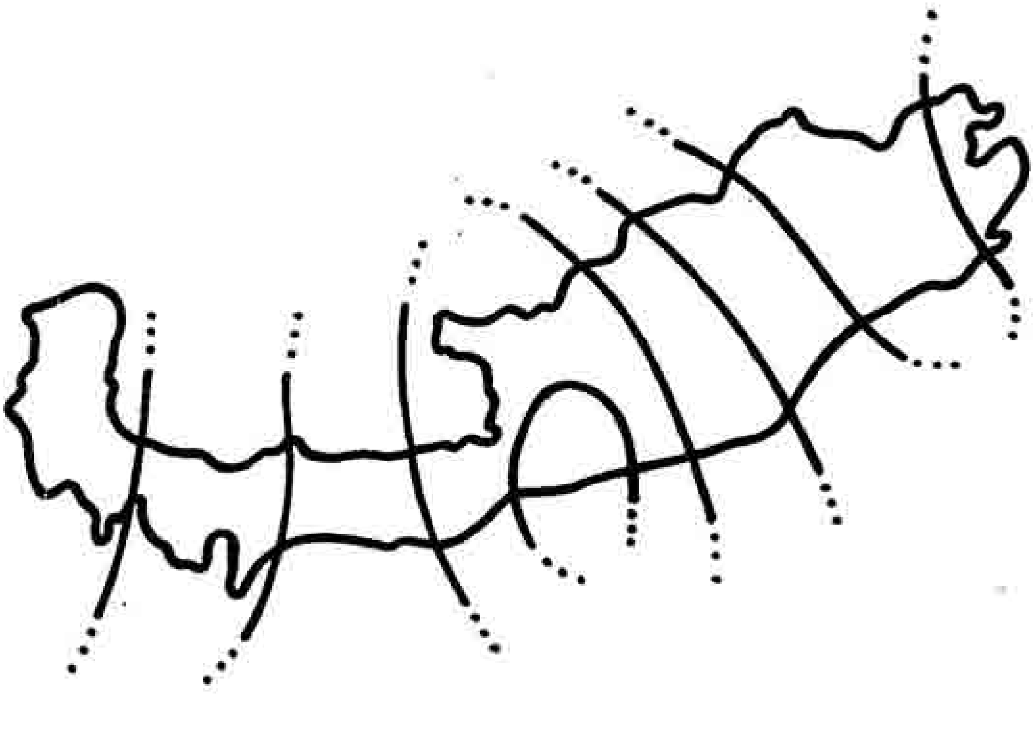
उत्तरी-ब्रह्मपुत्र (उप-अंचल-2ए) की बाढ़ आकलन का विवरण

यूनिट जलारेख सिद्धान्त पर आधारित एक पद्धति

FLOOD ESTIMATION REPORT FOR NORTH BRAHMAPUTRA BASIN (SUBZONE-2a)

A METHOD BASED ON
UNIT HYDROGRAPH PRINCIPLE



HYDROLOGY (SMALL CATCHMENTS)
HYDROLOGY STUDY ORGANISATION
CENTRAL WATER COMMISSION
NEW DELHI

A JOINT WORK OF
CENTRAL WATER COMMISSION
RESEARCH DESIGNS AND
STANDARDS ORGANISATION
AND INDIA METEOROLOGICAL DEPTT.
AND MIN. OF SURFACE TRANSPORT

FLOOD ESTIMATION REPORT FOR NORTH BRAHMAPUTRA SUB ZONE 2(A) WAS PLACED BEFORE FLOOD ESTIMATION PLANNING AND COORDINATION COMMITTEE IN ITS 49TH MEETING HELD ON 24TH AND 25TH OCTOBER 1990 AT GUWAHATI

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FLOOD ESTIMATION REPORT FOR NORTH BRAHMAPUTRA SUBZONE 2(a)

A METHOD BASED ON UNIT HYDROGRAPH PRINCIPLE
DESIGN OFFICE REPORT NO. NB/18/1991

HYDROLOGY (SMALL CATCHMENTS) DIRECTORATE
CENTRAL WATER COMMISSION
NEW DELHI

1991

F O R E W O R D

In the recent years considerable advances have taken place in the field of Hydrology and these are being applied to the design of major projects. However, Hydrologic design of structures like road, Railway bridges, cross drainage works, small irrigation tanks is not receiving comparable attention. Consequently, the waterway and other parameters provided in these bridges prove, in many a case, grossly inadequate. The Committee of Engineers set up by the Government of India in 1957 under the chairmanship of Dr. A.N.Khosla went into this problem and after reviewing the methods available for estimating the design flood discharge, recommended the adoption of rational methodolgy, involving use of design storms and unit hydrographs for the estimation of design floods. This methodology is not normally adopted for small and medium structures, partly due to lack of adequate rainfall and runoff data for analysis and partly due to the time and cost involved in such analysis. For overcoming these problems and as a follow up on the recommendations of the Committee of Engineers, four organisations concerned with the design of bridges, viz., Research Designs and Standards Organisation of the Ministry of Railways, the Ministry of Surface Transport, the India Meteorological Department and Central Water Commission have got together for a joint effort at collecting rainfall-runoff data for a period of about 5 years in the catchments of small and medium bridges, analysing the data and developing a rational methodology based on unit hydrograph. This methodology would enable, through a set of charts and graphs, quick estimation of design flood for ungauged catchments.

The data is being collected by both the Ministry of Railways and the Central Water Commission (on behalf of the Ministry of Surface Transport). The India Meteorological Department has analysed the rainfall data and the Central Water Commission developed the unit hydrograph based methodolgy.

Since it would be impracticable and grossly erroneous to attempt development of a single set of reference charts and graphs for the whole country, the country has been divided into 26 hydrologically homogeneous subzones. So far studies on 18 subzones have been completed and 16 reports covering these studies have been brought out.

The present report is the 17th in this series and covers the studies on North Brahmaputra Sub-zone 2(a). The methodologies contained in these reports will drastially reduce the time and cost involved in the hydrologic design of small and medium bridges.

In order to familiarise the design and construction engineers of various organisations with the methodology developed, CWC has conducted workshops at Calcutta, Bhubaneswar, Guwahati, Patna, Bhopal, Bangalore, Lucknow, Hyderabad and Madras. Similar workshops are also being planned in other regions of the country.

I am sure that this very useful report would be widely referred to by the designers of small and medium bridges in this zone.

I would like to place on record my appreciation of the excellent cooperative effort of the officers and staff of the four organisations mentioned above in producing this report.

MSReddy

(M.S. REDDY)
Member (Water Planning)
Central Water Commission

New Delhi.
January 1991

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 under-estimation or over-estimation of design flood resulting in the loss and destruction 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 forumlae do not take into account the basic meteorologic factor of storm rainfall components and other physiographic and hydrologic 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 Systematic and sustained collection of hydro-meteorological data at selected catchments in different climatic zones of India. The committee felt that design discharge should be the 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 year 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 based on the ground and meteorological characterstics obtained on the basis of design storm"

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 become necessary for hydro-meteorologically homogeneous regions in the country. Broadly two main regional approaches are open for adoption depending on the availability of the storm rainfall and flood data. The first approach needs long term discharge 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 runoff data of the representative catchments over a period of 5 to 10 years to develop a regional "rainfall-loss-rate runoff(UH) model" and long term rainfall records at a large number of stations to develop "design storm values". This approach has been adopted in the prepration of flood estimation reports under short term plan and for each of the 22 sub-zones under long term plan. For this purpose, the country has been devided into 26 hydrometeorologically homogeneous subzones.

Systematic and sustained collection of Hydro-meteorological data at the representative catchment 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 Designs and Standards Organisation of the Ministry of Railways. Similarly the Ministry of Transport has undertaken the collection of data for 45 catchments through Central Water Commission since 1979. Such rainfall and runoff data was supplied to Hydrology(Small Catchments) Directorate of Central Water Commission and rainfall data alone to India Meteorological Department (IMD) for necessary studies.

Hydrology (Small Catchments) Directorate of CWC has carried out the analysis of selected concurrent rainfall and floods for the gauged catchments to derive unit hydrographs of mostly 1-hr unit duration on the basis of data of rainfall, gauge and discharges collected during the monsoon season. The bridges and floods wing of RDSO has provided assistance as required from time to time in interpretation of data, removing inconsistencies and other additional information during analysis stage. Representative 1-hr. unit hydrographs have been obtained for each of the gauged catchments. The characterstics of the catchments and their unit hydrographs prepared for several catchments in a subzone have been correlated by regression analysis and the equations for synthetic unit hydrographs for the subzone were derived. The loss rate and base flow studies were also carried out.

Studies of Rainfall-Depth-Duration-Frequency, point to areal ratios and time distribution of storm were carried out by Hydromet Cell of IMD and results were provided to Hydrology (SC) Dte., for preparing the full report for the subzone. The reports are approved by the Flood Estimation Planning and Coordination Committee (FEPCC) during their meetings. A "Foreword" as provided in the report by Member CWC recommended the extensive use of the report for estimation of design flood from small and medium catchments. The reports are published by the Central Water Commission.

Flood Estimation Reports for the following subzones have already been prepared, approved by FEPCC and published and circulated to various States and Central agencies for the use of design engineers:

A. UNDER SHORT TERM PLAN

1. Estimation of Design Flood Peak (1973)

B. UNDER LONG TERM PLAN

1. Lower Gangetic 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 Basin 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)

The present report for North Brahmaputra subzone - 2(a) is based on the detailed rainfall and runoff studies of 21 representative catchments. The data at each of the 28 catchments was collected for a period varying from 1 to 11 years by North Frontier RailWays under the guidance of R.D.S.O. Besides this, the data of 180 ordinary raingauge stations maintained by IMD/States alongwith data of 62 self-recording raingauge stations maintained by IMD/Railways has been made use of in preparation of this report.

The North Brahmaputra subzone- 2(a) report deals with the estimation of design flood of 25-yr., 50-yr. and 100-yr. return periods for small and medium catchments in this subzone covering mainly parts of Assam, and small portion of Sikkim, Arunachal Pradesh and West Bengal based on design storm rainfall and synthetic unitgraph. The report is divided into five parts. The part I deals with the summary and contents of the approaches of design flood estimation. Illustartive examples covering both the approaches are also given. General description of the subzone detailing locatons of gauging sites, river systems, rainfall, temperature and various types of soil is given in part II. It also brings out the SUH relations of the subzone along with the various regression equations for estimating Q_{25}, Q_{50} and Q_{100}. The storm studies carried out by IMD are dealt in part III of the report. The part IV is the portion where the step by step procedure to compute design flood is described. The last part i.e. part V describes the limitations, assumptions and conclusions made in the report.

The report on subzone-2(a) is recommended for estimation of design flood from small and medium catchments varying in areas from 25 to 2500 sq. km. This report may also be used for catchment areas upto 5000 sq. km. judiciously after comparison of loss rate values in the neighbouring catchments having more or less similar characteristics.

This report is a joint effort of Central Water Commission of Ministry of Water Resources, Research Designs & Standards Organisation of Ministry of Railways, Roads and Bridges wing of Ministry of Surface Transport and Hydromet Directorate of India Meteorological Department, Ministry of Science and Technology.

The methodology adopted and conclusions arrived at are subject to periodical review and revision in the light of further data being collected and analysed as also the advancements in theory and techniques.

Sd/-

(R.V. GODBOLE)
DIRECTOR, HYDROLOGY (SC) DTE.
CENTRAL WATER COMMISSION

CONTENTS

PART - IV

UTILITY OF REPORT

PART - V

ASSUMPTIONS, LIMITATIONS AND CONCLUSIONS

LIST OF TABLES, PLATES, FIGURES AND ANNEXURES

TABLES

PLATES

FIGURES

ANNEXURES:

SYMBOLS AND ABBREVATIONS

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 sq.km.
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 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(SC),CWC	Hydrology (Small Catchments) 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-hours 50-yr 24-hours 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. (D.R.H.)	Surface Runoff Hydrograph (Direct Runoff Hydrograph)
Sec	Seconds
Sq	Square
Sq.km	Square Kilometres, Km^2
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
t_p	Time from the centre of Unit Rainfall Duration to the Peak of Unit Hydrograph in hours
t_r	Unit Rainfall Duration adopted in a specific study in hours
U.G.	Unit Hydrograph
W_{50}	Width of U.G. measured at 50% peak Discharge Ordinate (Q_p) in hours.

W_{75}	Width of the U.G. measured at 75% peak Discharge Ordinate (Q_p) in hours.
W_{R50}	Width of the rising side of U.G. measured at 50% of peak Discharge Ordinate (Q_p) in hours.
W_{R75}	Width of the rising side of U.G. measured at 75% of peak Discharge Ordinate (Q_p) in hours.
%	Percent.
<	Summation

PART - I

SUMMARY AND CONTENTS OF APPROACHES

1.0 Approaches for design flood estimation:

The Flood Estimation report for North Brahmaputra Sub-Zone 2(a) may be used for estimation of design flood (25-yr, 50-yr and 100-yr) for ungauged and inadequately gauged catchment in the subzone. There are two approaches discussed in the report namely (a) Detailed approach (b) Simplified approach. To elucidate the procedure, an illustrative example is given below with relevant details by both the approaches.

1.1 Detailed SUH approach :

The various steps necessary to estimate the design flood peak/design flood hydrograph are as under :

i) Preparation of catchment area plan of the ungauged catchment in question.

ii) Determination of physiographic parameters viz: catchment area (A), Length of the longest stream (L) and equivalent stream slope (S).

iii) Determination 1-hr. SUG parameters i.e. q_p, Q_p, t_p, T_m, W_{50}, W_{75}, W_{R50}, W_{R75} & T_B.

iv) Drawing of SUG.

v) Estimation of design storm duration (TD)

vi) Estimation of point rainfall and areal rainfall for design storm duration (TD) and to obtain rainfall increments for unit duration intervals.

vii) Distribution of areal rainfall during the design storm duration (TD) and to obtain rainfall increments for unit duration intervals.

viii) Estimation of effective rainfall units by substracting the prescribed design loss rate from the rainfall increments.

ix) Estimation of base flow.

x) Computation of design flood peak.

xi) Computation of design flood hydrograph.

1.1.1 Illustrative Example:

A typical example with reference to Railway Bridge Catchment (treated as ungauged) is worked out for illustrating the procedure. The particulars of the catchment under study are as under:

i)	Name & Number of sub-zone	North Brahmaputa 2(a)
ii)	Name of site (i.e. point of study)	Rly.Br. 373
iii)	Name of Rly Section	Alipurdwar - Bongaigaon (NFR)
iv)	Name of Tributary	GANGIA
v)	Shape of catchment	Elongated
vi)	Location	Lat 26°-23'-10" Long 90°-07'-10"
vii)	Topography	Moderate slope

The procedure is explained stepwise:

Step-1:- Preparation of Catchment Area Plan:

The point of interest (Railway Bridge Site in this case) was located on the Survey of India toposheet and catchment boundary was marked using the contours along the ridge line and also from the spot levels in the plains. A catchment area plan (Fig. A-1) showing the rivers, contours and spot levels was prepared.

Step-2: Determination of Physiographic Parameters:

The following physiographic parameters were determined from the catchment area plan:

1)	Area (A)	595.70 sq km
2)	Length of the longest stream (L)	75.62 km
3)	Length of the longest stream from a point opposite C.G. of catchment to point of study (Lc)	47.14 km
4)	Equivalent stream slope (S)	1.701 m/km

Step-3: Computation of equivalent stream slope:

Following methods are adopted for computation of Slope(s):

(a) By Graphical Method:

Draw a longitudinal section of the longest main stream from contours crossing the stream and the spot levels along the banks from the sources to the point of study from the catchment plan as shown in Fig A-1. Draw a sloping line by trial to replace the plotted 'L' section having different slopes such that the areas below and above the line with reference to origninal plot (of sloping lines) are equal. Then compute the slope (S) on this line.

(b) By Analytical Method:

The computations of (S) shown in Table T-1 with reference to Fig A-1 are self-explanatory.

Step-4:- Derivation of Synthetic (1-hr.) Unitgraph Parameters:

The following equations appearing in para 2.3.13 were used to compute the Synthetic Unitgraph parameters with the known values of A,L and S:

i) $q_p = 2.272\ (LLc/S)^{-0.409}$

$= 2.272\ (2095.70)^{-0.409}$

$= 0.0995$ Cumecs per sq km say 0.10 Cumecs per sq km.

ii) $t_p = 2.164\ (q_p)^{-0.940}$

$= 2.164\ (0.100)^{-0.940}$

$= 18.85$ hrs

(rounded off to 18.50 hrs.)

iii) $W_{50} = 2.084\ (q_p)^{-1.065} = 2.084(0.100)^{-1.065} = 24.20$ hrs

iv) $W_{75} = 1.028\ (q_p)^{-1.071} = 1.028(0.10)^{-1.071} = 12.10$ hrs.

v) $W_{R50} = 0.856\ (q_p)^{-0.865} = 0.856(0.10)^{-0.865} = 6.25$ hrs.

vi) $W_{R75} = 0.440\ (q_p)^{-0.918} = 0.440(0.10)^{-0.918} = 3.64$ hrs.

vii) $T_B = 5.428(t_p)^{0.852} = 5.428(18.5)^{0.852}$
$= 65.20$ hrs.

Say 65.00 hrs.

viii) $t_m = t_p + t_r/2 = 18.50+0.50=19.00$ hrs

ix) $Q_p = q_p \times A = 0.10 \times 595.70$
$= 59.57$ Cumecs.

Estimated parameters of unitgraph in step-4 were plotted to scale 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 = tr = 1 hr interval were summed up and multiplied by tr (=1) i.e <Qi ti = 1654.72 m^3/s as shown in Fig F-2 and compared with the volume of 1.00 cm Direct Runoff Depth over the catchment with the Formula <Qi*ti = A.d/ti*0.36

Where A = Catchment area in Sq. Km.

d = 1.0 cm depth

ti = tr (the unit duration of the UG) = 1 hr.

$$\Sigma Qi*ti = \frac{A * d}{0.36 * tr} = \frac{595.70 * 1}{0.36 * 1} = 1654.72$$

Thus the unitgraph so drawn was found to be in order.

In case the <Qiti for the unithraph drawn is higher or lower than the volume worked out by the above formulae, then preferably falling limb and/or rising limb may be suitably modified keeping the points of the synthetic parameters as per the calculation to get the correct volume of the unitgraph.

Step-5: Estimation of Design Storm Duration:

The Design Storm Duration (T_D) is equel to T_B as recommended in Section 3.1.0.

Adjusting the design storm duration limited to 24 hour, the adopted design storm duration (T_D) is 24.0 hrs.

Step-6: Estimation of Point Rainfall and Areal Rainfall:

The catchment under study was located on plate - 9 showing 50-yr 24-hr point rainfall. The point rainfall is found to be 35.00 cm. Since T_D = 24 hrs, 50-yr 24-hr point rainfall is reckoned as 35:00 cm.

Areal reduction factor of 0.84 corresponding to a catchment area of 595.70 sq.km for T_D = 24-hr. was interpolated from Table 6 or Fig 11(b) for conversion of point to areal rainfal. Hence 50-yr 24-hr areal rainfall = 35.00 x 0.84 cm = 29.40 cm.

Note : When the catchment under study falls between two isohyets the point rainfall may be computed for the catchment taking into account both the isohyets.

Step-7: Time Distribution of Areal Rainfall:

50-yr 24-hr areal rainfall = 29.40 cm was distributed with the distribution coefficients (col.24 of Table T-2) or from mean average time distribution curve for storms of 19-24 hrs in Fig 12 corresponding to 24-hrs to get 1-hr rainfall increments as follows:

Duration 1	Distribution coefficient 2	Areal Rainfall (cms) .3	Hourly rainfall increments 4
1	0.13	3.82	3.82
2	0.25	7.35	3.53
3	0.32	9.41	2.06
4	0.40	11.76	2.35
5	0.47	13.82	2.06
6	0.52	15.29	1.47
7	0.56	16.46	1.17
8	0.61	17.93	1.47
9	0.65	19.11	1.18
10	0.69	20.29	1.18
11	0.73	21.46	1.17
12	0.76	22.34	0.88
13	0.79	23.23	0.89
14	0.81	23.81	0.58
15	0.84	24.70	0.89
16	0.86	25.28	0.58
17	0.88	25.87	0.59
18	0.90	26.46	0.59
19	0.92	27.05	0.59
20	0.93	27.34	0.29
21	0.95	27.93	0.59
22	0.97	28.52	0.59
23	0.98	28.81	0.29
24	1.00	29.40	0.59

Step-8: Estimation of Effective Rainfall Units:

A design loss rate of 0.24 cm/hr as recommended in para 2.3.11 has been adopted.

The following table shows the computation of 1-hr effective rainfall units in col. (4) by subtracting the design loss rate in col. (3) from 1-hr rainfall increments in col. (2).

Time hrs	Rainfall incre- ments (cms)	Design loss rate cm/hr	Effective Rainfall (col.2-col.3) (cms)
1	2	3	4
1	3.82	0.24	3.58
2	3.53	0.24	3.29
3	2.06	0.24	1.82
4	2.35	0.24	2.11
5	2.06	0.24	1.82
6	1.47	0.24	1.23
7	1.17	0.24	0.93
8	1.47	0.24	1.23
9	1.18	0.24	0.94
10	1.18	0.24	0.94
11	1.17	0.24	0.93
12	0.88	0.24	0.64
13	0.89	0.24	0.65
14	0.58	0.24	0.34
15	0.89	0.24	0.65
16	0.58	0.24	0.34
17	0.59	0.24	0.35
18	0.59	0.24	0.35
19	0.59	0.24	0.35
20	0.29	0.24	0.05
21	0.59	0.24	0.35
22	0.59	0.24	0.35
23	0.29	0.24	0.05
24	0.59	0.24	0.35

The column (2) in above table is taken from col. (4) of table in Step - 7.

Step-9: Estimation of Base Flow:

The design base flow of 0.05 cumecs per sq km has been adopted as recommended in para 2.3.12.

Total Base Flow = A * Rate of base flow
= 595.70 * 0.05 = 29.78 cumecs.

Step-10: Estimation of 50-yr Flood (Peak only):

For the estimation of the peak discharge the effective rainfall units were re-arranged against the ordinates such that the maximum effective rainfall was placed against the maximum U.G. ordinate, the next lower value of rainfall effective against the next lower value of U.G. ordinate and so on as shown in col. (2) and (3) in the following table. Summation of the product of U.G. ordinates and the rainfall gives the total direct runoff as under.

Time (hrs)	U.G. ordinate cumecs	1-hr effec. rainfall (cms)	Direct Runoff (cumecs)
1	2	3	4
13	32.00	0.05	1.60
14	37.00	0.35	12.95
15	43.00	0.64	27.52
16	49.50	0.94	46.53
17	55.50	1.82	101.01
18	58.00	2.11	122.38
19	59.57	3.58	213.26
20	58.70	3.29	193.12
21	57.00	1.82	103.74
22	55.00	1.23	67.65
23	52.75	1.23	64.88
24	50.75	0.94	47.71
25	48.75	0.93	45.34
26	46.90	0.93	43.62
27	45.00	0.65	29.25
28	43.50	0.65	28.28
29	41.60	0.35	14.56
30	40.00	0.35	14.00
31	38.50	0.35	13.48
32	37.00	0.35	12.95
33	35.50	0.35	12.42
34	34.25	0.34	11.65
35	32.75	0.34	11.14
36	31.50	0.05	1.58
		Total	1240.60
		Base Flow	29.78
		50-yr Flood Peak	1270.38

Step-11: Computation of Design Flood Hydrograph:

The 1-hr effective rainfall sequence shown in col. (3) of Table in Step-10 was reversed to obtain the critical sequence as shown below:

Time in hrs	Critical 1-hr effective rainfall sequence cms
(1)	(2)
1	0.05
2	0.34
3	0.34
4	0.35
5	0.35
6	0.35
7	0.35
8	0.35
9	0.65
10	0.65
11	0.93
12	0.93
13	0.94
14	1.23
15	1.23
16	1.82
17	3.29
18	3.58
19	2.11
20	1.82
21	0.94
22	0.64
23	0.35
24	0.05

For computation of design flood hydrograph, the U.G. ordinates for 1-hr interval were tabulated in col(2) of Table T-3 against time (hrs) in col. (1). The critical sequence of 1-hr effective rainfall units were entered in col.3 to 26, horizontally as shown in Table T-3. The direct runoff resulting from each of the 1-hr effective rainfall units was obtained by multiplying the 1-hr effective rainfall with the synthetic 1-hrs U.G. ordinates in col. (2) and direct runoff values were entered in vertical columns against each unit with a successive lag of 1-hr since the unit duration of S.U.G. is 1-hr. The direct runoff so obtained are shown in col (3) to (26). The direct runoff were added horizontally and the total direct runoff is shown in col. (27). The total base flow of 29.78 m^3/sec. was entered in col. (28), col. (29) gives (the addition of col. (27) and (28)) the design flood hydrograph ordindates. The total discharge in col. (29) were plotted against time in col. (1) to get the design flood hydrograph as shown in Fig A-3.

1.2 Simplified Approach:

In the simplified approach, the 25-yr, 50-yr and 100-yr flood peak is only estimated on the basis of regression relationship. Flood peak, with physiographic parameters and corresponding 25-yr, 50-yr and 100-yr TD-hr point rainfall as read from the isopluvial maps (plates 8,9, 10) supplied by the I.M.D. are obtained by substituting the corresponding parameters in the emperical relation developed on the basis of regression analysis. 25-yr, 50-yr and 100-yr flood values for each of the 21 gauged catchment for different sizes were computed by detailed approach.

Series of Q_{25}, Q_{50} and Q_{100}, for the 21 catchments as dependent variables were related by multiple regression analysis to their respective physiographic parameters A, S and meteorologic parameter of point rainfall R_{25}, R_{50} and R_{100} as independent variables The derived flood formulae for Q_{25}, Q_{50} and Q_{100} with their respective coefficient of correlation (r) are as under:

$$Q_{25} = 0.6855(A)^{0.91839}(L)^{-0.39454}(Lc)^{-0.19945}(S)^{0.31391}(R_{25})^{1.11481} \quad r = 0.996$$

$$Q_{50} = 0.7262(A)^{0.90265}(L)^{-0.37461}(Lc)^{-0.19224}(S)^{0.31348}(R_{50})^{1.09719} \quad r = 0.997$$

$$Q_{100} = 0.8372(A)^{0.90662}(L)^{-0.36538}(Lc)^{-0.20383}(S)^{0.31028}(R_{100})^{1.05471} \quad r = 0.997$$

Where Q_{25}, Q_{50} and Q_{100} are 25-yr, 50-yr and 100-yr flood in cumecs respectively.

1.2.1 Illustrative Example:

Illustrative example for estimation of 25-yr, 50-yr and 100-yr flood for catchment area upto Rly. Br. No. 373 is considered for solution of the problem by flood formulae. The physiographic and meteorologic parameters for the catchment under study are:

A = 595.70 sq km

L = 75.62 km

Lc= 47.14 km

S = 1.701 m/km

R_{25} = 30.00 cm, R_{50} = 35.00 cm, R_{100} = 42.00 cm

$$Q_{25} = 0.6855(A)^{0.91839}(L)^{-0.39454}(Lc)^{-0.19945}(S)^{0.31391}(R_{25})^{1.11481}$$

$$= 0.6855(595.70)^{0.91839}(75.62)^{-0.39454}(47.14)^{-0.19945}(1.701)^{0.31391}(30.00)^{1.11481}$$

= 1068.62 Cumecs.

$$Q_{50} = 0.7262(A)^{0.90265}(L)^{-0.37461}(Lc)^{-0.19224}(S)^{0.31348}(R_{50})^{1.09719}$$

$$= 0.7262(595.70)^{0.90265}(75.62)^{-0.37461}(47.14)^{-0.19224}(1.701)^{0.31348}(35.00)^{1.09719}$$

= 1279.25 Cumecs.

$$Q_{100} = 0.8372(A)^{0.90662}(L)^{-0.36538}(Lc)^{-0.20383}(S)^{0.31028}(R_{100})^{1.05471}$$

$$= 0.8372(595.70)^{0.90662}(75.62)^{-0.36538}(47.14)^{-0.20383}(1.701)^{0.31028}(42.00)^{1.05471}$$

= 1566.37 Cumecs.

The percentage variations in the values of Q_{25}, Q_{50} and Q_{100} by the detailed approach and the flood formulae with respect to the flood values by detailed approach for the catchment under study are -2.61 , -0.70 and -1.24 respectively. Therefore, the flood values for 25-yr, 50-yr and 100-yr return periods estimated by the respective flood formulae are reasonable for adoption in preliminary designs.

PART - II

GENERAL DESCRIPTIONS OF NORTH BRAHMAPUTRA SUBZONE AND S.U.H. STUDIES

2.1.0 General Description of the sub-zone:

2.1.1 Location:

The North Brahmaputra subzone - 2(a) lies approximately between 88^0 and. 97^0-20 longitudes(East) and 26^0 and 29^0-25′ latitudes (North). Plate-1 shows the location of North Brahmaputra Subzone and Annexure - 1 shows the list of sub-zones in India.

The Sub-zone 2(a) is mostly bounded by international boundaries on all the four sides. It has Bhutan and China on the north, Burma on the east, Nepal on west and Bangla Desh on South-west. Sub-zone 2(b) lies adjacent to the South of Brahmaputra river.

The states covered by this subzone are Assam (Lower and Upper) part of west Bengal, Sikkim and Arunachal Pradesh. The important towns and cities in the subzone are Gangtok the capital of Sikkim, Siliguri, Itanagar, North Lakhimpur, Jalpaiguri, Tezpur, Hanagai and Anini in Arunachal Pradesh.

2.1.2 River System:

Plate-2 depicts the river system of the North Brahmaputra subzone. Of the 25 principal north bank tributaries, the Subansiri, the Manas, the Dibang, Dhansiri, Torsa, Testa are few major ones. The Brahmaputra with a total catchment of 0.94 million sq. km. is one of the biggest river in the world. The total length of the river in India is 885 km. The drainage area of the Brahmaputra basin in India is 1,95,000 sq. km The course of the Brahmaputra river in the plain divides the Brahmaputra basin into Northern and Southern Brahmaputra.Out of the total drainage area the North Brahmaputra basin has a drainage area of 1,21,444 sq.km.

The drainage areas of the river system in North Brahmaputra subzone are as under:

S.No.	Name of river/tributary	Drainage area (sq.km.)
1	2	3
1.	Tista	1,0616.74
2.	Jaldhaka	4356.87
3.	Torsa	3405.37
4.	Manas	4056.39
5.	Pagladiya	1702.68
6.	Dhansiri	1852.92
7.	Kamag	1,0766.97
8.	Subansiri	1,7427.47
9.	Dinag	1,5724.79
10.	Dibang	1,2369.50
11.	Others	3,9164.30
	Total area of North Brahmaputra Basin	1,21,444.00

2.1.3 Topography and Relief:

Plate - 3 shows the general topography of North Brahmaputra subzone - 2(a), The North Bank tributaries have comparatively moderate steep slope, meandering channels almost from the foothills, beds and banks of alluvial soils and comparatively low silt charge.

2.1.4 Rainfall:

Plate - 4 shows the normal annual rainfall of the North Brahmaputra subzone and the histograms of normal monthly rainfall at different parts. The south-west monsoon and cyclonic storm causes the rainfall in the subzone from May to October. The normal annual rainfall varies from 2000 mm to 5000 mm.

2.1.5 Temperature:

Plate-5 shows the normal annual temperature in the subzone alongwith the histograms showing the minimum, maximum and mean monthly temperature at Darjeeling and Jalpaiguri. The variation of the mean annual temperature in the Central and Western parts of subzone is between 22.5^0c to 25^0c.

2.1.6 Soil:

The subzone 2(a) comprises of variety of soils as shown in plate - 6. Broadly they can be classified as red loamy soil, brown hill soil, terai soil and alluvial soil of recent origin. The red loamy soil is found towards north-east and continues through a belt in the middle of the subzone up to Itanagar. A small patch of brown hill soil is found in the northern and western corner of the subzone. The alluvial soil is also depicted in flood plain covering north eastern part to the west all along the main river Brahmaputra touching important towns of Itanagar, Tezpur, Jalpaiguri. A belt of Terai soil runs through the middle of the subzone to the west.

2.1.7 Land use:

The land use map at plate no-7 has been prepared from the Irrigation Atlas of India 1972. The subzone 2(a) has considerable area of forests which may have undergone changes in the recent times because of more inhabitations.

2.1.8 Communications:

2.1.8.1 Railway sections:

The following railway sections of North Frontier zone partly or fully traverse the area of this subzone - 2(a).

1 SILIGURI - DARJEELING
2 NEW JALPAIGURI - HALDIBAR
3 SILIGURI JUNCTION - RANGIYA MURKONG SCLAK
4 NEWJALPAIGURI - RANGIYA AGTHERI
5 RANGAPARA - TEZPUR
6 NEW BONGAIGAON - JOGIGHOPA
7 FAKIRAGRAM - DHUBRI
8 ALIPUR DWAR - NEW GITALDAHA
9 GITALDAHA - BAMANHAT
10 NEWMAL - CHANGRA BANDHA

2.1.8.2. Highways:

The following major highways partly and fully pass through the subzone :

1. DALKHORA - SILIGURI - NH - 31
2. SILIGURI - GANGTOK - NH - 31
3. SILIGURI - COOCHBEHAR - NH - 31
4. COOCHBEHAR - GOALPARA - NH - 31
5. BONGAIGAON - DESPUR - NH - 31
6. DISPUR - TEZPUR - NH - 52
7. TEZPUR - JONAI - NH - 52
8. JONAI - BRAHMKUND - NH - 52

2.2.0 Synthetic Flood Hydrograph Studies:

2.2.1 Design Flood:

The Khosla Committee of Engineers had recommended a design flood of generally 50-year return period for fixing the waterway of the bridges. The committee of Engineers had suggested that 50-year flood may be considered as the maximum observed discharge from the yearly peak discharge records available for over 50-years. However the present Indian Railway Bridge substructure code reccommends that the design dischage may be computed statistically as a 50-yr flood using records of larger than/equal to/ less than 50-yrs. In the absense of adequate data of peak discharges, storm rainfall and runoff data for the selected catchments shall be collected for a required period and detailed studies carried out to derive the unitgraph for these catchments and to prepare storm rainfall maps for different durations. In this connection, the Committee had suggested to develop a suitable rational methodology for estimation of 50-yr flood subzonewise based on application of storm rainfall to unitgraph. In this approach, it is assumed that 50-year frequency rainfall when applied to unit hydrograph produces flood of same frequency. Recently IRC has also adopted flood peaks of 50-year frequency for design of road bridge waterways.

2.2.2 Data Required:

For conducting the unitgraph and design storm rainfall studies, the following concurrent rainfall and runoff data for a number of catchments of small and medium sizes representatively located in a subzone are required for a minimum period of 5 to 8 years during the monsoon season:

i) Hourly gauge data at the gauging site (bridge site) round the clock.

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

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

The following catchment details are also required .

iv) Catchment area plans showing the river net-work, location of raingauge stations and gauge and dischar ge sites, contours, highway and railway network, natural and man made sto-rages, habitations, forests, agricultural and irrigated areas, soils etc.

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

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

In addition to the above rainfall data of ordinary/self-recording raingauge stations maintained by India Meteorological Department is also required.

2.2.3 Data Collected:

The North East Frontier Railway under the supervision and guidance of Research Designs and Standards Organisation (RDSO) has observed and collected the required data in Section 2.2.2 for 28 catchments in the North Brahmaputra subzone 2(a) for a period ranging from 1 to 11 years. The size of the gauged catchments vary from 26.18 sq.km to 1350.00 sq.km. Concurrent rainfall, gauge and discharge data for 131 bridge catchment years from 21 catchments were available and could be utilised for the studies.

The locations of the gauging sites are shown in Plate-2. India Meteorological Department has collected the rainfall data of additional raingauge stations maintained by IMD and states falling in North Brahmaputra subzone-2(a). Central Water Commission (CWC) has prepared the detailed plans of gauged catchments showing information in 2.2.2 (iv). Table-1 shows the names of streams, railway bridge numbers with railway sections, their catchment areas, number of raingauge stations and the period of concurrent rainfall, gauge and discharge data. R.D.S.O. has made available the data collected to CWC and IMD for carrying out the studies.

2.2.4 Analysis of Data for obtaining sub-zonal synthetic unit hydrograph equations (one hour):

The synthetic unitgraph is a unitgraph of unit duration for a catchment under study obtained from the relations established between the physiographic and unitgraph parameters of the representative catchments in a hydro-meteorologically homogenous region. In order to obtain a synthetic unitgraph, the following steps have to be followed:

i) Analysis of physiographic parameters of the catchments.

ii) Scrutiny of data and finalisation of gauge discharge rating curves.

iii) Selection of flood and corresponding storm events.

iv) Computation of hourly catchment rainfall.

v) Separation of base flow and computation of direct runoff-depth.

vi) Computation of infilteration loss (ϕ-index) and 1-hourly rainfall excess unit.

vii) Derivation of 1-hourly unitgraph.

viii) Drawing of representative unitgraphs and measuring the parameters.

ix) Establishing relationships between physiographic and representative unitgraph parameters.

x) Derivation of 1-hour synthetic unitgraph using such equations for an ungauged catchment.

The above steps are briefly described as under:

2.2.5 Physiographic parameters of the catchement:

The representative catchments selected for the study were analysed for physiographic parameters. The catchment parameters shown in Fig. 1 are as under :

2.2.5.1 Catchment Area(A):

On a reliable map, the watershed boundary is marked. The area enclosed in this boundary upto the gauging site may be referred to as the catchment area.

2.2.5.2 Length of the Main Stream (L) and (Lc):

"L" implies the Longest length of the main river from the farthest watershed boundary of the catchment area to the gauging site. Lc is the longest of the main river course from the point opposite to the C.G. to the point of study.

2.2.5.3 Equivalent Stream Slope (S):

One of the physiographic parameter is slope. The slope may be equivlent slope or statistical slope. In this report equivalent stream slope has been used for developing the SUH relation.

(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/gauging site. A line is so drawn by trials 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.

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

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

where L_i = 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 D are the heights of successive bed location at contour and intersections.

L = Length of the longest stream as defined in section 2.2.5.2 in km.

The physiographic parameters A, L, Lc and S which were obtained only for 21 catchments found suitable for analysis are shown in Table-2.

2.2.6 Scrutiny of data and finilisation of gauge discharge rating curve:

The data was scrutinised through arithmetical checks. Where wide dispersions were observed in the stage-discharge curve, log-log fitting was adopted. The stages for conceivable floods were converted into discharges initially identified with reference to rise and fall in the stages of the river.

2.2.7 Selection of flood and corresponding storm events:

The general guidelines adopted for selection of flood events for each catchment are as under :

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

ii) The selected flood should result from significant rainfall excess generally not less than one cm.

2.2.8 Computation of hourly catchment rainfall:

The Thiessen network was drawn for the raingauge stations on the catchment map and then Theissen Weights were computed. The hourly point rainfall at each station was multiplied by their respective Theissen Weight and added to obtain the catchment rainfall for each one hour duration during the storm period.

2.2.9 Computation of Infiltration loss (Ø-index) and 1-hourly effective rainfall units:

With the known values of 1-hourly catchment rainfall in section 2.2.8 and the direct runoff depth in section 2.2.10 for each flood event, the infiltration loss (constant loss rate) by trials was estimated. The 1-hourly infiltration loss was deducted from the 1-hourly rainfall to get 1-hourly rainfall excess units.

2.2.10 Seperation of base flow:

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

2.2.11 Derivation of 1-Hour Unitgraph:

A unit duration of 1-hour was adopted for derivation of unitgraphs. The 1-hour unitgraphs were derived from the rainfall excess hyetographs and their corresponding direct runoff hydrographs by iterative methods. The iterations were carried out till the observed and estimated direct runoff hydrographs compared favourably. Normally 5 to 15 unitgraphs are derived for each of the 21 catchments considered.

2.2.12 Drawing of representative Unitgraphs and measuring their parameters:

The set of Unitgraphs as obtained vide para 2.2.11 above were superimposed and an average/representative Unitgraph (RUG) was derived. This excercise was repeated for all samples. Each RUH was then tested by reproducing the direct surface run-off hydrograph by applying RUH ordinates to the corresponding observed rainfall excesses and comparing with the observed hydrograph. The relevant parameters of RUH i.e. t_p, q_p, W_{50}, W_{75}, W_{R50}, W_{R75} and T_B as illustrated in Fig.2, were measured for each Catchment. List showing these parameters for 21 catchments is given in Table-3.

2.2.13 Establishing relationships between physiographic and Representative Unitgraph Parameters:

Following simple model was adopted for establising the relationships between RUH parameters and catchment characterstics.

$$Y = C\ X^{p} \qquad \text{.......................} \qquad 2.2.13.1$$

where

Y = Dependent variable
X = Independent variable
C = A constant
P = An exponent
From above equation, it follows that
Log Y = Log C + P log X

Thus if Y and X are plotted on a log-log paper, one may expect a straight line relationship.

Various trials of relationship between the physiographic parameters (Table-2) and one of the unitgraph parameters (Table-

3) for 21 gauged catchments considered suitable for the studies were_ made. The relationship between physiographic parameters (LLc/S) and U.G. parameter qp was found to be significant. Afterwards t_p was related to unit peak discharge of the U.G. (q_p) and q_p was related to various U.G. parameters like W_{50}, W_{75}, WR_{50}, WR_{75}. The T_B could be significantly correlated to tp. The priniciple of least squares was used in the regression analysis to get the relationships in the form of equation 2.2.13.1 to predict the parameters of the Synthetic unitgraph in an unbiased manner. The following relationships have been derived for estimating the 1-hr unitgraph parameters in the subzone - 2(a).

Relationships	Equation No.	Fig. No.	correlation Coefficient (r)
1	2	3	4
$q_p = 2.272(LLc/s)^{-0.409}$	2.2.13.2	3	0.911
$t_p = 2.164\ (qp)^{-0.940}$	2.2.13.3	4	0.884
$W_{50} = 2.084(qp)^{-1.065}$	2.2.13.4	5	0.985
$W_{75} = 1.028(qp)^{-1.071}$	2.2.13.5	6	0.956
$W_{R50} = 0.856(qp)^{-0.865}$	2.2.13.6	7	0.910
$W_{R75} = 0.440(qp)^{-0.918}$	2.2.13.7	8	0.879
$TB = 5.428(tp)^{0.852}$	2.2.13.8	9	0.939
$T_m = t_p + t_r/2$	2.2.13.9		
$Q_p = q_p \times A$	2.2.13.10		

Attempts were made to develop a confidence band which could cover all the 21 samples and it was found that with a 95% upper and lower band all the 21 samples are within the band. List of physical and unit hydrograph parameters studied to establish relationship and co-effecient of correlations are shown in Annexure-2.

The above relationships may be utilised to estimate the parameters of 1-hour synthetic unitgraph for an ungauged catchment with its known physiographic characteristics like A, L, Lc and S.

2.2.14 Derivation of 1-Hour Synthetic Unitgraph for an Ungauged catchment:

Considering the hydro-meteorological homogeneity of subzone-2(a), the relations established between physiographic and unitgraph parameters in section 2.2.13 for 21 representative catchments are applicable for derivation of 1-hour Synthetic unitgraph for an ungauged catchment in the same 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 LLc/S is calculated.

ii) Substitute LLc/S in the equation 2.2.13.2 to obtain q_p and this q_p in equation 2.2.13.2.3 to get t_p in hours.

iii) Substitute the value of q_p/t_p in the equations 2.2.13.4 to 2.2.13.8 to obtain W_{50}, W_{75}, W_{R50}, W_{R75}, T_B and T_m in hours.

iv) Plot the parameters of 1-hour unitgraph viz. T_m, T_B, Q_p, W_{50}, W_{75}, W_{R50}, and W_{R75}, on a graph paper as shown in illustrative Fig. 2 and sketch the unitgraph through these points.

Sum of discharge ordinates of tr-hr Unitgraph is accuratety obtained by using the following equation:

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

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

A = Catchment area in sq.km.

tr = Unit duration in hours.

Suitable modifications can be made in rising and falling limbs upto W_{50} points, and a smooth Unitgraph be drown.

2.3.0 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 complex and topography alongwith temporal and spatial variations of storm rainfall.

Following method of estimating design loss rate was adopted:

Constant loss rates were estimated based on various selected observed storm rainfall and flood events of reasonably higher magnitude for derivation of unitgraphs. About 233 flood events were analysed for 21 bridge catchments. Number of flood occasions for each bridge catchment under different loss rate ranges at intervals of .2cm/hr were tabulated. All flood events have been considered for estimating the modal loss rate shown in Table-4.

The modal value of loss rate of 0.24 cm/hr is recommonded for adoption as Design Loss Rate. The designer can however modify this value as per the local site conditions.

2.4 Design Base Flow:

Similarly number of ocassions with different base flow under various intervals for 237 flood events are shown in table-5. For 100 flood events out of 237 the base flow rates fall under the range of .1cumecs per sq.km. An average base flow rate of .05 cumecs per sq.km. may be adopted for estimating the design base flow for a catchment under study. The summary of the base flow for all the floods studied is given in Table-5.

2.5 Simplified Approach:

For the preliminary studies some times desginers are interested in only the return period peak flood values, without going into much detail of design flood estimation.

So a simple equation relating the return period (25-yr, 50-yr and 100-yr) flood peak are derived after obtaining the return period flood from the synthetic unit hydrograph approach and relating this peak with the physiographic parameters and meterological paramter of point rainfall applying least square method for fitting.

$$Q\ (peak) = C\ (A)^a\ (L)^b\ (Lc)^c\ (S)^d\ (Rt)^e$$

where Qpeak = Return period peak flood.
C = Constant.
A = Catchment area in sq. km.
L = Length of the longest stream from the catchment boundary to the site under study (km).
Lc = Length of the stream from the centroid of the catchment to the point of study (km).
S = Equivalent stream slope m\km.
Rt = Return period point rainfall to be found from plates 8, 9, 10 in cm for td hour.

The derived flood formulae for 25-yr, 50-yr and 100-yr return period flood peaks are as under with the co-efficient of co-relation.

$$Q_{25} = 0.6855(A)^{0.91839}\ (L)^{-0.39454}\ (Lc)^{-0.19945}\ (S)^{0.31391}\ (R_{25})^{1.11481} \quad r = 0.996 \quad 2.4.1$$

$$Q_{50} = 0.7262(A)^{0.90265}\ (L)^{-0.37461}\ (Lc)^{-0.19224}\ (S)^{0.31348}\ (R_{50})^{1.09719} \quad r = 0.997 \quad 2.4.2$$

$$Q_{100} = 0.8372(A)^{0.90662}\ (L)^{-0.36538}\ (Lc)^{-0.20383}\ (S)^{0.31028}\ (R_{100})^{1.05471} \quad r = 0.997 \quad 2.4.3$$

The coefficients of correlation for all the above relationships are extremely high and therefore the relationships derived are very reasonable. Further overall range of the + and - percentage variations in the computed flood values (Q_{25}, Q_{50} and Q_{100}) by both the respective derived formulae and the detailed approach for the 21 catchments shown in Table-8 are within tolerable limits of + or - 15% as given below:

	Variation Range (percentage) (+)	(-)
Q_{25}	1.11 to 11.87	0.29 to 13.69
Q_{50}	0.26 to 11.28	0.24 to 12.52
Q_{100}	0.04 to 10.05	0.45 to 13.15

The flood formulae for computation of 25-yr, 50-yr and 100-yr flood may be applied only for preliminary designs.

PART III

DESIGN STORM INPUT

3.1 The point rainfall amount for the design storm duration and its areal and time distribution are the three main meteorological factors deciding the shape of design flood hydrograph. Studies on such components have been carried out by IMD and the results have been given in the form of 25, 50 and 100 year 24 hour isopluvial maps, ratios for short durations to 24 hours, Tables for point to areal values and time distribution values.

Rainfall data of self recording and ordinary raingauges was collected from a large number of stations within and around the subzone for as long a period as possible by IMD and other organisations including Railways and MOT. Methodology adopted for analysis for each component is discussed in subsequent paras.

3.1.1 Design Storm Duration:

The duration of the storm rainfall which causes the maximum discharge in a drainage basin is called the design storm duration (TD). Alternative studies were carried out assuming Td= 1.1 tp and TD = TB for estimating 25yr, 50yr and 100yr flood for 21 catchments. The TD = TB design storm duration is adopted as it gives higher discharges in 16 cases out of 21 bridge catchments as shown in Table-9.

The design storm duration Td which is equal to TB may be rounded off to the nerest full hour for any specific site study the designer can adopt any other value out of the trials made by him to suit the requirement.

3.1.2 Rainfall Depth-Duration-Frequency Analysis:

India Meteorological Department have conducted this study utilizing the data of 12 Self Recording Raingauge Stations and 13 Ordinary Raingauge Stations maintained departmentally, 82 Ordinary Raingauge Stations belonging to the States of West Bengal, Sikkim, Assam and Arunachal Pradesh, and 24 Self Recording Raingauge Stations maintained by Railways in their 8 bridge catchments falling in Subzone 2(a).

The annual maximum series of one-day rainfall were formed for each of 95 ordinary raingauge stations in and around the sub-zone using the rainfall records of 50 to 80 years. The annual extreme values series were subjected to frequency analysis by Gumbel's extreme value distribution and the rainfall estimates for one-day corresponding to 25, 50 and 100 year return periods were computed. The daily values of 25-years, 50 years and 100 years rainfall estimates were converted into 24 hour rainfall estimates of corresponding return periods by using the conversion factor of 1.15. These 24-hour rainfall estimates for all the stations in and around the sub-zone were plotted on base maps and isopluvial maps of 25-year, 50-year and 100-year return period were drawn. These maps are shown in plates 8, 9 and 10.

The hourly rainfall data recorded at 12 Self Recording Raingauge Stations maintained by India Meteorological Department were analysed by frequency analysis (partial duration series) method and the rainfall estimates for various return periods (viz. 2,5,10,25,50 and 100 years) were computed for duration 1,3,6,9,12,15,18 and 24 hours. The rainfall estimates corresponding to duration from 1 to 18 hours for each of the 12 stations were converted into ratios with respect of 24 hours estimates for each of the above mentioned return periods. Averaged ratios for various durations for each return period were computed for the whole sub-zone. It was noticed that for a specified duration the average ratios, except for return period of more than 5-years were comparable in magnitude. The averaged ratios for various durations for converting 24-hour rainfall into short duration rainfall are given below :-

Duration	Ratio
1	0.260
3	0.457
6	0.615
9	0.720
12	0.805
15	0.875
18	0.930
24	1.000

$$\text{Ratio} = \frac{\text{50-yr T-hr Point Rainfall}}{\text{50-yr 24-hr Point rainfall}}$$

Fig. 10 shows the ratios for short duration point rainfall with respect to 24-hr point rainfall.

The short duration rainfall estimates for various short duration (1,3,6,9,12,15 & 18 hrs) can be computed by using the respective ratios. The value of 24-hr rainfall estimates for a particular station for 25-yr,50-yr and 100-yr return period can be obtained by plates 8, 9 & 10 and the short duration rainfall estimates can be obtained by multiplying with the corresponding ratio for that particular short duration obtained from Fig. 10. Statement of highest ever recorded daily rainfall atselected stations in the subzone is at Table - 7.

3.1.3 Point to Areal Rainfall:

R.D.S.O. supplied short duration rainfall data of about 90 stations in 21 bridge catchments but the short duration rainfall data of only 8 bridge catchments were used for this study. The data of remaining 13 bridge catchments could not be utilised as the period of data were either less than 4 years and/or concurrent years data were not recorded continuously for 4 years over the stations in a bridge catchment. 2-yr point rainfall values for specified duration for each station in the catchments were computed by frequency analysis. Arithmetic average of 2-yr point rainfall of all the stations in the catchment was calculated to get the 2-year representative point rainfall for the catchment. Events of maximum average depth for a particular duration in each year were then selected on the basis of simultaneous occurrence of rainfall at each station in the catchment. The areal rainfall series thus obtained was subjected to frequency analysis of 2-year areal rainfall and depths for specified durations were computed. The percentage ratio of 2-year areal rainfall to 2-year representative point rainfall for the catchment was calculated and plotted against the area of the catchment for various durations. The best fit curves were drawn for specified durations on the points obtained for all the catchments. Fig. 11(a) to 11(b) give the curves for conversion of point rainfal into areal rainfall for 1,3,6,12 and 24 hours. The areal reduction factor (ARF) at different intervals of catchment areas for the above durations are given in Table 6.

3.1.4 Time Distribution Studies:

The time distribution studies have been carried out for the following rainfall durations:

1) Rain storm of 2 to 3 hours

2) Rain storm of 4 to 6 hours

3) Rain storm of 7 to 12 hours

4) Rain storm of 13 to 18 hours

5) Rain storm of 19 to 24 hours

2207 rainstorms of various durations upto 24 hours occurring in various parts of the subzone were analysed based on 147 station year data. Rain storms selected at each station were grouped under the avove 5 categories and plotted on different graphs as dimensionless curves with cumulative percentage of the total rainfall orrdinate and the percentage of the short duration along the abscissa. Thus, five different graphs were prepared for each station corresponding to various durations, and were then examined. The average time distribution curves for the various durations were drawn for each station. All the average curves for the stations thus obtained were plotted on a single graph and a single average curve for the subzone as a whole was drawn for storms of different durations as shown in Fig. 12. Time distribution co-effecients for different durations read from these curves are presented in Table - T-2.

3.2.0 Procedure for Estimation of Design Storm Rainfall:

The following procedure is recommended to be adopted for estimation of critical distribution of storm rainfall to cause the maximum flood due to rainfall of a specified duration:

Step-1: Estimate T_D = Which can be obtained from the computed values of T_B (Equation 2.2.13.8)

Step-2: Locate bridge catchment under study on the 50-yr, 24-hr isopluvial map (plate-9) and obtain the 50-yr 24-hr point rainfall value in cms. For catchment covering more than one isohyte, compute the average point storm rainfall.

Step-3: Read the conversion ratio for T_D hours from Fig. 10 and multiply the 50-yr 24-hr rainfall in Step-2 by the ratio to obtain 50-yr T_D-hr point rainfall.

Step-4: Convert the 50-yr T_D-hr point rainfall to 50-yr T_D-hr areal rainfall by multiplying it with the areal reduction factor (ARF) corresponding to the given values of catchment area and T_D-hr duration from Table-6 or by interpolation from Fig. 11(a) and 11(b) in section 3.1.4.

Step-5: Apply the cumulative percentage of total rainfall against the cumulative percentage of storm duration curves in Fig. 12 or from Table T - 2 corresponding to design storm duration T_D to obtain the depths at 1-hr interval, since the unit duration of synthetic U.G. is 1-hour.

Step-6: Obtain the 1-hourly rainfall increments by subtraction of successive 1-hour cumulative values of rainfall in step-5.

Step-7: Rearrange rainfall excess values in a specific sequence depending upon the necessity. (Peak only or complete hydrograph)

PART IV

UTILISATION OF SUH APPROACH FOR DESIGN FLOOD ESTIMATION

4.1.0 Estimation of Design Flood for an Ungauged Catchment:

The following procedure is recommended:

Step-1 Determine the 1-hr synthetic unitgraph vide section 2.2.13.

Step-2 Determine the design storm rainfall input vide section 3.2.0.

Step-3 Adopt the design loss rate as recommended vide section 2.3.0.

Step-4 Obtain the hourly effective rainfall units upto the design storm duration T_D by subtracting the design loss rate from the hourly areal rainfall units vide section 3.2.0.

Tabulate the S.U.G. ordinates obtained from Step-1 at 1-hour interval.

Arrange the effective rainfall values against the 1-hourly synthetic U.G. ordinates such that the maximum value of effective rainfall comes against the peak discharge of synthetic U.G., the next lower value of effective rainfall units comes against the next lower discharge ordinate and so on upto T_D hour duration.

The sum of the product of unitgraph ordinates and the effective rainfall values as tabulated above gives the 50-yr flood peak value after addition of base flow in Step-8 given below.

However, the subsequent Steps-5 to 9 should be followed, for computation of design flood hydrograph.

Step-5 Reverse the sequence of effective rainfall units obtained in Step-4 which will give the critical sequence of the effective rainfall.

Step-6 Multiply the first 1-hr effective rainfall with the synthetic ordinates at 1-hr interval which will give the corresponding direct runoff ordinates. Likewise repeat the procedure with the rest of the hourly effective rainfall units giving a lag of 1-hr to sucessive direct runoff ordinates.

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

Step-8 Obtain the base flow rate in cumecs/sq.km vide section 2.3.12. Multiply base flow rate in cumecs/ sq.km with the catchment areas under study to get the total base flow.

Step-9 Add the total base flow to the direct runoff ordinates at 1-hr interval in Step-7 to get the 50-yr flood hydrograph. Plot the hydrograph.

Likewise 25-yr flood and 100-yr flood hydrographs are computed following the above steps in section 3.1.6 and 4.1.0 corresponding the 25-yr and 100-yr storm rainfall for design storm duration $T_D = T_B$

4.2.0 Other Purposes:

The report may also be used for estimation of frequency flood for the following categories of structures as per the Indian Standard.

i) Small Dams:

The Indian Standard - gudelines for fixing spillway capacity of Dams under clauses 3.1.2 and 3.1.3 of IS : 11223 - 1985 recommends 100-yr floods as inflow design flood for small dams having either gross storage behind the dam between 0.5 to 10 million cu.m. or hydraulic head (from normal or annual average flood level on the downstream to the maximum water level) between 7.5 m to 12 m. The report may be made use of for estimation of 100-yr flood for safety of small dams. 100-yr flood may be estimated using the modal loss rate of 0.24 cm/hr.

ii) Minor Cross Drainage Works:

The Indian Standard - code of practice for design of cross drainage works, part-1 General Features under clause 6.2 of IS : 7784 (part-1) - 1975 recommends 10 to 25 years frequency flood with increase afflux for the design of waterway of minor cross drainage works. The report may be made use of for estimation of 25-yr flood for fixing the waterway of minor cross drainage works. The flood of different return periods say from 10 to 20 years may be estimated by using the detailed methodology given in the report on the basis of 10 to 20 years 24-hr. point storm rainfall determined for the ungauged catchments under study.

4.3.0 Computation of Design H.F.L. Corresponding to Design Flood:

4.3.1 General:

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.

4.3.2 Stage Discharge Relationship:

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 logarthmic 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 berm 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 dishcarge rating curve so determined may be used for fixing the design HFL corresponding to design flood by extrapolation if necessary.

While 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 H.F.L. is generally done with the help of Manning's formula in which Manning's 'N' is a very important factor affecting the discharge of a river or Nalla. In applying the Manning's formula the greatest difficulty lies in the determination of the roughness coefficient (N). In reality, the value of N is highly variable and depends on a number of factors. In selecting a proper value of N for various design conditions, a basic knowledge of the factors affecting Manning's roughness coefficient shoud be found very useful. The factors that exert the greatest influence upon the coefficient of roughness in natural channels are 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 effect of the constriction by way of raising the design HFL under natural conditions has to be evaluated in the water elevations to arrive at the revised design HFL under constricted 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 orrifice formula of hydraulics is generally used depending on the upstream and downstream depths to estimate the revised design HFL under constricted conditions.

4.3.3 Back Water Effect:

Sometimes it happens that the cross section of river or nalla on the downstream side of across drainage structure may be too 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 and hene there will be heading up of water in its upstream side which ultimately efffects on 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 affect of the main stream joining downstream. In such cases back water study shall be essential.

4.3.4 Hydraulic Gradient:

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

4.3.5 Unfavourable Crossing Site:

If the crossing site is located across the river/drainage in the unfavourable reach i.e. not complying with the usual requirement of gauge site, the design flood elevation shall be computed in a straight reach downstream of the crossing and then from back water streams, design flood elevation of the crossing site shall be decided.

PART V

ASSUMPTIONS, LIMITATIONS AND CONCLUSIONS

5.1.0 Assumptions:

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

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

5.2.0 Limitations:

5.2.1 The data of 21 catchments has been considered for developing a generalised approach however, for more reliable relationships the data for more suitable catchments would be desirable.

5.2.2 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.

5.2.3 The approach developed mostly covers the catchment with flat to moderate slopes.

5.3.0 Conclusions:

5.3.1 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.

5.3.2 The report also recommends the adoption of design flood of 25-yr and 100-yr return periods taking in to account the type and relative importance of the structures.

5.3.3 The flood formulae with different return periods shall be used only for preliminary design. However, for final design, the design flood shall be estimated using the detailed approach in illustrative example under Part-I.

5.3.4 Formulae for fixing the linear waterway of cross drainage structures on streams in North Brahmaputra subzone 2(a) may be used at the discretion of the design engineer.

5.3.5 25-yr, 50-yr and 100-yr flood may be estimated using design loss rate of 0.24 cm/hr.

5.3.6 The report is applicable for the catchment area ranging from 25 sq km to 1500 sq km. Further the report may be used for large catchments upto 5000 sq km based on sound judgement and considering the data of neighbouring catchments also. However, individual site conditions may necessitate special site study. Engineer-in-charge at site is advised to take a pragmatic view while deciding the design discharge of a bridge.

Referances:

1. Report of the Khosla Committee of Engineers (October, 1959) Government of India, Ministry of Railways.

2. "Hand Book of Hydrology", Ven Te Chow

3. "Open Channel Hydraulics", Ven Te Chow

4. Guide to Hydrological Practices (Third Edition) World Meteorological Organisation No. 168, 1974.

5. Estimation of Design Flood "Recommended Procedures, September, 1972 Government of India, Central Water Commission, New Delhi.

6. "Engineering Hydrology" Wilson E.M.

7. Code of Practice by Indian Railways (Revised 1985).

8. IRC : 5 - 1985 - Standard specifications and code of practice for Road Bridges, Section - 1, General Features of Design 6th Revision) 1985, Indian Roads Congress.

9. IRC : SP : 13 - 1973 - Guidelines for the Design of Small Bridges and Culverts.

10. Flood Studies Report. Vol. 1 Hydrological Studies, Natural Environment Research Council, 27, Charing Cross Road, London, 1975.

11. "Economics of Water Resources Planning" L. Douglas James/Rober L. Lee.

COMPUTATION OF EQUIVALENT SLOPE (S) OF BRIDGE NO. : 373 C.A. = 595.70 Sq Km

L = 75.62 Km. Le = 47.14 Km. LLe = 3564.73

S.NO.	Reduced Distance Starting from Bridge Site (Point of Study) (Km)	Reduced Levels of River Bed (M)	Length of Each Segment L_i (Km)	Height Above Datum *(D)= Difference D_i Between thhe Datum and the its R.L. (M)	$(D_{i-1} + D_i)$ (M)	$L_i (D_{i-1} + D_i)$ (4) * (6) (Mt * Km)
1	2	3	4	5	6	7
1	0.00	46.33	0.00	0.00	0.00	0.00
2	40.22	60.96	40.22	14.63	14.63	588.42
3	47.14	81.44	6.92	35.11	49.74	344.20
4	50.52	91.44	3.38	45.11	80.22	271.14
5	55.51	121.92	4.99	75.59	120.70	602.29
6	61.14	152.40	5.63	106.07	181.66	1022.75
7	64.68	182.88	3.54	136.55	242.62	858.87
8	66.29	243.84	1.61	197.51	334.06	537.84
9	71.92	304.80	5.63	258.47	455.98	2567.17
10	72.73	365.76	0.81	319.43	577.90	468.10
11	74.17	457.20	1.44	410.87	730.30	1051.63
12	75.62	609.60	1.45	563.27	974.14	1412.50

$\mathrm{SUM}\ (L_i * (D_{i-1} + D_i)) = 9724.91$

$$S = \frac{(L_i * (D_{i-1} + D_i))}{L^2} = \frac{9724.91}{5718.38}$$

$$= 1.70 \text{ M/Km}$$

DATUM : 46.33 i.e. REDUCED LEVEL OF RIVER BED AT THE POINT OF STUDY

TABLE - T - 2

TIME DISTRIBUTION CO-EFFECIENTS OF AREAL RAINFALL
SUB-ZONE 2(a)

TIME HOURS	DISTRIBUTION CO-EFFECIENTS FOR DESIGN STORM DURATION OF 2 -24 HOURS																						TIME HOURS
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
24																							1.00	24
23																						1.00	0.98	23
22																					1.00	0.98	0.97	22
21																				1.00	0.98	0.97	0.95	21
20																			1.00	0.98	0.96	0.95	0.93	20
19																		1.00	0.98	0.96	0.95	0.93	0.92	19
18																	1.00	0.98	0.96	0.95	0.93	0.91	0.90	18
17																1.00	0.98	0.96	0.94	0.93	0.90	0.89	0.88	17
16															1.00	0.98	0.96	0.93	0.92	0.90	0.89	0.88	0.86	16
15														1.00	0.98	0.96	0.93	0.92	0.90	0.88	0.87	0.85	0.84	15
14													1.00	0.97	0.95	0.93	0.91	0.89	0.88	0.86	0.84	0.83	0.81	14
13												1.00	0.97	0.95	0.92	0.91	0.89	0.87	0.85	0.83	0.81	0.80	0.79	13
12											1.00	0.97	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.78	0.77	0.76	12
11										1.00	0.97	0.94	0.92	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.73	11
10									1.00	0.96	0.94	0.91	0.88	0.86	0.83	0.82	0.80	0.77	0.75	0.74	0.72	0.70	0.69	10
9								1.00	0.97	0.94	0.92	0.87	0.84	0.82	0.80	0.78	0.76	0.73	0.72	0.70	0.68	0.67	0.65	9
8							1.00	0.96	0.93	0.91	0.87	0.83	0.81	0.78	0.76	0.74	0.71	0.70	0.67	0.65	0.64	0.63	0.61	8
7						1.00	0.96	0.93	0.89	0.87	0.83	0.78	0.76	0.74	0.71	0.69	0.67	0.64	0.62	0.60	0.59	0.58	0.56	7
6					1.00	0.95	0.92	0.88	0.84	0.82	0.79	0.73	0.70	0.68	0.65	0.63	0.61	0.59	0.57	0.56	0.54	0.53	0.52	6
5				1.00	0.95	0.90	0.86	0.83	0.79	0.76	0.73	0.67	0.64	0.61	0.58	0.56	0.55	0.53	0.52	0.51	0.49	0.48	0.47	5
4			1.00	0.94	0.89	0.83	0.79	0.75	0.72	0.68	0.66	0.58	0.56	0.53	0.51	0.48	0.47	0.46	0.45	0.44	0.43	0.41	0.40	4
3		1.00	0.93	0.86	0.80	0.74	0.70	0.65	0.63	0.59	0.56	0.49	0.47	0.45	0.44	0.42	0.41	0.40	0.38	0.37	0.36	0.34	0.32	3
2	1.00	0.91	0.80	0.73	0.65	0.62	0.56	0.52	0.49	0.46	0.42	0.38	0.36	0.34	0.32	0.31	0.29	0.28	0.27	0.27	0.26	0.26	0.25	2
1	0.82	0.67	0.56	0.48	0.42	0.38	0.35	0.32	0.30	0.28	0.25	0.23	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.15	0.14	0.13	0.13	1

Note : Hourly rainfall distribution co-effecients are given in the vertical columns for various design storm durations from 2 - 24 hours.

COMPUTATION OF DESIGN FLOOD HYDROGRAPH (50 YR.)

Subzone - 2(a) Bridge No. 373 CA = 595.70 sq.km.

EFFECTIVE RAINFALL UNIT (cm) — DIRECT SURFACE RUN OFF IN CUMECS

TIME IN HOURS	S.U.H. ORDINATE IN CUMEC	0.05	0.34	0.34	0.35	0.35	0.35	0.35	0.35	0.65	0.65	0.93	0.93	0.94	1.23	1.23	1.82	3.29	3.58	2.11	1.82	0.94	0.64	0.35	0.05	TOTAL DIRECT RUNOFF IN CUMECS	BASE FLOW IN CUMECS	TOTAL FLOOD FLOW IN CUMECS
0	0.00	0.00																								0.00	29.78	29.78
1	2.00	0.10	0.00																							0.10	29.78	29.88
2	4.00	0.20	0.68	0.00																						0.88	29.78	30.66
3	6.00	0.30	1.36	0.68	0.00																					2.34	29.78	32.12
4	8.00	0.40	2.04	1.36	0.70	0.00																				4.50	29.78	34.28
5	9.75	0.49	2.72	2.04	1.40	0.70	0.00																			7.35	29.78	37.13
6	11.90	0.60	3.32	2.72	2.10	1.40	0.70	0.00																		10.83	29.78	40.61
7	14.00	0.70	4.05	3.32	2.80	2.10	1.40	0.70	0.00																	15.06	29.78	44.84
8	16.50	0.83	4.76	4.05	3.41	2.80	2.10	1.40	0.70	0.00																20.04	29.78	49.82
9	19.00	0.95	5.61	4.76	4.17	3.41	2.80	2.10	1.40	1.30	0.00															26.50	29.78	56.28
10	21.50	1.08	6.46	5.61	4.90	4.17	3.41	2.80	2.10	2.60	1.30	0.00														34.42	29.78	64.20
11	24.00	1.20	7.31	6.46	5.78	4.90	4.17	3.41	2.80	3.90	2.60	1.86	0.00													44.38	29.78	74.16
12	27.50	1.38	8.16	7.31	6.65	5.78	4.90	4.17	3.41	5.20	3.90	3.72	1.86	0.00												56.43	29.78	86.21
13	32.00	1.60	9.35	8.16	7.53	6.65	5.78	4.90	4.17	6.34	5.20	5.58	3.72	1.88	0.00											70.84	29.78	100.62
14	37.00	1.85	10.88	9.35	8.40	7.53	6.65	5.78	4.90	7.74	6.34	7.44	5.58	3.76	2.46	0.00										88.64	29.78	118.42
15	43.00	2.15	12.58	10.88	9.63	8.40	7.53	6.65	5.78	9.10	7.74	9.07	7.44	5.64	4.92	2.46	0.00									109.95	29.78	139.73
16	49.50	2.48	14.62	12.58	11.20	9.63	8.40	7.53	6.65	10.73	9.10	11.07	9.07	7.52	7.38	4.92	3.64	0.00								136.49	29.78	166.27
17	55.50	2.78	16.83	14.62	12.95	11.20	9.63	8.40	7.53	12.35	10.73	13.02	11.07	9.17	9.84	7.38	7.28	6.58	0.00							171.33	29.78	201.11
18	58.00	2.90	18.87	16.83	15.05	12.95	11.20	9.63	8.40	13.98	12.35	15.35	13.02	11.19	11.99	9.84	10.92	13.16	7.16	0.00						214.77	29.78	244.55
19	59.57	2.98	19.72	18.87	17.33	15.05	12.95	11.20	9.63	15.60	13.98	17.67	15.35	13.16	14.64	11.99	14.56	19.74	14.32	4.22	0.00					262.94	29.78	292.72
20	58.70	2.94	20.25	19.72	19.42	17.33	15.05	12.95	11.20	17.88	15.60	20.00	17.67	15.51	17.22	14.64	17.75	26.32	21.48	8.44	3.64	0.00				314.99	29.78	344.77
21	57.00	2.85	19.96	20.25	20.30	19.42	17.33	15.05	12.95	20.80	17.88	22.32	20.00	17.86	20.30	17.22	21.66	32.08	28.64	12.66	7.28	1.88	0.00			368.67	29.78	398.45
22	55.00	2.75	19.38	19.96	20.85	20.30	19.42	17.33	15.05	24.05	20.80	25.58	22.32	20.21	23.37	20.30	25.48	39.15	34.91	16.88	10.92	3.76	1.28	0.00		424.03	29.78	453.81
23	52.75	2.64	18.70	19.38	20.55	20.85	20.30	19.42	17.33	27.95	24.05	29.76	25.58	22.56	26.45	23.37	30.03	46.06	42.60	20.57	14.56	5.64	2.56	0.70	0.00	481.60	29.78	511.38
24	50.75	2.54	17.94	18.70	19.95	20.55	20.85	20.30	19.42	32.18	27.95	34.41	29.76	25.85	29.52	26.45	34.58	54.29	50.12	25.11	17.75	7.52	3.84	1.40	0.10	541.05	29.78	570.83
25	48.75	2.44	17.26	17.94	19.25	19.95	20.55	20.85	20.30	36.08	32.18	39.99	34.41	30.08	33.83	29.52	39.13	62.51	59.07	29.54	21.66	9.17	5.12	2.10	0.20	603.09	29.78	632.87
26	46.90	2.35	16.58	17.26	18.46	19.25	19.95	20.55	20.85	37.70	36.08	46.04	39.99	34.78	39.36	33.83	43.68	70.74	68.02	34.82	25.48	11.19	6.24	2.80	0.30	666.25	29.78	696.03
27	45.00	2.25	15.95	16.58	17.76	18.46	19.25	19.95	20.55	38.72	37.70	51.62	46.04	40.42	45.51	39.36	50.05	78.96	76.97	40.09	30.03	13.16	7.62	3.41	0.40	730.79	29.78	760.57
28	43.50	2.18	15.30	15.95	17.06	17.76	18.46	19.25	19.95	38.16	38.72	53.94	51.62	46.53	52.89	45.51	58.24	90.48	85.92	45.37	34.58	15.51	8.96	4.17	0.49	796.97	29.78	826.75
29	41.60	2.08	14.79	15.30	16.42	17.06	17.76	18.46	19.25	37.05	38.16	55.40	53.94	52.17	60.89	52.89	67.34	105.28	98.45	50.64	39.13	17.86	10.56	4.90	0.60	866.37	29.78	896.15
30	40.00	2.00	14.14	14.79	15.75	16.42	17.06	17.76	18.46	35.75	37.05	54.59	55.40	54.52	68.27	60.89	78.26	121.73	114.56	58.03	43.68	20.21	12.16	5.78	0.70	937.95	29.78	967.73
31	38.50	1.93	13.60	14.14	15.23	15.75	16.42	17.06	17.76	34.29	35.75	53.01	54.59	56.00	71.34	68.27	90.09	141.47	132.46	67.52	50.05	22.56	13.76	6.65	0.83	1010.51	29.78	1040.29
32	37.00	1.85	13.09	13.60	14.56	15.23	15.75	16.42	17.06	32.99	34.29	51.15	53.01	55.18	73.27	71.34	101.01	162.86	153.94	78.07	58.24	25.85	15.36	7.53	0.95	1082.58	29.78	1112.36
33	35.50	1.78	12.58	13.09	14.00	14.56	15.23	15.75	16.42	31.69	32.99	49.06	51.15	53.58	72.20	73.27	105.56	182.60	177.21	90.73	67.34	30.08	17.60	8.40	1.08	1147.92	29.78	1177.70
34	34.25	1.71	12.07	12.58	13.48	14.00	14.56	15.23	15.75	30.49	31.69	47.20	49.06	51.70	70.11	72.20	108.42	190.82	198.69	104.45	78.26	34.78	20.48	9.63	1.20	1198.53	29.78	1228.31
35	32.75	1.64	11.65	12.07	12.95	13.48	14.00	14.56	15.23	29.25	30.49	45.34	47.20	49.59	67.65	70.11	106.83	195.99	207.64	117.11	90.09	40.42	23.68	11.20	1.38	1229.51	29.78	1259.29
36	31.50	1.58	11.14	11.65	12.43	12.95	13.48	14.00	14.56	28.28	29.25	43.62	45.34	47.71	64.88	67.65	103.74	193.12	213.26	122.38	101.01	46.53	27.52	12.95	1.60	1240.60	29.78	1270.38
37	30.20	1.51	10.71	11.14	11.99	12.43	12.95	13.48	14.00	27.04	28.28	41.85	43.62	45.83	62.42	64.88	100.10	187.53	210.15	125.69	105.56	52.17	31.68	15.05	1.85	1231.88	29.78	1261.66
38	28.75	1.44	10.27	10.71	11.46	11.99	12.43	12.95	13.48	26.00	27.04	40.46	41.85	44.09	59.96	62.42	96.01	180.95	204.06	123.86	108.42	54.52	35.52	17.33	2.15	1209.34	29.78	1239.12
39	27.60	1.38	9.78	10.27	11.03	11.46	11.99	12.43	12.95	25.03	26.00	38.69	40.46	42.30	57.69	59.96	92.37	173.55	196.90	120.27	106.83	56.00	37.12	19.42	2.48	1178.32	29.78	1208.10
40	26.25	1.31	9.38	9.78	10.57	11.03	11.46	11.99	12.43	24.05	25.03	37.20	38.69	40.89	55.35	57.69	88.73	166.97	188.85	116.05	103.74	55.18	38.12	20.30	2.78	1137.54	29.78	1167.32
41	25.20	1.26	8.93	9.38	10.06	10.57	11.03	11.46	11.99	23.08	24.05	35.81	37.20	39.10	53.51	55.35	85.36	160.39	181.69	111.30	100.10	53.58	37.57	20.85	2.90	1096.50	29.78	1126.28
42	24.00	1.20	8.57	8.93	9.66	10.06	10.57	11.03	11.46	22.26	23.08	34.41	35.81	37.60	51.17	53.51	81.90	154.30	174.53	107.08	96.01	51.70	36.48	20.55	2.98	1054.82	29.78	1084.60
43	22.75	1.14	8.16	8.57	9.19	9.66	10.06	10.57	11.03	21.29	22.26	33.02	34.41	36.19	49.20	51.17	79.17	148.05	167.90	102.86	92.37	49.59	35.20	19.95	2.94	1013.92	29.78	1043.70
44	21.50	1.08	7.74	8.16	8.82	9.19	9.66	10.06	10.57	20.48	21.29	31.85	33.02	34.78	47.36	49.20	75.71	143.12	161.10	98.96	88.73	47.71	33.76	19.25	2.85	974.41	29.78	1004.19
45	20.20	1.01	7.31	7.74	8.40	8.82	9.19	9.66	10.06	19.63	20.48	30.46	31.85	33.37	45.51	47.36	72.80	136.86	155.73	94.95	85.36	45.83	32.48	18.46	2.75	936.05	29.78	965.83
46	19.00	0.95	6.87	7.31	7.96	8.40	8.82	9.19	9.66	18.69	19.63	29.30	30.46	32.20	43.67	45.51	70.07	131.60	148.93	91.79	81.90	44.09	31.20	17.76	2.64	898.57	29.78	928.35
47	17.75	0.89	6.46	6.87	7.53	7.96	8.40	8.82	9.19	17.94	18.69	28.09	29.30	30.79	42.13	43.67	67.34	126.67	143.20	87.78	79.17	42.30	30.02	17.06	2.54	862.76	29.78	892.54
48	16.65	0.83	6.04	6.46	7.07	7.53	7.96	8.40	8.82	17.06	17.94	26.74	28.09	29.61	40.28	42.13	64.61	121.73	137.83	84.40	75.71	40.89	28.80	16.42	2.44	827.78	29.78	857.56
49	15.50	0.78	5.66	6.04	6.65	7.07	7.53	7.96	8.40	16.38	17.06	25.67	26.74	28.39	38.75	40.28	62.34	116.80	132.46	81.24	72.80	39.10	27.84	15.75	2.35	794.01	29.78	823.79
50	14.50	0.73	5.27	5.66	6.21	6.65	7.07	7.53	7.96	15.60	16.38	24.41	25.67	27.03	37.15	38.75	59.61	112.68	127.09	78.07	70.07	37.60	26.62	15.23	2.25	761.27	29.78	791.05
51	13.40	0.67	4.93	5.27	5.83	6.21	6.65	7.07	7.53	14.79	15.60	23.44	24.41	25.94	35.36	37.15	57.33	107.75	122.62	74.91	67.34	36.19	25.60	14.56	2.18	729.31	29.78	759.09
52	12.25	0.61	4.56	4.93	5.43	5.83	6.21	6.65	7.07	13.98	14.79	22.32	23.44	24.68	33.95	35.36	54.96	103.64	117.25	72.27	64.61	34.78	24.64	14.00	2.08	698.01	29.78	727.79
53	11.25	0.56	4.17	4.56	5.07	5.43	5.83	6.21	6.65	13.13	13.98	21.16	22.32	23.69	32.29	33.95	52.33	99.36	112.77	69.10	62.34	33.37	23.68	13.48	2.00	667.40	29.78	697.18
54	10.25	0.51	3.83	4.17	4.69	5.07	5.43	5.83	6.21	12.35	13.13	20.00	21.16	22.56	31.00	32.29	50.23	94.59	108.12	66.46	59.61	32.20	22.72	12.95	1.93	637.00	29.78	666.78
55	9.25	0.46	3.49	3.83	4.29	4.69	5.07	5.43	5.83	11.54	12.35	18.79	20.00	21.39	29.52	31.00	47.78	90.80	102.93	63.72	57.33	30.79	21.92	12.43	1.85	607.18	29.78	636.96
56	8.25	0.41	3.15	3.49	3.94	4.29	4.69	5.07	5.43	10.82	11.54	17.67	18.79	20.21	27.98	29.52	45.86	86.36	98.81	60.66	54.96	29.61	20.96	11.99	1.78	577.98	29.78	607.76
57	7.25	0.36	2.81	3.15	3.59	3.94	4.29	4.69	5.07	10.08	10.82	16.51	17.67	18.99	26.45	27.98	43.68	82.91	93.98	58.24	52.33	28.39	20.16	11.46	1.71	549.23	29.78	579.01
58	6.40	0.32	2.47	2.81	3.24	3.59	3.94	4.29	4.69	9.43	10.08	15.48	16.51	17.86	24.85	26.45	41.41	78.96	90.22	55.39	50.23	27.03	19.33	11.03	1.64	521.19	29.78	550.97
59	5.40	0.27	2.18	2.47	2.89	3.24	3.59	3.94	4.29	8.71	9.43	14.42	15.48	16.69	23.37	24.85	39.13	74.85	85.92	53.17	47.78	25.94	18.40	10.57	1.58	493.12	29.78	522.90
60	4.50	0.23	1.84	2.18	2.54	2.89	3.24	3.59	3.94	7.96	8.71	13.49	14.42	15.65	21.83	23.37	36.76	70.74	81.45	50.64	45.86	24.68	17.66	10.06	1.51	465.21	29.78	494.99
61	3.50	0.18	1.53	1.84	2.24	2.54	2.89	3.24	3.59	7.31	7.96	12.46	13.49	14.57	20.48	21.83	34.58	66.46	76.97	48.00	43.68	23.69	16.80	9.66	1.44	437.41	29.78	467.19
62	2.50	0.13	1.19	1.53	1.89	2.24	2.54	2.89	3.24	6.66	7.31	11.39	12.46	13.63	19.07	20.48	32.31	62.51	72.32	45.37	41.41	22.56	16.13	9.19	1.38	409.80	29.78	439.58
63	1.75	0.09	0.85	1.19	1.58	1.89	2.24	2.54	2.89	6.01	6.66	10.46	11.39	12.60	17.84	19.07	30.30	58.40	68.02	42.62	39.13	21.39	15.36	8.82	1.31	382.63	29.78	412.41
64	0.75	0.04	0.60	0.85	1.23	1.58	1.89	2.24	2.54	5.36	6.01	9.53	10.46	11.52	16.48	17.84	28.21	54.78	63.55	40.09	36.76	20.21	14.56	8.40	1.26	355.97	29.78	385.75
65	0.00	0.00	0.26	0.60	0.88	1.23	1.58	1.89	2.24	4.71	5.36	8.60	9.53	10.58	15.07	16.48	26.39	51.00	59.61	37.45	34.58	18.99	13.76	7.96	1.20	329.92	29.78	359.70
			0.00	0.26	0.61	0.88	1.23	1.58	1.89	4.16	4.71	7.67	8.60	9.64	13.84	15.07	24.39	47.71	55.49	35.13	32.31	17.86	12.93	7.53	1.14	304.59	29.78	334.37
				0.00	0.26	0.61	0.88	1.23	1.58	3.51	4.16	6.74	7.67	8.70	12.61	13.84	22.30	44.09	51.91	32.71	30.30	16.69	12.16	7.07	1.08	280.06	29.78	309.84
					0.00	0.26	0.61	0.88	1.23	2.93	3.51	5.95	6.74	7.76	11.38	12.61	20.48	40.30	47.97	30.60	28.21	15.65	11.36	6.65	1.01	256.07	29.78	285.85
						0.00	0.26	0.61	0.88	2.28	2.93	5.02	5.95	6.82	10.15	11.38	18.66	37.01	43.86	28.27	26.39	14.57	10.66	6.21	0.95	232.84	29.78	262.62
							0.00	0.26	0.61	1.63	2.28	4.19	5.02	6.02	8.92	10.15	16.84	33.72	40.28	25.85	24.39	13.63	9.92	5.83	0.89	210.40	29.78	240.18
								0.00	0.26	1.14	1.63	3.26	4.19	5.08	7.87	8.92	15.02	30.43	36.70	23.74	22.30	12.60	9.28	5.43	0.83	188.64	29.78	218.42
									0.00	0.49	1.14	2.33	3.26	4.23	6.64	7.87	13.20	27.14	33.12	21.63	20.48	11.52	8.58	5.07	0.78	167.45	29.78	197.23
										0.00	0.49	1.63	2.33	3.29	5.54	6.64	11.65	23.85	29.54	19.52	18.66	10.58	7.84	4.69	0.73	146.95	29.78	176.73
											0.00	0.70	1.63	2.35	4.31	5.54	9.83	21.06	25.96	17.41	16.84	9.64	7.20	4.29	0.67	127.39	29.78	157.17
												0.00	0.70	1.65	3.08	4.31	8.19	17.77	22.91	15.30	15.02	8.70	6.56	3.94	0.61	108.71	29.78	138.49
													0.00	0.71	2.15	3.08	6.37	14.81	19.33	13.50	13.20	7.76	5.92	3.59	0.56	90.96	29.78	120.74
														0.00	0.92	2.15	4.55	11.52	16.11	11.39	11.65	6.82	5.28	3.24	0.51	74.14	29.78	103.92
															0.00	0.92	3.19	8.23	12.53	9.50	9.83	6.02	4.64	2.89	0.46	58.19	29.78	87.97
																0.00	1.37	5.76	8.95	7.39	8.19	5.08	4.10	2.54	0.41	43.77	29.78	73.55
																	0.00	2.47	6.27	5.28	6.37	4.23	3.46	2.24	0.36	30.67	29.78	60.45
																		0.00	2.69	3.69	4.55	3.29	2.88	1.89	0.32	19.31	29.78	49.09
																			0.00	1.58	3.19	2.35	2.24	1.58	0.27	11.20	29.78	40.98
																				0.00	1.37	1.65	1.60	1.23	0.23	6.06	29.78	35.84
																					0.00	0.71	1.12	0.88	0.18	2.88	29.78	32.66
																						0.00	0.48	0.61	0.13	1.22	29.78	31.00
																							0.00	0.26	0.09	0.35	29.78	30.13
																								0.00	0.04	0.04	29.78	29.82
																									0.00	0.00	29.78	29.78

LIST OF SELECTED RAILWAY BRIDGE CATCHMENTS IN SUB-ZONE 2(a) 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. (N.F.R.)	G.Site Location						Catch-ment area (sq.km)	No of rain-gauge	Data availability	No. of years
				Longitude			Latitude						
				Deg.	Min.	Sec.	Deg.	Min.	Sec.				
(A) Bridges considered for U.G. studies													
1	DIKRONG	RANGAPARA - NURKONG SELEK	240	93	50'	30"	27	06'	30"	1350.00	3	1975-79 & 81-82	7
2	PUTHIMARI	RANGIA - BAIHATA	521	91	39	35	26	21	40	1016.00	11	1970-73	4
3	SIMEN	RANGAPARA NORTH - NURKONGSELEK	376	94	52	00	27	43	00	758.00	7	1975-79, 81	6
4	GANGIA	ALIPURDWAR - BONGAIGAON	373	90	07	10	26	23	10	595.70	6	1971-73, 76	4
5	BALASON	SILIGURI - BARSOI	6(B)	88	23	00	26	43	00	345.30	6	1958,61,62,64, 65,66, 67-74	14
6	KALDIA	RANGIA - FAKIRAGRAM	486	91	15	10	26	28	45	326.00	5	1978,81,82,84.	5
7	PAKDA	ALIPURDWAR - AMINGAON	363	90	03	25	26	25	15	323.23	8	1961,62,64, 67-74	11
8	DOLANI	ALIPURDWAR - RANGIA	450	90	42	00	26	29	50	233.10	10	1968-72,83-87	10
9	NEORA	MAL - CHANGRABANDHA	6/12	88	46	00	26	44	10	230.45	7	1966, 68-74	8
10	KALJANI	SILIGURI - ALIPURDWAR	242	89	24	30	26	41	20	229.99	7	1961,68,69-73	7
11	PANCHNOI	RANGIA - RANGAPARA NORTH	210	92	20	00	26	48	30	220.87	3	1970-72,77,78, 81,82 &84-87	11
12	MANGSIRI	BALIPARA - NORTH LAKHIMPUR	22	92	48	50	26	49	00	213.05	4	1970-73	4
13	CHEL - R	SILIGURI - ALIPURDWAR	95	88	38	12	26	51	51	119.14	2	1966-67	2
14	DHARSIRI R.	NEW ALIPURDWAR - BONGAIGAON	285	89	39	20	26	29	30	92.46	5	1961,62,68-73	8
15	BIRPARA JHORA R.	SILIGURI - ALIPURDWAR	196	89	10	00	26	42	20	85.47	4	1968-71	4
16	KANIBAR R.	ALIPURDWAR - BONGAIGAON	429	90	26	04	26	27	07	69.60	2	1964	1
17	KHAGA	RANGIA - RANGAPARA NORTH	114	92	02	35	26	44	30	66.00	6	1978,81,82, 84-86	6
18	TIPKAI	SAPATGRAM - TIPKAI	8(S)	90	03	10	26	17	50	61.38	5	1961,62,64-65	4
19	BEL R	CHAUTARA - FAKIRGRAM	385	90	11	00	26	21	44	46.62	2	1961,62,64-65	4
20	SUKRATI	SILIGURI - HALDIBARI	24	88	34	35	26	35	40	42.10	2	1961,62,64,65, 67-69	7
21	MOJNAI	SILIGURI - ALIPURDWAR	201	89	13	30	26	41	20	38.49	2	1961,62,64-65	4
(B) Bridges not considered for U.G. studies													
22	RETHIKHOLA	SILIGURI - ALIPURDWAR	190	89	06	20	26	43	30	114.48	5	1966,70-73	5
23	DIMA	SILIGURI - ALIPURDWAR	252	89	30	00	26	38	00	111.26	2	1958,61 & 62	3
24	TRIBUTARY OF MAHANANDA	SILIGURI - ALIPURDWAR	29	88	24	37	26	48	21	90.91	6	1961,62,64,65 1967-69	7
25	TARANG	ALIPURDWAR - FAKIRAGRAM	406	90	18	30	26	25	00	85.47	4	1962	1
26	DIKRAI	BALIPARA - NORTH LAKHIMPUR	45	92	58	30	26	45	30	50.19	2	1970-73	4
27	DHANSIRI	MANGALDOI - TEJPUR	NOT.2	92	15	15	26	42	00	1905.00	6	1981-85	5
28	BALAM	TEJPUR - LAKHIMPUR	NOT.1	93	30	20	26	49	00	43.00	1	1982-87	6

TABLE - 2

BASIN CHARACTERISTICS OF SUBZONE - 2(a)

Sl.No.	Bridge No	Area (sq.km.)	L (km)	Lc (km)	SEQ (m/km)	LLc\ S
1	2	3	4	5	6	7
1	240	1350.00	108.00	61.00	10.88	606.00
2	521	1016.00	120.75	89.36	7.41	1456.00
3	376	758.00	60.62	22.00	4.46	299.00
4	373	595.70	75.62	47.14	1.70	209.50
5	8(B)	345.30	42.34	27.37	21.28	54.00
6	486	326.00	62.75	35.40	1.95	1139.00
7	363	323.23	69.23	42.99	2.68	1111.00
8	450	233.10	38.62	29.77	1.84	625.00
9	6/12	230.45	54.71	29.94	23.47	70.00
10	242	229.99	34.59	18.82	22.53	29.00
11	210	220.87	36.06	17.07	9.10	68.00
12	22	213.05	42.00	25.76	1.52	712.00
13	95	119.14	27.29	16.74	34.07	13.00
14	285	92.46	36.06	26.89	0.88	1099.00
15	196	85.47	21.56	11.26	19.81	12.00
16	429	69.60	32.52	15.30	1.00	500.00
17	114	66.00	23.00	11.00	12.67	20.00
18	8(S)	61.38	22.54	8.36	0.63	299.00
19	385	46.62	24.94	16.25	0.26	1535.00
20	24	42.10	12.88	8.21	0.77	137.00
21	201	38.49	21.33	11.75	9.97	25.00

REPRESENTATIVE 1-HOUR UNIT GRAPH PARAMETERS NORTH BRAHMAPUTRA SUBZONE 2(A)

TABLE - 3

SL.NO.	BRIDGE NO.	tp IN HOURS	QP IN m\sq km	qp IN SQ/KM	tr IN HOURS	TB IN HOURS	W50 IN HOURS	W75 IN HOURS	WR50 IN HOURS	WR75 IN HOURS
1	2	3	4	5	6	7	8	9	10	11
1	240	10.50	210.00	0.16	1.00	38.00	16.75	9.25	5.55	3.60
2	521	10.50	168.00	0.17	1.00	43.00	14.50	7.20	5.10	3.40
3	376	7.50	202.02	0.27	1.00	23.00	10.00	6.30	3.77	2.60
4	373	22.50	51.00	0.09	1.00	103.00	26.15	14.00	7.40	4.00
5	3(D)	4.50	179.50	0.51	1.00	15.00	4.77	2.77	1.87	1.20
6	[illegible]	37.50	26.40	0.08	1.00	125.00	22.50	7.50	5.50	2.70
7	[illegible]	14.50	28.80	0.09	1.00	62.00	31.20	15.90	7.60	3.90
8	[illegible]	21.50	44.40	0.19	1.00	60.00	11.00	5.20	4.80	2.20
9	6/12	4.40	125.00	0.54	1.00	14.00	4.20	1.80	1.70	0.80
10	242	4.50	140.00	0.61	1.00	21.00	3.00	1.40	1.30	0.60
11	210	1.50	146.90	0.67	1.00	12.00	3.20	1.66	0.90	0.58
12	22	16.50	21.36	0.10	1.00	72.00	24.75	12.25	4.00	2.50
13	95	4.50	53.32	0.45	1.00	18.00	4.80	2.30	1.80	1.10
14	285	6.50	22.53	0.24	1.00	23.00	11.35	6.10	3.55	2.00
15	196	2.50	85.00	0.99	1.00	11.00	1.60	0.70	0.40	0.15
16	429	16.50	13.95	0.20	1.00	52.00	9.95	4.65	3.95	2.10
17	114	4.50	36.62	0.55	1.00	15.00	4.10	2.00	1.80	1.00
18	8(S)	3.50	14.70	0.24	1.00	30.00	10.40	5.00	2.00	1.00
19	385	20.50	4.08	0.09	1.00	91.00	28.70	16.20	4.90	3.20
20	24	4.50	14.00	0.33	1.00	18.00	8.15	4.55	2.90	1.75
21	201	6.50	18.45	0.48	1.00	21.00	4.70	2.30	1.87	0.97

TABLE - 4

LOSS RATE RANGES (cms/hr) FOR OBSERVED FLOOD IN SUBZONE - 2(a)

Sl.No	Br. No.	Area (sq.km.)	0.1	0.11 0.3	0.31 0.5	0.51 0.7	0.71 0.9	0.91 1.1	1.11 1.3	1.31 1.5	1.51 1.7	1.71 1.9	1.91 2.1	2.11 2.3	2.31 2.5	2.51 2.7	2.71 2.9	2.91 3.1	3.11 3.3	3.31 & above	Total
1	240	1350.00	12	9	3																24
2	521	1016.00	3	3		1															7
3	376	758.00		5	3		1														9
4	373	595.70			1						1					1		1		7	11
5	8(B)	345.30			1	3	1	2	1	1	1										10
6	486	326.00	1	2	3	2	2		1	1				1							13
7	363	323.23	4	10	12	6	2	2	2												38
8	450	233.10						2	1				2		1		1	1	1	3	12
9	6/12	230.45		2	1			1		1								1			6
10	242	229.99	2	1		2	2	1	1			1									10
11	210	220.87		3	2	3	3	1			1	1	1								15
12	22	213.05	2		1	1		1													5
13	95	119.14				2			3												5
14	285	92.46		1		2	2	1	1	2	2				2	2	1				16
15	196	85.47	1	1			1		1												4
16	429	69.60		1		1					1										3
17	114	66.00	1	1	1				2										1		6
18	8(S)	61.38	1	4	2	3		1						1							12
19	385	46.62			2			1	1	1		1	1			1				1	9
20	24	42.10			2	1			1	1		1	1	1							8
21	201	38.49		1		6		1	2												10
			27	44	34	33	14	14	17	7	6	4	5	3	3	4	2	3	2	11	233

$$\text{MODAL LOSS RATE} = L1 + \left(\frac{(FM - F1)*(H)}{(2Fm - F1 - F2)}\right) = 0.24 \text{ cms/hr}$$

WHERE L1 = LOWER LIMIT OF THE MODAL CLASS

Fm = FREQUENCY OF THE MODAL CLASS
F1 = FREQUENCY OF THE CLASS PRECEDDING THE MODAL CLASS
F2 = FREQUENCY OF THE CLASS SUCCEEDING THE MODAL CLASS
H = WIDTH OF THE MODAL CLASS

Table-5

OBSERVED BASE FLOW RANGES FOR OBSERVED FLOOD EVENTS
(In cumecs per square kilometre)

Sl.No	Br. No.	Area (sq.km.)	0.1	0.11 0.2	0.21 0.3	0.31 0.4	0.41 0.5	0.51 0.6	0.61 0.7	0.71 0.8	0.81 0.9	0.91 1	1.01 1.1	1.11 1.2	1.21 1.3	1.31 1.4	1.41 1.5	1.51 1.6	Total
1	240	1350.00	23	1															24
2	521	1016.00	3	4															7
3	376	758.00		2	3		2	1	3		1								12
4	373	595.70	3	4	1			2		1									11
5	8(B)	345.30	2	2	2	1		2	1										10
6	486	326.00	10	3															13
7	363	323.23	11	25	2														38
8	450	233.10	4	4	3				1										12
9	6/12	230.45		1	1	1		1			1			1					6
10	242	229.99	7		2			1											10
11	210	220.87	14	1															15
12	22	213.05	4	1															5
13	95	119.14	1						3					1					5
14	285	92.46	2	7	1	3	3		1										17
15	196	85.47	1	1	2														4
16	429	69.60		1				1					1						3
17	114	66.00	3	2	1														6
18	8(S)	61.38	8	2		2													12
19	385	46.62	1	2	2	1	2				1								9
20	24	42.10	3	3	2														8
21	201	38.49			1	1		1	1	2	1	1			1		1		10
	Total		100	66	23	9	7	9	10	3	4	1	1	2	1	0	1	0	237

Base flow = 0.05 cumecs/s

Out of 237 flood, 100 floods fall in the first range of 0.1 cumces/km sq.
Therefore an average value of 0.05 m /km is recommended.

Table - 6

POINT TO AREAL RAINFALL RATIO'S (PERCENTAGE)

Area in sq. km.	1-hr	3-hr	6-hr	12-hr	24-hr
50	83	88	92	97	98
100	74	81	88	94	96
150	67	75	84	91	94
200	63	71	81	89	93
250	60	68	78	87	91
300		65	76	86	89
350		64	74	84	88
400			73	83	87
450			72	82	86
500			71	81	85
600				79	84
700				78	82
800				77	81
900				77	80
1000				76	80
1500					79
2000					78
2500					77

TABLE - 7

STATEMENT OF HIGHEST RECORDED DAILY RAINFALL IN SUBZONE 2(a)

S.No.	State	District	Station	Maximum Rainfall (mm)	Date
1.	Assam	Goalpara	Damra	508.0	13.8.1968
2.			Lakhipur	490.3	5.5.1959
3.			Bijni	486.4	9.7.1895
4.			Kachugaon	366.0	28.6.1903
5.			Mankachar	366.0	18.6.1971
6.			Goalpara	357.4	12.5.1958
7.		Nowgong	Kampur	385.0	5.8.1966
8.			Lanka	471.9	6.10.1916
9.			Lumding	360.0	26.9.1976
10.		Darang	Goupur	312.7	16.1.1971
11.		Lakhimpur	Moran	381.0	4.9.1968
12.		Kamrup	Baruduar	417.0	20.6.1934
13.			Patacharkuchi	406.4	20.6.1989
14.	Arunachal Pradesh	Tirap	Passighat	467.0	11.7.1948
15.	West Bengal	Jalpaiguri	Jalpaiguri	403.3	8.7.1892
16.			Alipurduar	378.5	24.7.1959
17.			Buxa	538.5	8.6.1921
18.			Kalchini	354.1	20.7.1901
19.			Kumargram	381.0	5.6.1935
20.		Darjeeling	Darjeeling	454.1	12.6.1950
21.			Kalimpong	419.2	5.10.1950
22.			Mongpoo	546.1	12.6.1950
23.			Kurseong	501.7	11.6.1950
24.		Coochbehar	Dinnata	364.5	18.9.1896
25.			Mathabhanga	403.3	20.7.1878
26.	Sikkim		Dikchu	400.8	25.8.1969
27.			Singhik	504.2	12.5.1981

Table - 8

Comparision of Q_{25}, Q_{50} and Q_{100} Values obtained by SUH and Simplified Method

Sr. No.	Br. No.	C.A.	25 - years		50 - years		100 - years	
			Observed based on	Estimated: Simplif-ied Equation	Observed SUH	Estimated: Simplif-ied Equation	Observed SUH	Estimated: Equation
1	240	1350.00	1714.71	1893.67	1978.16	2158.42	2504.16	2700.02
2	521	1016.00	1328.44	1146.52	1425.86	1247.23	1475.11	1321.54
3	376	758.00	2341.70	2291.57	2900.48	2790.25	3826.12	3663.23
4	373	595.70	1041.45	1068.37	1252.58	1279.19	1547.2	1566.34
5	8(B)	345.30	1777.96	1915.89	2040.82	2206.07	2378.57	2559.45
6	486	326.00	537.32	543.30	625.24	633.63	684.59	700.11
7	363	323.23	858.69	852.24	1008.84	1006.42	1125.3	1117.81
8	450	233.10	702.50	685.53	862.87	839.43	888.99	865.98
9	6/12	230.45	1527.21	1679.46	1740.93	1937.29	1912.41	2104.72
10	242	229.99	1844.60	1832.17	1951.34	1942.77	2218.49	2208.57
11	210	220.87	857.94	920.48	982.39	1056.05	1106.16	1200.57
12	22	213.05	354.08	353.04	411.44	410.60	503.32	503.52
13	95	119.14	1600.39	1416.04	1759.25	1560.78	1898.06	1681.49
14	285	92.46	281.31	288.15	328.66	329.51	365.46	363.97
15	196	85.47	1008.63	864.68	1176.18	1021.93	1232.09	1070.08
16	429	69.60	265.95	252.72	302.26	290.66	337.76	324.69
17	114	66.00	402.16	410.29	473.37	490.46	562.17	587.89
18	8(S)	61.38	215.73	204.45	251.72	239.51	305.45	292.04
19	385	46.62	110.05	109.35	127.35	128.25	157.46	157.73
20	24	42.10	194.95	208.22	224.34	240.09	253.71	271.99
21	201	38.49	306.67	343.10	378.06	404.09	407.99	434.94

COMPARISION OF DISCHARGES BY DETAILED APPROACH WHEN TD = TB AND TD = 1.1 * tp
SUBZONE 2(a)

Sl.No.	Br.No.	C.Area in sq km.	Discharge in Cumecs by Detailed Approach					
			When TD = TB			When TD = 1.1 * tp		
			Q25	Q50	Q100	Q25	Q50	Q100
1	240	1350.00	1714.71	1978.16	2504.16	1760.31	2010.61	2507.87
2	521	1016.00	1328.44	1425.86	1475.11	1338.72	1432.83	1480.27
3	376	758.00	2341.70	2900.48	3826.12	2274.84	2778.38	3621.13
4	373	595.70	1041.45	1252.58	1547.20	1034.56	1239.94	1506.70
5	8(b)	345.30	1777.96	2040.82	2378.57	1626.86	1712.66	1993.62
6	486	326.00	537.32	625.24	684.59	530.07	613.64	670.72
7	363	323.23	858.69	1008.84	1125.30	834.14	945.85	1084.44
8	450	233.10	702.50	862.87	888.99	673.97	820.16	844.85
9	6/12	230.45	1527.21	1740.93	1912.41	1409.08	1600.13	1753.59
10	242	229.99	1844.60	1951.34	2218.49	1527.81	1614.50	1832.92
11	210	220.87	857.94	982.39	1106.16	795.65	930.07	1042.47
12	22	213.05	354.08	411.44	503.32	352.13	407.28	495.21
13	95	119.14	1600.39	1759.25	1898.06	300.98	1420.77	1540.26
14	285	92.46	281.31	328.66	365.46	222.78	320.84	354.65
15	196	85.47	1008.63	1176.18	1232.09	842.52	980.34	1027.09
16	429	69.60	265.95	302.26	337.76	265.51	299.75	333.76
17	114	66.00	402.16	473.37	562.17	408.36	477.88	566.77
18	8(s)	61.38	215.73	251.72	305.45	206.06	238.41	286.88
19	385	46.62	110.05	127.35	157.46	110.74	127.68	157.21
20	24	42.10	194.95	224.34	253.71	192.27	219.77	247.19
21	201	38.49	306.67	378.06	407.99	315.95	363.19	373.33

Note: Out of 21 bridge catchments 16 bridge catchments at Sl.No. 3,4,5,6,7,8,9,10,11,12,13,14,15,16,18 and 20 are showing more value by TD =TB than Td = 1.1 tp. Hence, TD =TB is adopted in this report.

ANNEXURE-1

LIST OF HYDRO-METEOROLOGICAL SUB-ZONES

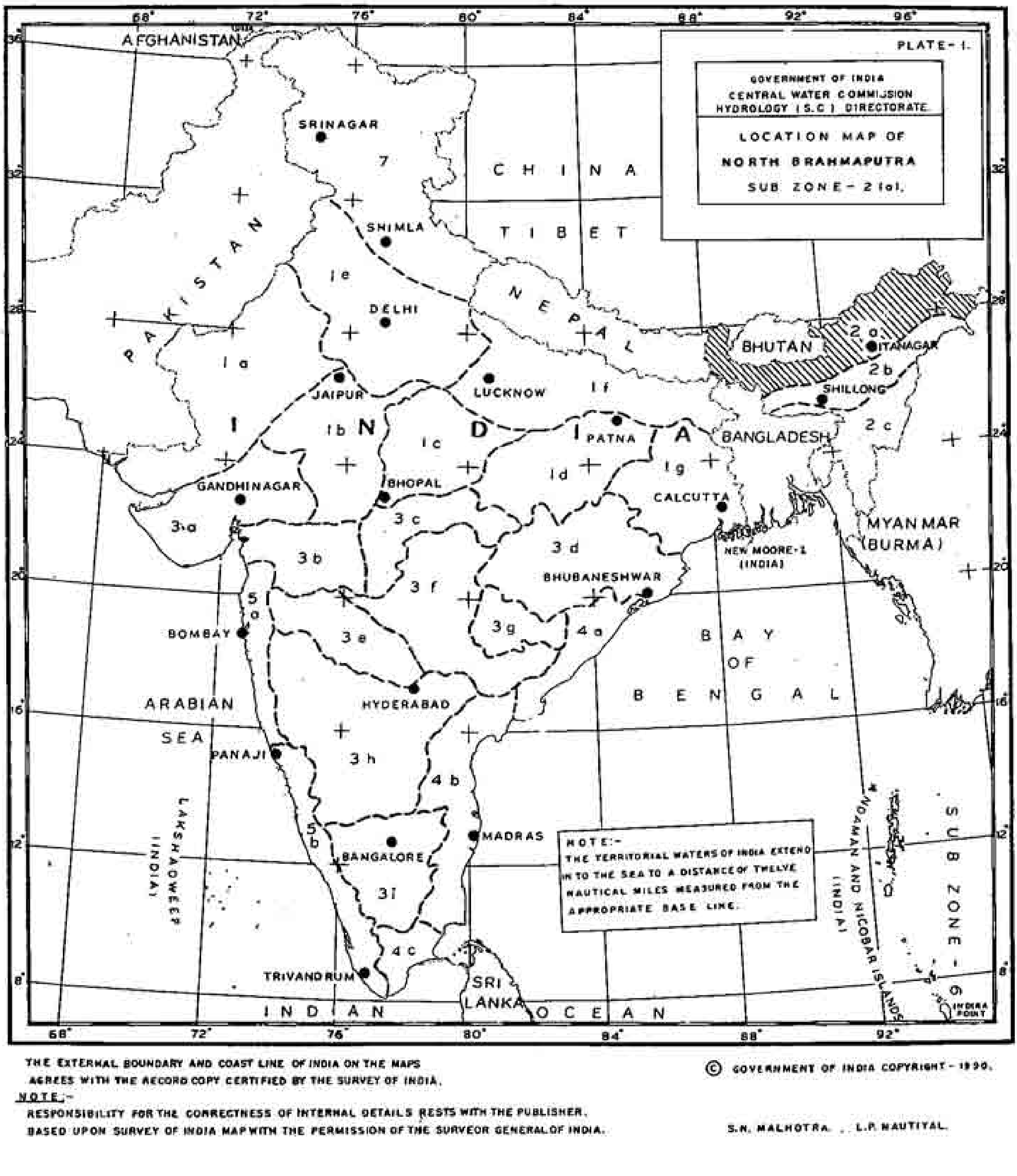
Sub-zone	Name of subzone (designated earlier)	Name of sub-zone (designated now)	River Basins included in the sub-zone
1	2	3	4
1(a)	Luni basin & Thar (Luni & other rivers of Rajasthan and Kutch)	Luni	Luni river, Thar (Luni & other rivers of Rajasthan and Kutch and Banas river).
1(b)	Chambal Basin	Chambal	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 Basin.
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 & Mechha Bhandar, 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 & Penner rivers except coastal region.
3(i)	Kaveri & East flowing rivers aexcept 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 Penner, Cheyyar, Palar, North Penner, 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.

LIST OF PHYSICAL AND UNIT HYDROGRAPH PARAMETERS STUDIE TO ESTABLISH RELATIONSHIPS WITH THEIR COEFFICIENT OF CORRELATION
SUBZONE - 2(a)

Sl. No.	Independent variables Physiographic Parameters/unit graph parameters	Constant	Dependent variables Unitgraph Parameters	Exponent	Coefficient of correlation
1	2	3	4	5	6
1	Lc	0.986	tp	-0.667	0.513
2	$LLc/\sqrt{S}$	5.302	qp	-0.500	0.838
3	A	2.625	tp	0.209	0.267
4	tp	1.410	qp	-0.831	0.884
5	L	0.738	tp	0.642	0.442
6	$LLc/\sqrt{S}$	0.474	tp	0.460	0.728
7	LLc/S	1.210	tp	0.355	0.711
8	$Lc/\sqrt{S}$	1.427	tp	0.710	0.774
9	Lc/S	4.008	tp	0.396	0.713
10	$ALc/\sqrt{S}$	0.714	tp	0.214	0.545
11	LLc/S	2.272	qp	-0.409	0.911
12	qp	2.164	tp	-0.940	0.884
13	qp	2.084	W_{50}	-1.065	0.986
14	qp	1.028	W_{75}	-1.071	0.957
15	qp	0.856	WR_{50}	-0.865	0.910
16	qp	0.440	WR_{75}	-0.918	0.879
17	tp	5.428	TB	0.852	0.940



THE EXTERNAL BOUNDARY AND COAST LINE OF INDIA ON THE MAPS AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

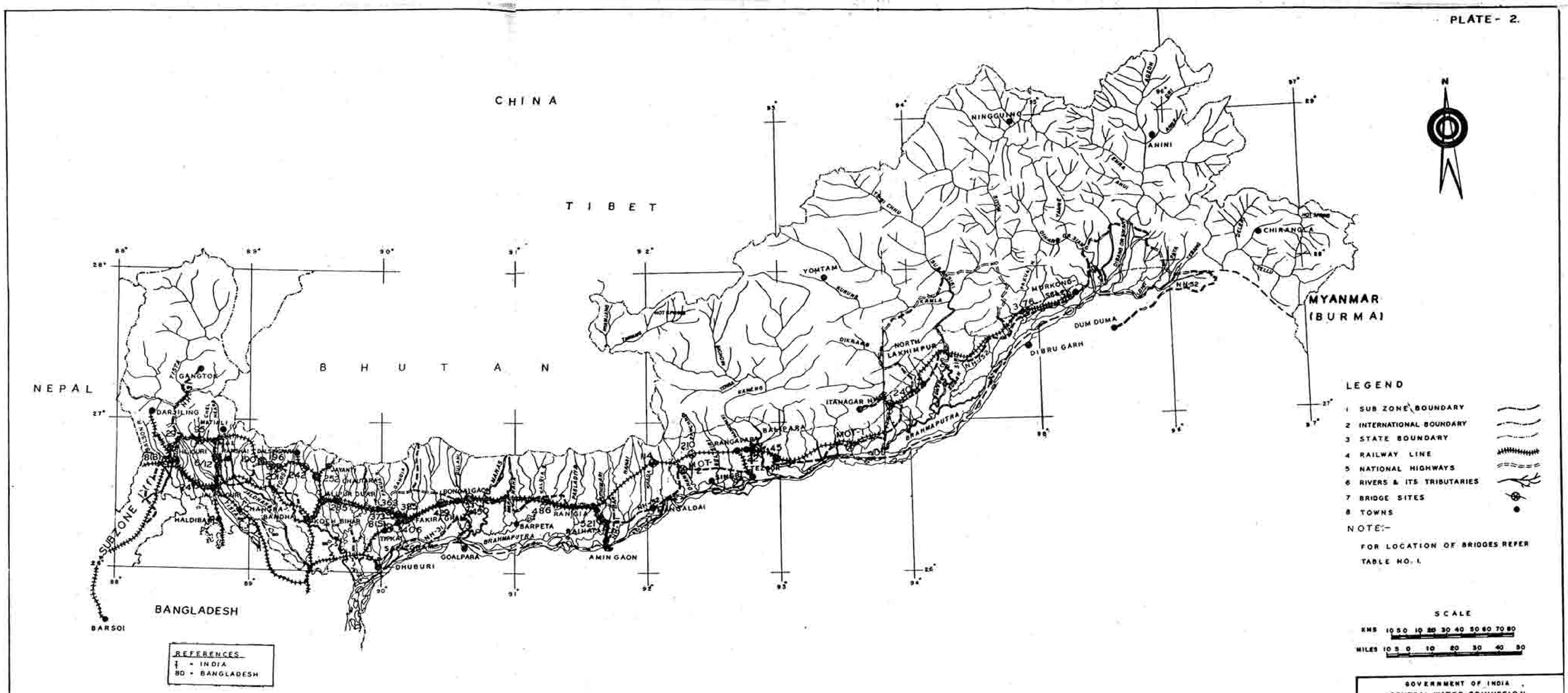
NOTE:-

RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.

S.N. MALHOTRA . . L.P. NAUTIYAL.

PLATE - 2.



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

NORTH BRAHMAPUTRA

SUB ZONE 2 (a)

RIVER SYSTEM AND LOCATION OF ROAD AND RAILWAY BRIDGES (G & D SITES)

DRAWN BY- S. N. MALHOTRA, L. P. NAUTIYAL | CHECKED BY-A. K. GHOSH

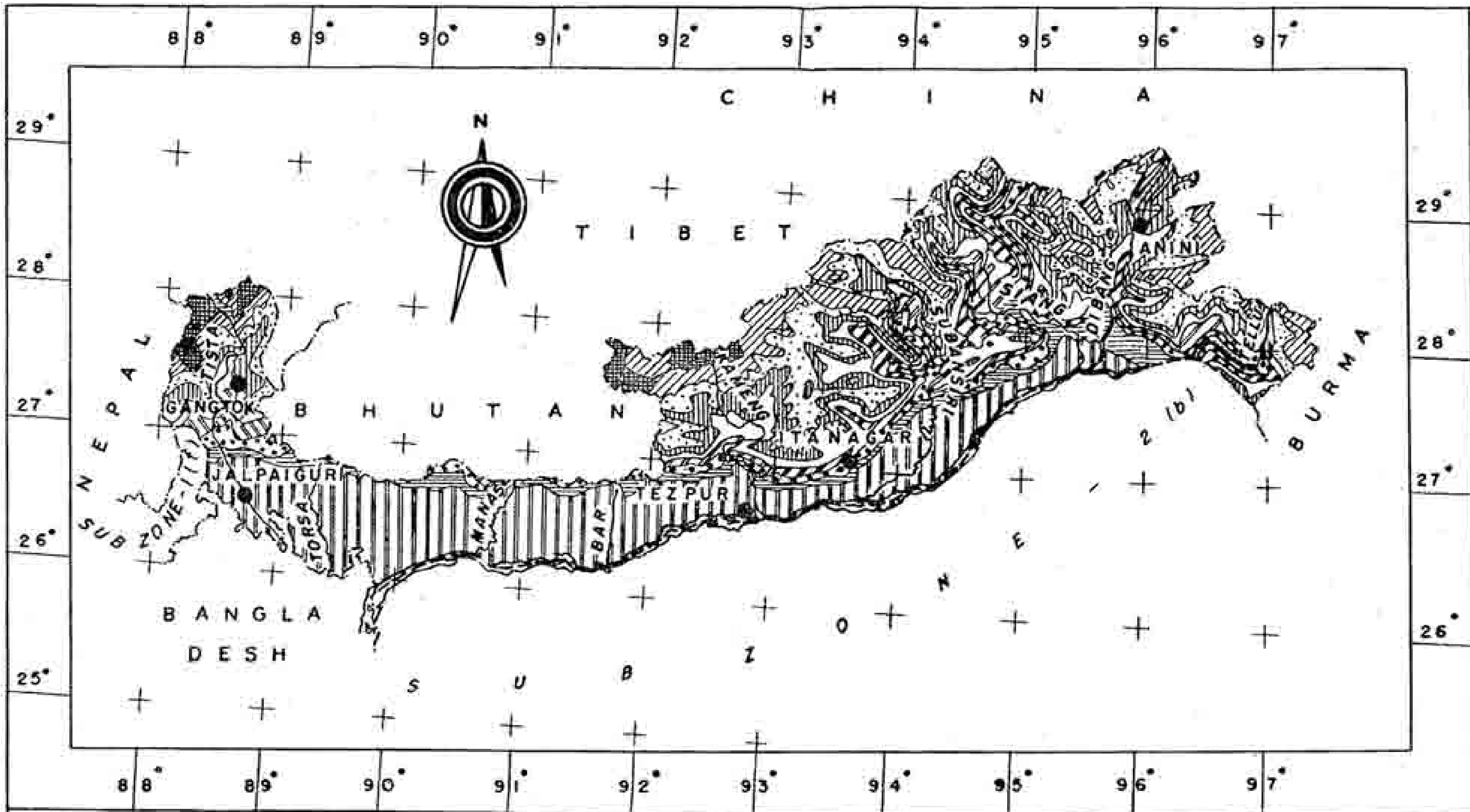
NOTES:-

THE EXTERNAL BOUNDARY OF INDIA ON THIS MAP AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

BASED UPON SURVEY OF INDIA MAP WITH PERMISSION OF SURVEYOR GENERAL OF INDIA.

PLATE - 3.



LEGEND

SL.NO	ALTITUDE IN MTS.	SYMBOLE
1.	0 - 150	
2.	150 - 300	
3.	300 - 600	
4.	600 - 900	
5.	900 - 1350	
6.	1350 - 1800	
7.	1800 - 3000	
8.	3000 - 4500	
9.	4500 - 6000	
10.	6000 - 7500	

100 50 0 100 200 KMS.

50 0 50 100 MILES

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA
SUB ZONE - 2 (a)
PHYSIOGRAPHY

DRAWN BY - S. N. MALHOTRA, L. P. NAUTIYAL

CHECKED BY - A. K. GHOSH.

NOTE :-

THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA. (1971). PLATE - 3.

REFERENCES :-

1. INTERNATIONAL BOUNDARY
2. SUB ZONE BOUNDARY
3. RIVER AND IT'S TRIBUTARIES
4. TOWNS

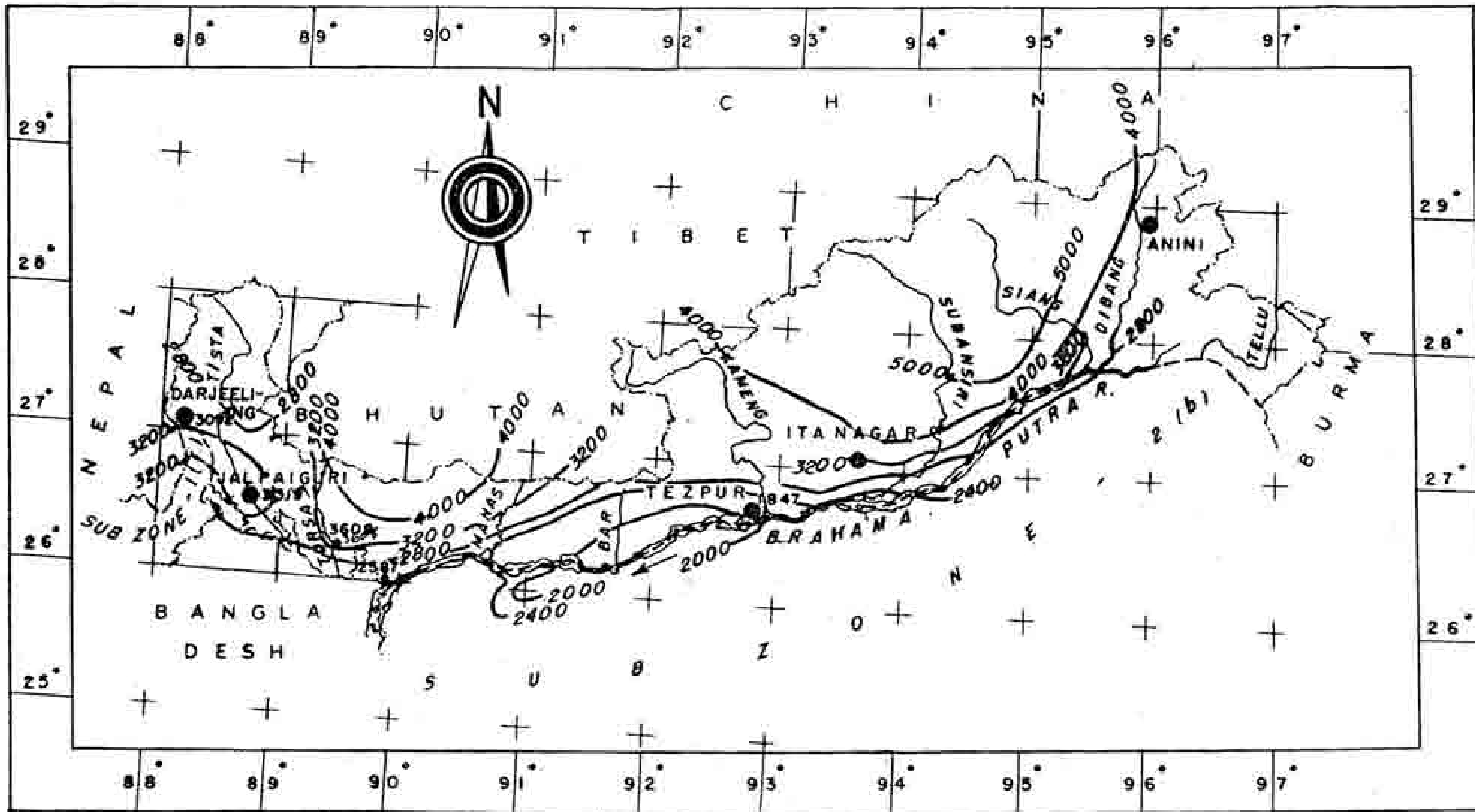
NOTES:-

I. THE EXTERNAL BOUNDARY OF INDIA ON THIS MAP AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

II. RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

III. BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF SURVEOR GENERAL OF INDIA.

PLATE- 4.



NOTES:—

1. HISTOGRAMS FOR TWO STATIONS WITH NAMES.
2. EACH VERTICAL COLUMN REPRESENTS THE MEAN MONTHLY RAINFALL FOR EACH MONTH (FROM JANUARY TO DECEMBER.)
3. THE THICK VERTICAL LINES AT THE CENTRE OF EACH COLUMN INDICATES THE PERCENTAGE OF RAINFALL IN THE MONTH TO THE MEAN ANNUAL TOTAL.
4. THIS MAP HAS BEEN CRAWN FROM THE IRRIGATION ATLAS OF INDIA (1971) PLATE- 6.

SCALE

100 50 0 100 200 KMS.

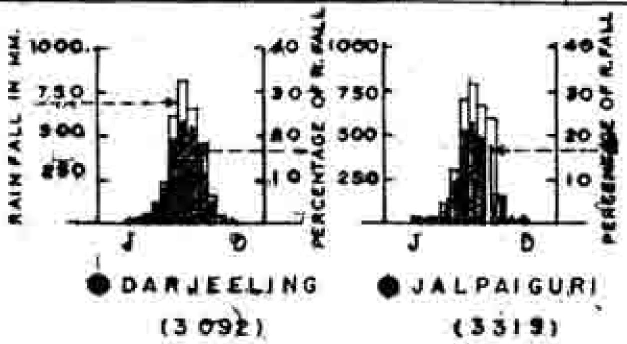
50 0 50 100 MILES

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA SUB ZONE - 2 (a) NORMAL ANNUAL RAINFALL

DRAWN BY— S. N. MALHOTRA, L. P. NAUTIYAL

CHECKED BY— R. K. GUPTA



REFERENCES

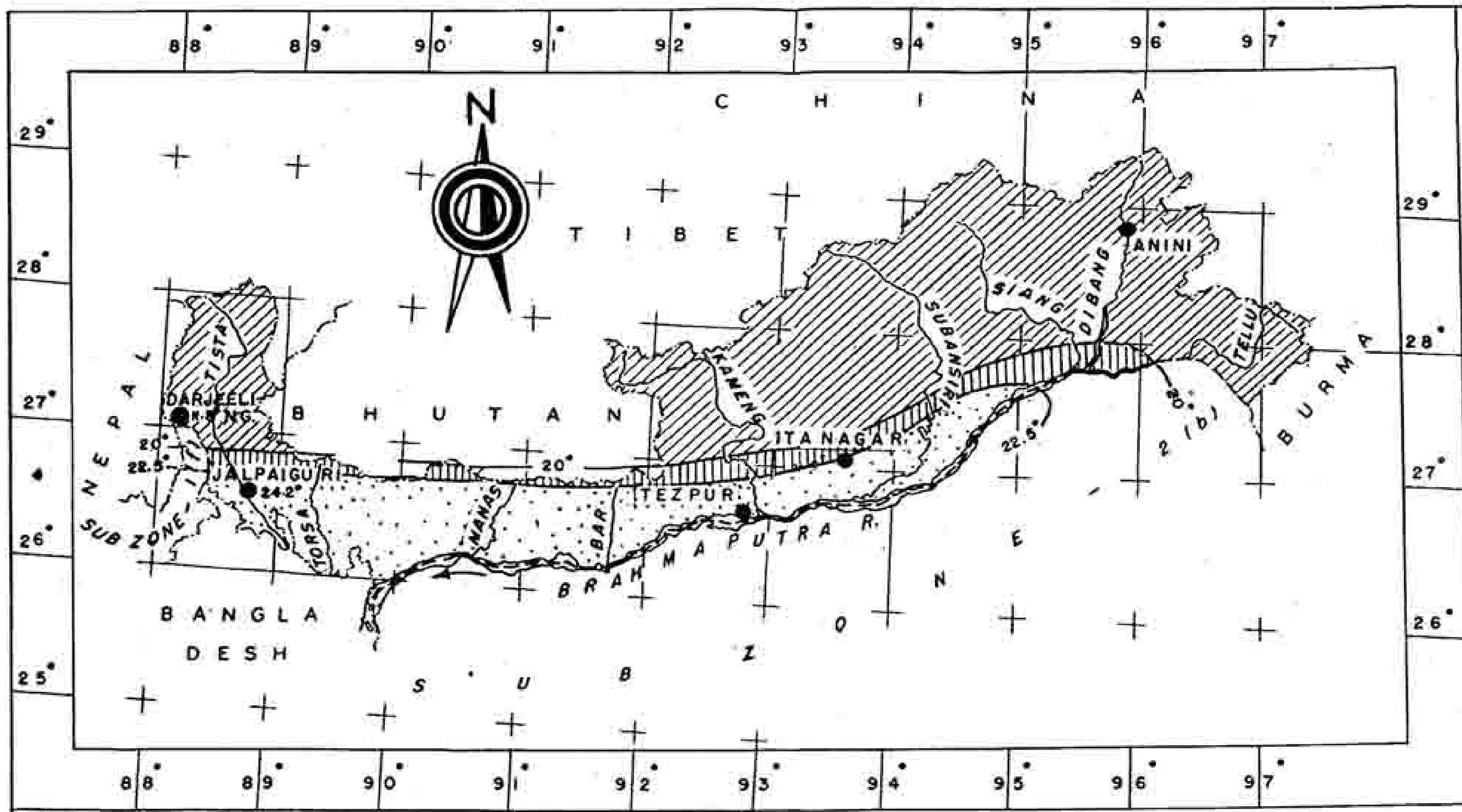
1. ISOHYETAL-LINES WITH VALUE IN MM. (NORMAL ANNUAL) 2000
2. INTERNATIONAL BOUNDARY
3. SUB ZONE BOUNDARY
4. RIVERS
5. TOWNS
6. SPOT RAINFALL (MM.) 3092

NOTES:- I. THE EXTERNAL BOUNDARY OF INDIA ON THIS MAP AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

II. RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

III. BASED UP ON SURVEY OF INDIA MAP WITH THE PERMISSION OF SURVEOR GENERAL OF INDIA.

PLATE- 5.



REFERENCES

1. TEMPERATURE BELOW 20°C.
2. TEMP. BETWEEN 20°C TO 22.5°C.
3. TEMP. BETWEEN 22.5°C TO 25°C.
4. INTERNATIONAL BOUNARY
5. SUB ZONE BOUNDARY
6. RIVERS
7. TOWNS
8. ISOTHEMS WITH VALUE IN 'C' DEGREES.

SCALE

100 50 0 100 200 KMS.

50 0 50 100 MILES

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA

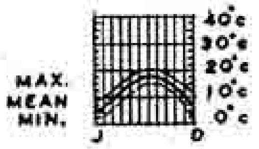
SUB ZONE - 2 (a)

NORMAL ANNUAL TEMERATURE

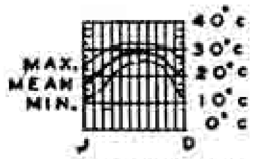
DRAWN BY —	CHECKED BY —
S. N. MALHOTRA L. P. NAUTIYAL	R. K. GUPTA.

NOTES:—

THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1971) PLATE - 4.



DARJEELING
(11.8°C)



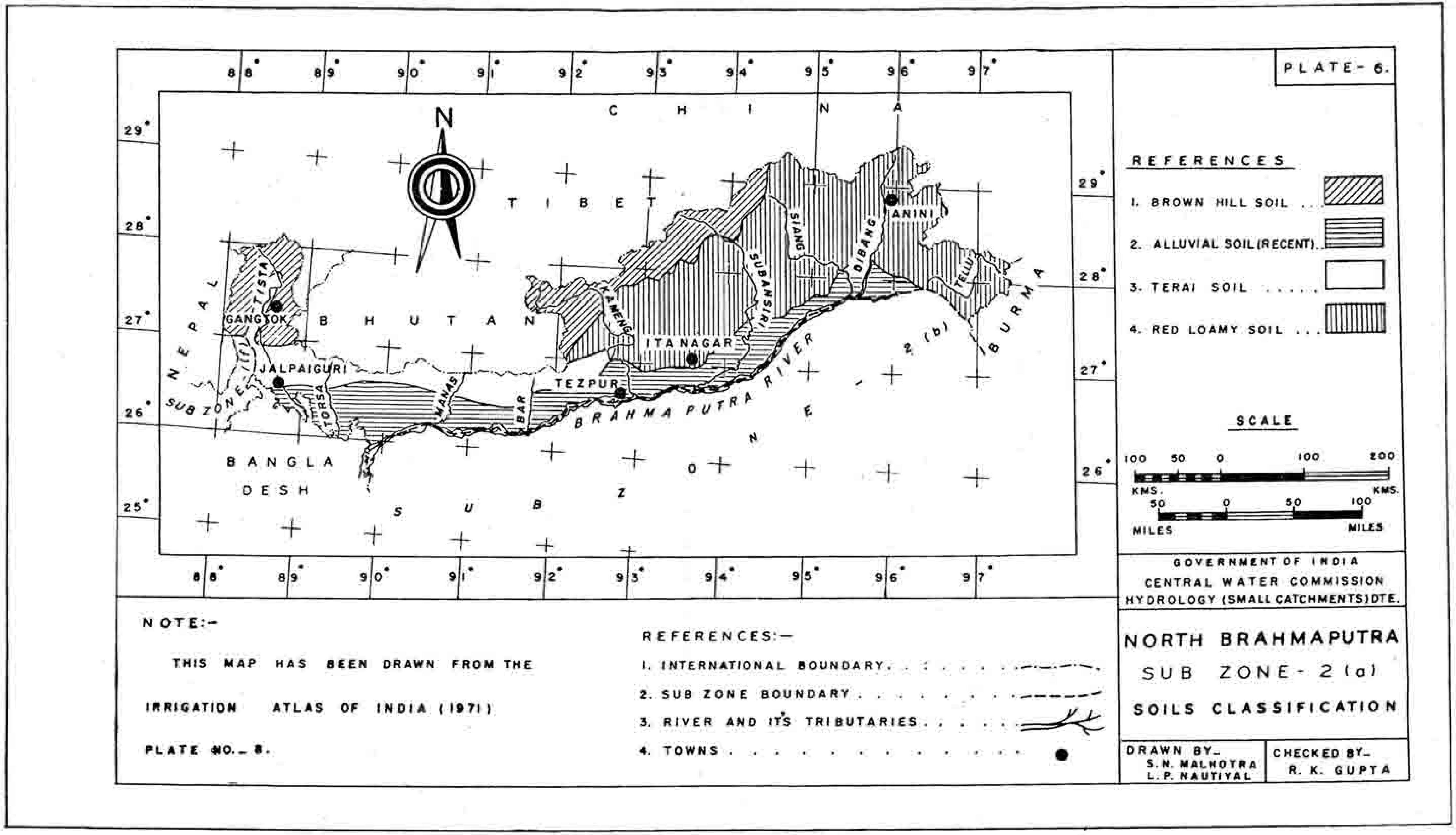
JALPAIGURI
(24.2°C)

NOTES:—

I. THE EXTERNAL BOUNDARY OF INDIA ON THIS MAP AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

II. RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

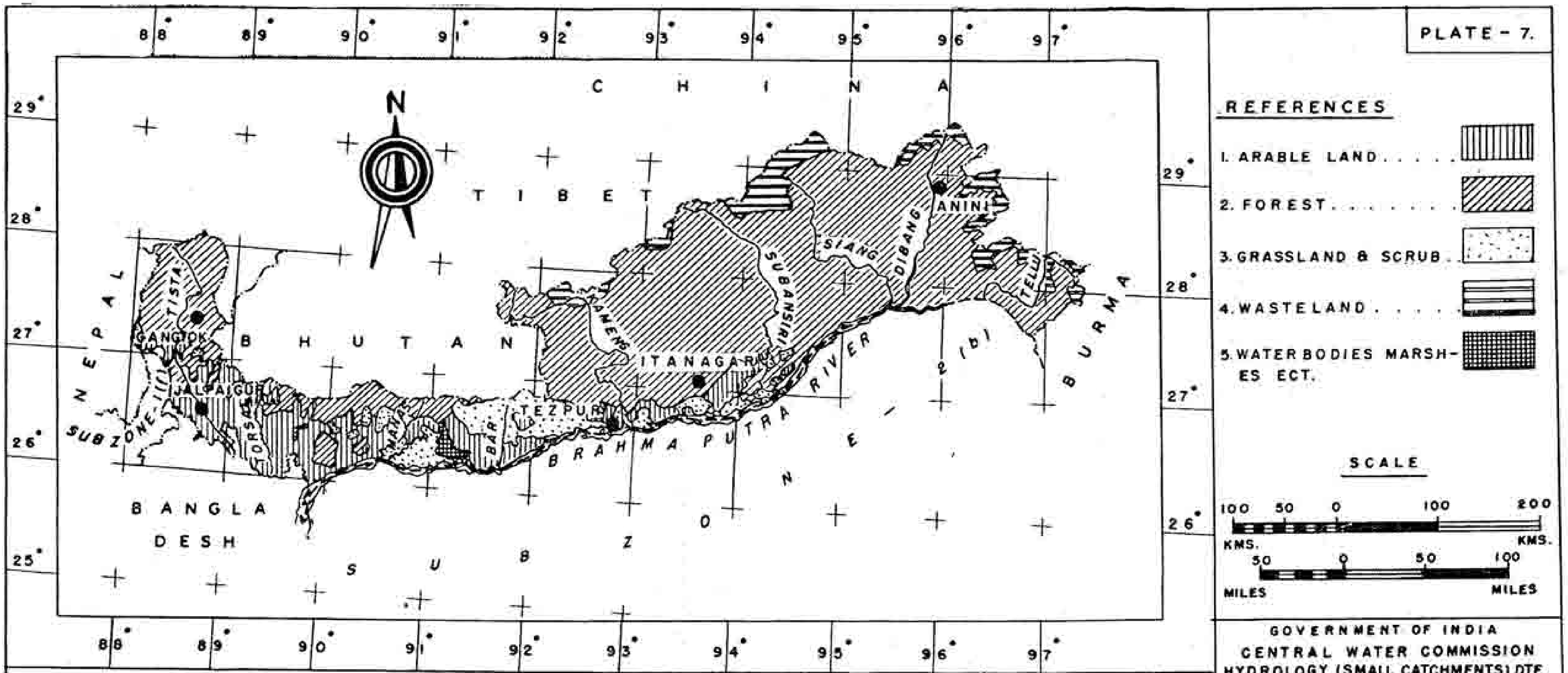
II. BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF SURVEOR GENERAL OF INDIA.



NOTES:- I. THE EXTERNAL BOUNDARY OF INDIA ON THIS MAP AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

II. RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

III. BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF SURVEYOR GENERAL OF INDIA.



GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA

SUB ZONE - 2 (a)

LAND USE

DRAWN BY— S. N. MALHOTRA, L. P. NAUTIYAL

CHECKED BY— A. K. GHOSH

NOTE:-

THIS MAP HAS BEEN DRAWN FROM THE IRRIGATION ATLAS OF INDIA (1971).

PLATE NO. _9.

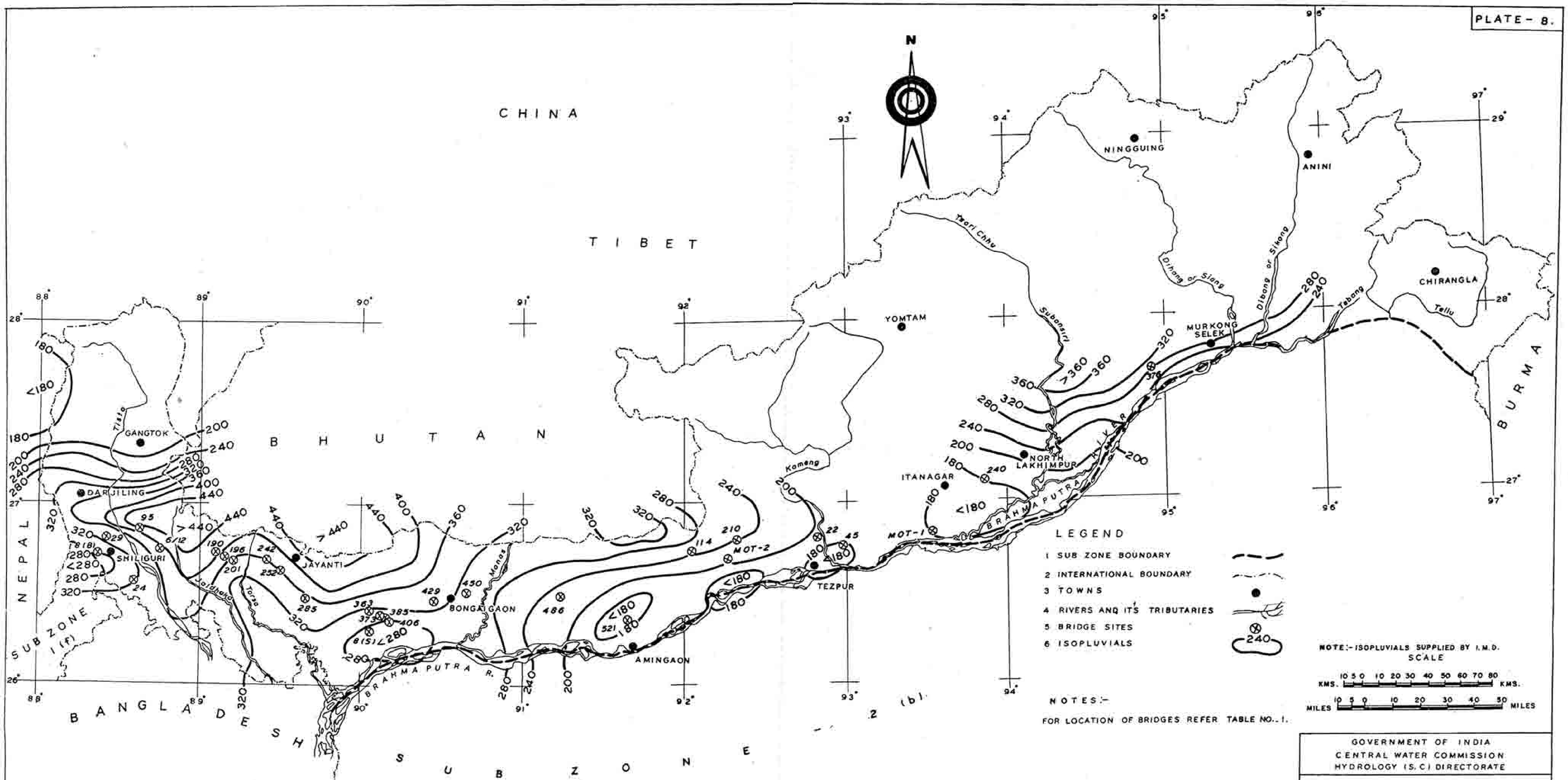
REFERENCES:-

1. INTERNATIONAL BOUNDARY.
2. SUB ZONE BOUNDARY
3. RIVER & ITS TRIBUTARIES
4. TOWNS

NOTES:- I. THE EXTERNAL BOUNDARY OF INDIA ON THIS MAP AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

II. RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

III. BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF SURVEOR GENERAL OF INDIA.



NOTES:-

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

NORTH BRAHMAPUTRA
SUB ZONE 2 (a)
25 YEAR - 24 HOUR RAINFALL (mm.)

DRAWN BY.—	CHECKED BY.—
S. N. MALHOTRA. L. P. NAUTIYAL.	ANIL KUMAR GHOSH.

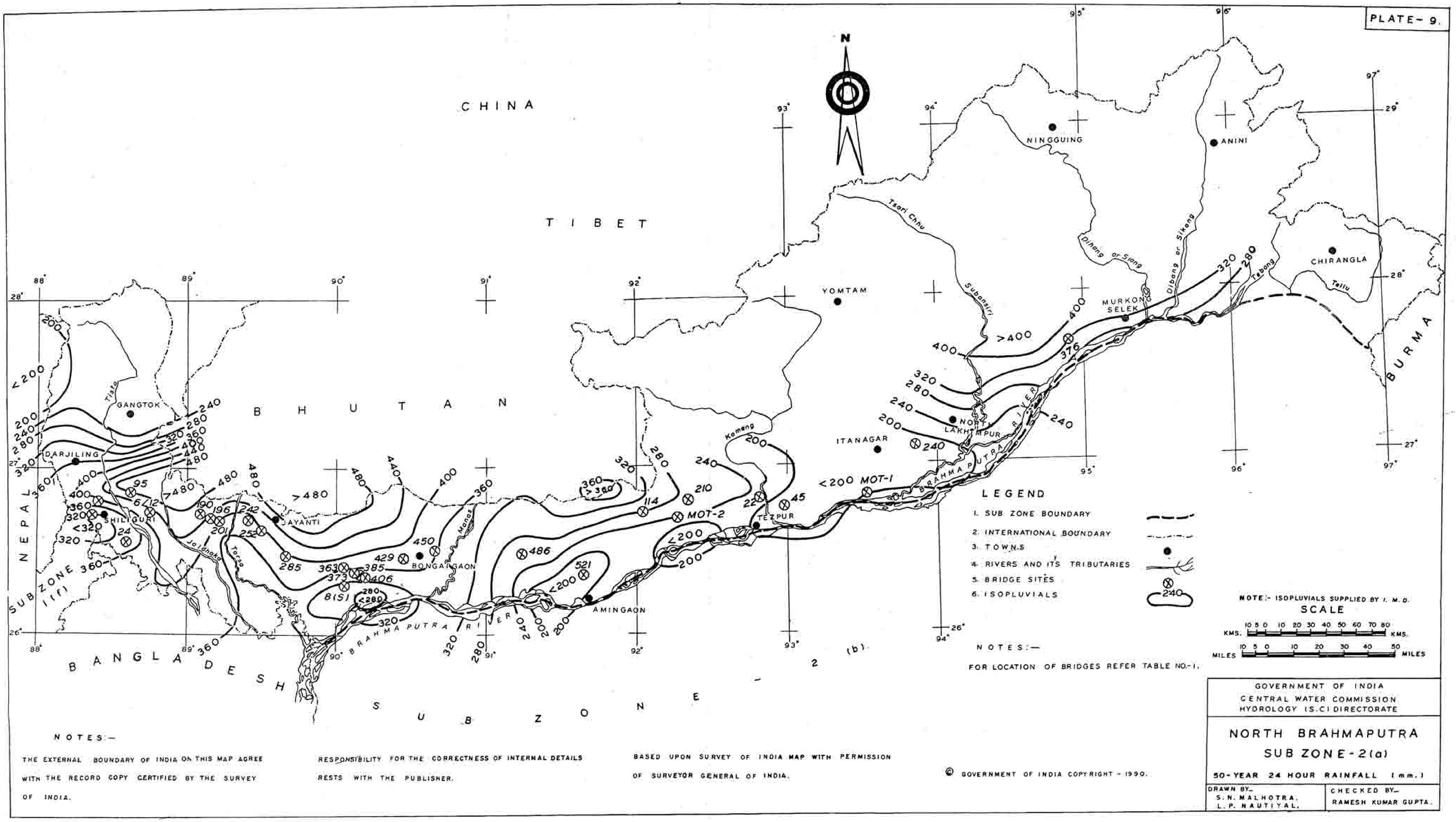
PLATE- 9.
CHINA
TIBET
BHUTAN
NEPAL
BANGLADESH
BURMA
SUB ZONE 1(f)
SUB ZONE 2 (b)
GANGTOK
DARJILING
SHILIGURI
JAYANTI
BONGAIGAON
AMINGAON
TEZPUR
ITANAGAR
NORTH LAKHIMPUR
MURKONG SELEK
YOMTAM
NINGGUING
ANINI
CHIRANGLA
MOT-1
MOT-2
BRAHMAPUTRA RIVER
Tista
Jaldhaka
Torsa
Manas
Kameng
Subansiri
Tsari Chhu
Dibang or Siang
Dibang or Sikang
Tebang
Tellu
LEGEND
1. SUB ZONE BOUNDARY
2. INTERNATIONAL BOUNDARY
3. TOWNS
4. RIVERS AND ITS TRIBUTARIES
5. BRIDGE SITES
6. ISOPLUVIALS
NOTE:- ISOPLUVIALS SUPPLIED BY I. M. D.
SCALE
KMS.
MILES
NOTES:—
FOR LOCATION OF BRIDGES REFER TABLE NO.-1.
NOTES:—
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RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.
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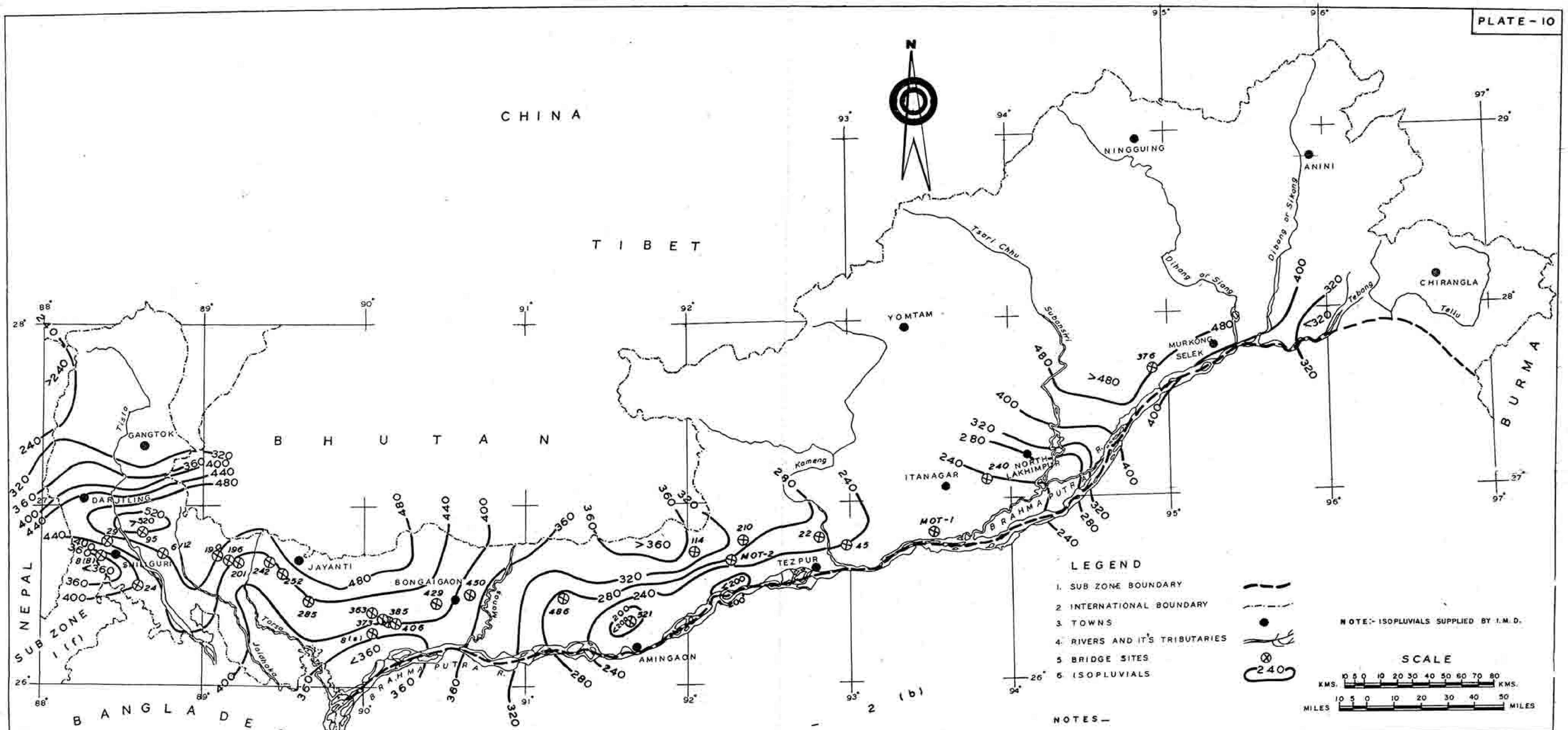
CENTRAL WATER COMMISSION
HYDROLOGY (S.C) DIRECTORATE
NORTH BRAHMAPUTRA
SUB ZONE-2(a)
50-YEAR 24 HOUR RAINFALL (mm.)
DRAWN BY_ S. N. MALHOTRA, L. P. NAUTIYAL,
CHECKED BY_ RAMESH KUMAR GUPTA.



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CENTRAL WATER COMMISSION
HYDROLOGY (S.C) DIRECTORATE

NORTH BRAHMAPUTRA
SUB ZONE - 2 (a)
100 - YEAR 24 HOUR RAINFALL (m.m.)

DRAWN BY— S.N. MALHOTRA, L.P. NAUTIYAL
CHECKED BY— ANIL KUMAR GHOSH

NOTES:—

THE EXTERNAL BOUNDARY OF INDIA ON THIS MAP AGREE WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA.

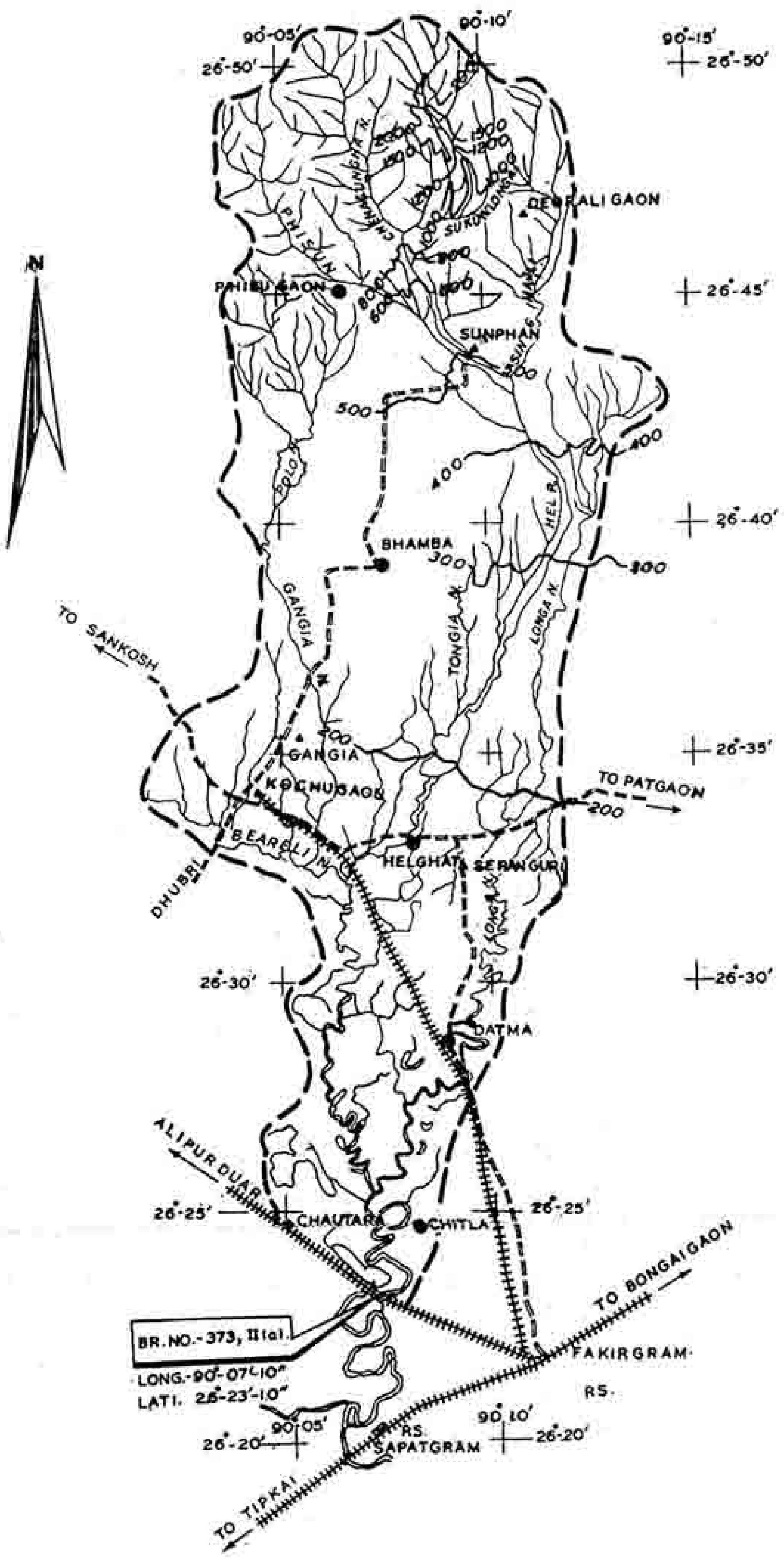
RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS RESTS WITH THE PUBLISHER.

BASED UPON SURVEY OF INDIA MAP WITH PERMISSION OF SURVEYOR GENERAL OF INDIA.

FIG.- A - I.

NOTES:-

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



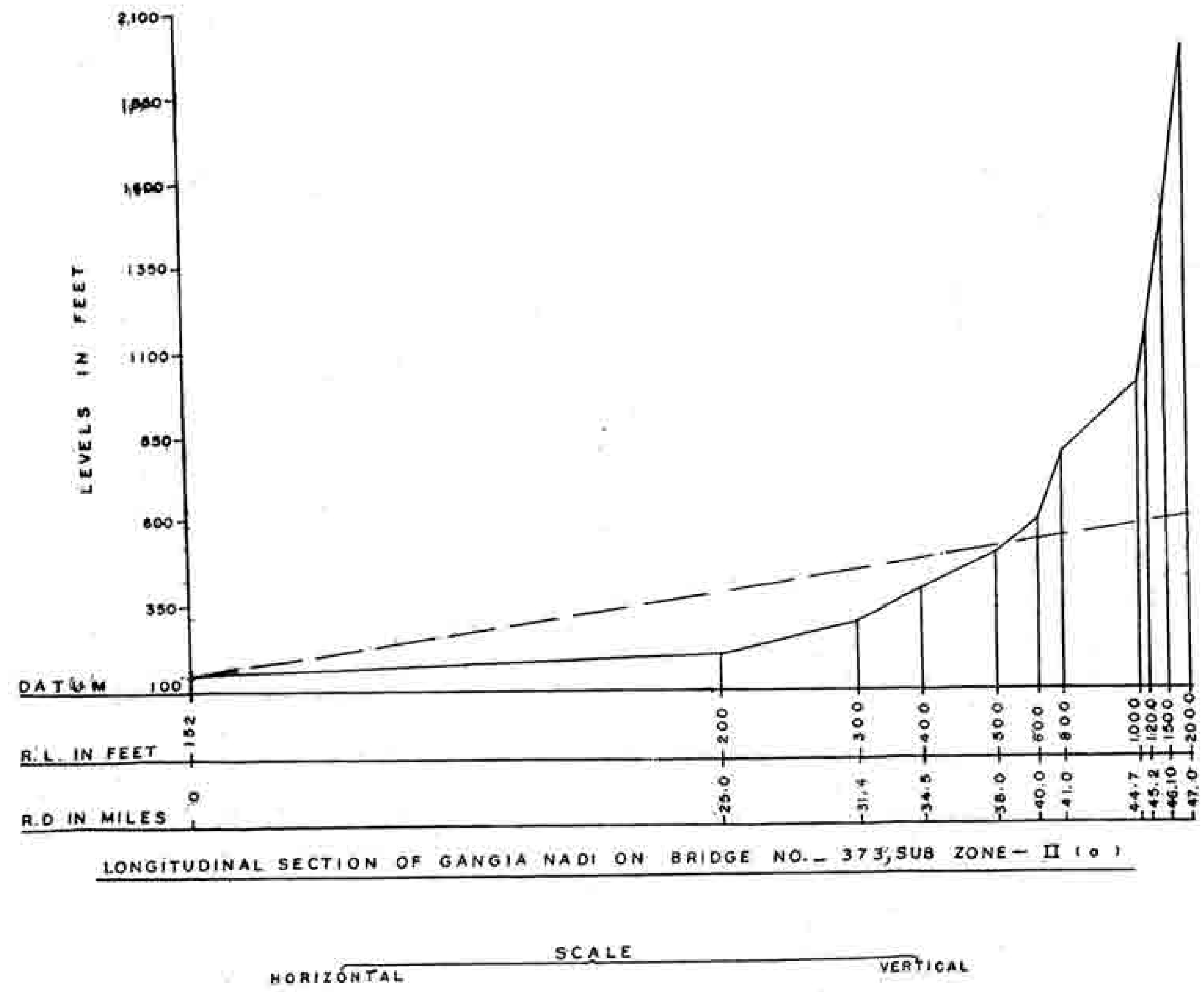
REFERENCES

1. CATCHMENT BOUNDARY
2. RAILWAY LINE
3. RIVER AND IT'S TRIBUTARIES
4. RAINGAUGE STATIONS
5. CONTOURS
6. ROADS
7. TOWNS
8. TO PO SHEETS NO.- 78J/NW & I/SW, 78J/SW (EDITION 1931.)

DETAILS OF CATCHMENT AREA

1. CATCHMENT AREA ---------- 230 Sq. MILES Or 595 Km.^{2}
2. SHAPE OF THE CATCHMENT ---------- LEAF
3. LENGTH ---------- 75.62 Km.
4. L_C ---------- 47.14 Km.
5. $\frac{LL_c}{\sqrt{S}}$ ---------- 2733.22
6. $S_{eq.}$ ---------- 1.701 M/Km.

	NAME OF THE RAIN GAUGE STATION	LONG.	LATI.	STATION WEIGHTS	
				1971	72 - 1976
1.	PHISUGAON	90°-06'-30"	26°-45'-08	0.351	0.351
2.	BHAMBA	90°-07'-30"	26°-39'-10"	0.270	0.270
3.	HELGHAT	90°-08'-10"	26°-33'-10"	0.219	0.219
4.	DATMA	90°-09'-00"	26°28'35"	0.095	0.095
5.	CHITLA	90°-08'-08"	26°-24'-35"	0.065	0.049
6.	BRIDGE SITE	90°-07'-10"	26°-23'-10"	-	0.016



LONGITUDINAL SECTION OF GANGIA NADI ON BRIDGE NO.- 373, SUB ZONE- II (a)

SCALE

HORIZONTAL: MILES 4 3 2 1 0 4 8 12

VERTICAL: 250 150 500 250 500 750 FEET

SCALE

MILES 2 1 0 2 4 6

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

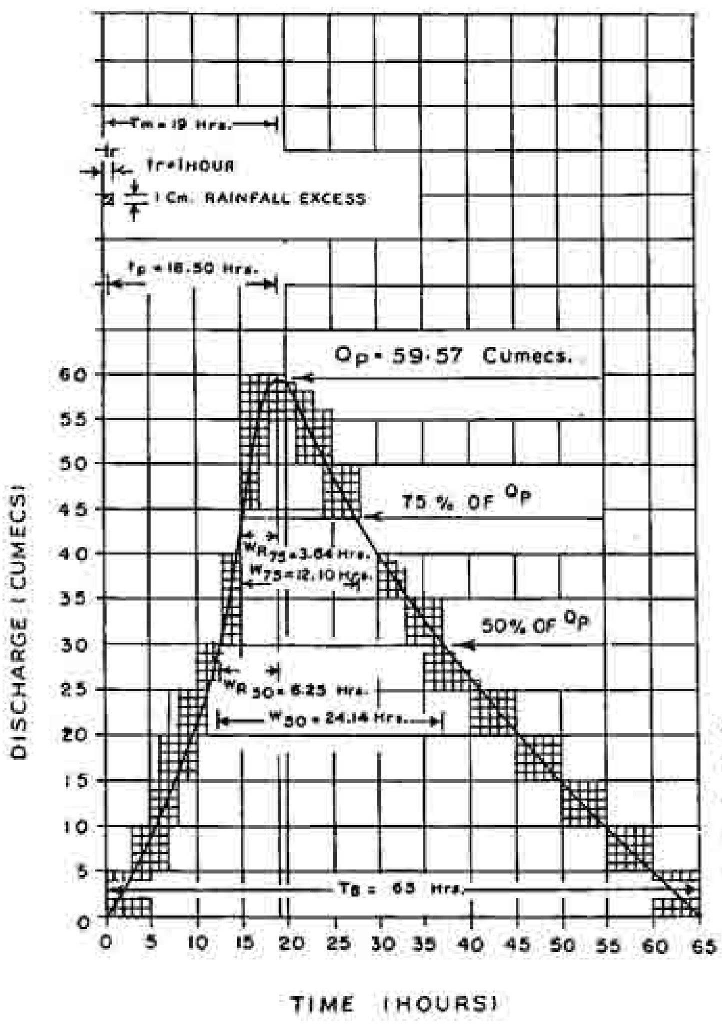
NORTH BRAHMAPUTRA

SUB ZONE - 2 (a).

CATCHMENT AREA PLAN OF BRIDGE NO.- 373. OF RIVER GANGIA N. AT Km. 191/13-14 BETWEEN ALIPURDUAR-BONGAIGAON.

DRAWN BY-	CHECKED BY-
S. N. MALHOTRA L. P. NAUTIYAL	A. K. GHOSH

FIG._ A.- 2



1_HOUR SYNTHETIC U.G ORDINATES

TIME IN (HOUR)	ORDINATES (CUMECS)	TIME IN (HOUR)	ORDINATES (CUMECS)	TIME IN (HOUR)	ORDINATES (CUMECS)	TIME IN (HOUR)	ORDINATES (CUMECS)	TIME IN (HOUR)	ORDINATES (CUMECS)
0	0.00	14	37.00	28.	43.80	42.	24.00	56.	8.25
1.	2.00	15	43.00	29.	41.60	43.	22.75	57.	7.25
2.	4.00	16.	49.50	30.	40.00	44.	21.50	58.	6.40
3.	6.00	17.	55.50	31.	38.50	45.	20.20	59.	5.40
4.	8.00	18.	58.00	32.	37.00	46.	19.00	60.	4.50
5.	9.75	19.	59.57	33.	35.50	47.	17.75	61.	3.50
6.	11.90	20.	58.70	34.	34.25	48.	16.65	62.	2.50
7.	14.00	21.	57.00	35.	32.75	49.	15.50	63	1.75
8.	16.50	22.	55.00	36.	31.50	50.	14.50	64.	0.75
9.	19.00	23.	52.75	37.	30.20	51.	13.40	65.	0.00
10.	21.50	24.	50.75	38.	28.75	52.	12.25	TOTAL_	1654.72 Cumecs.
11.	24.00	25	48.75	39.	27.60	53.	11.25		
12.	27.50	26.	46.90	40.	26.25	54	10.25		
13.	32.00	27.	45.00	41.	25.20	55.	9.25		

SYNTHETIC U.G PARAMETERS

1. C.A. = 595.70 Sq.Km.
2. t_p = 18.50 Hrs.
3. T_B = 65.00 Hrs.
4. Q_p = 59.57 Cumecs
5. W_{50} = 24.14 Hrs.
6. W_{75} = 12.10 Hrs.
7. WR_{50} = 6.25 Hrs.
8. WR_{75} = 3.64 Hrs.
9. q_p = 0.10 $M^3/Sq.Km.$
10. T_m = 19.00 Hrs.
11. $\frac{LLc}{\sqrt{S}}$ = 2095.70
12. d = 1.00 Cms.

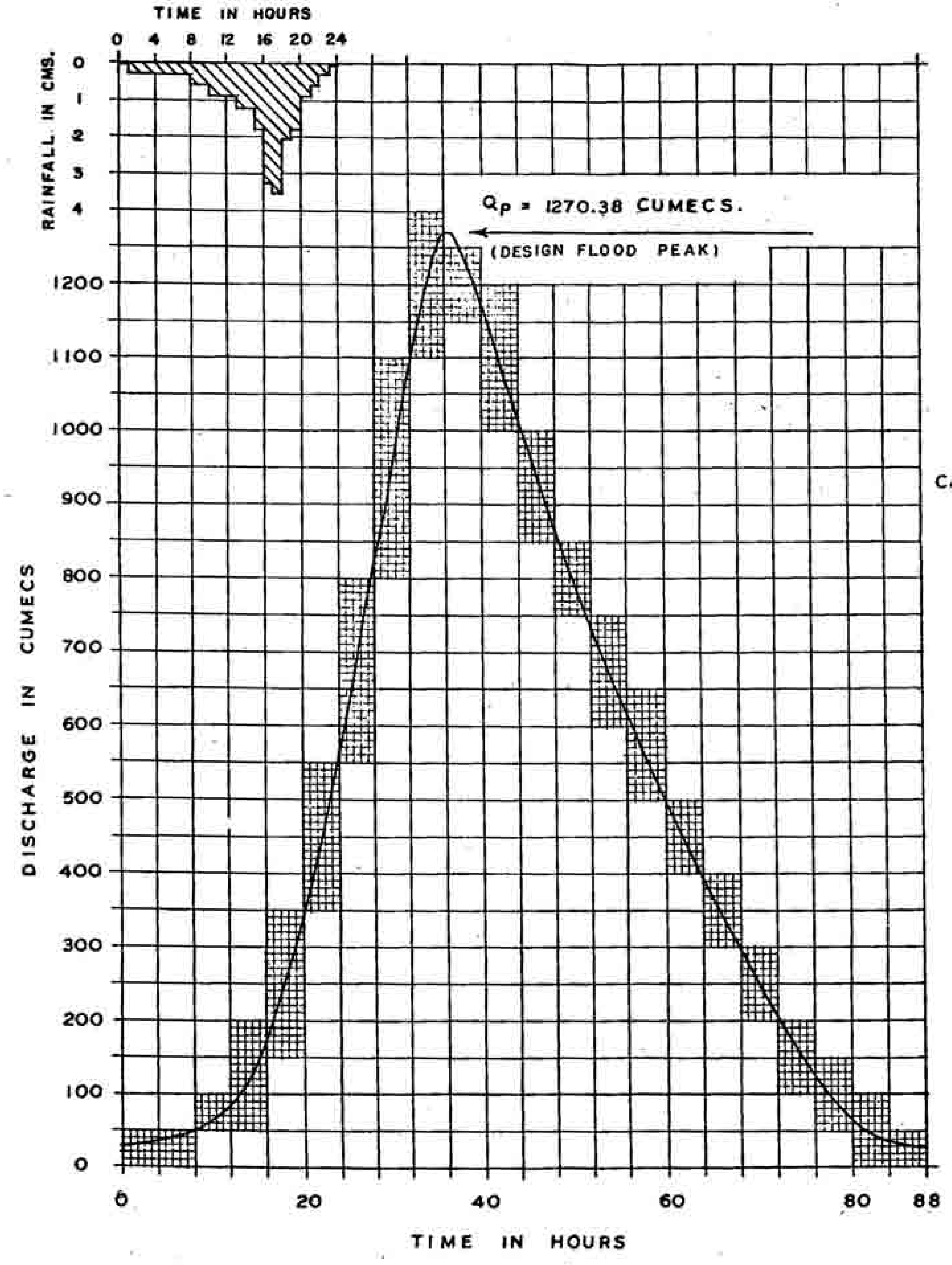
$$Q_i = \frac{A \times d}{t_r \times 0.36} = \frac{595.70 \times 1.00}{1.00 \times 0.36} = 1654.72 \text{ Cumecs}$$

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA
SUB ZONE - 2 (a).
SYNTHETIC UNIT HYDROGRAPH
BRIDGE NO._ 373.

DRAWN BY_	CHECKED BY_
S. N. MALHOTRA L. P. NAUTIYAL	G. S. RAO.

FIG.– A. 3.



CATCHMENT AREA 230 Sq. MILES

(595 Sq. KMS.)

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA

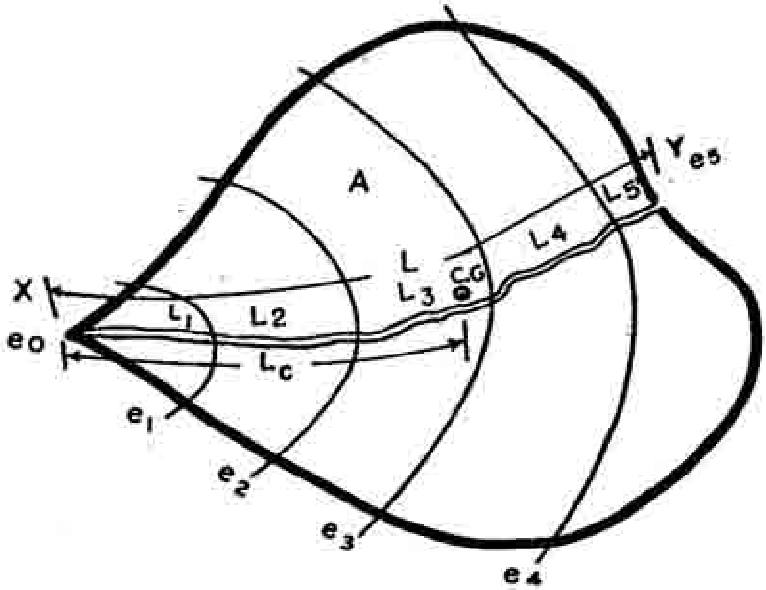
SUB ZONE – 2 (a).

DESIGN FLOOD HYDROGRAPH

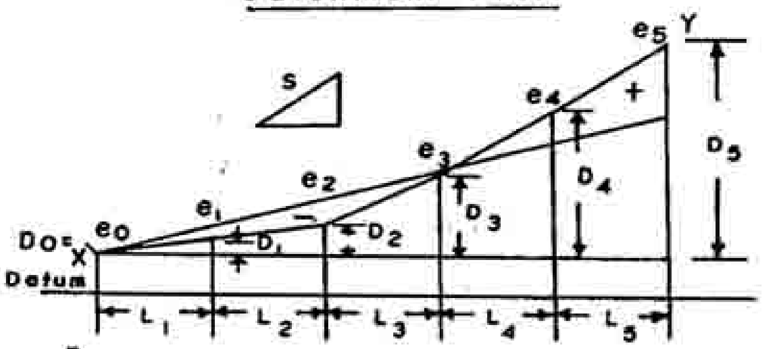
BR. NO.- 373., ON GANGIA NADI

DRAWN BY–	CHECKED BY–
S. N. MALHOTRA. L. P. NAUTIYAL.	C. S. AGARWAL.

FIG.- I



Catchment Plan



L - Section

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

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

L = Length of longest stream course (km.).

$L_i = L_1, L_2, L_3$ ---------- L_n Segment lengths (km.).

$e_i = e_0, e_1, e_2$ -------- e_n contour elevation (m).

$D_i = D_0, D_1, D_2$ -------- D_n

$= (e_0 - e_0), (e_1 - e_0)$ --------

$(e_n - e_0)$ (m).

A = Catchment Area (Sq. km).

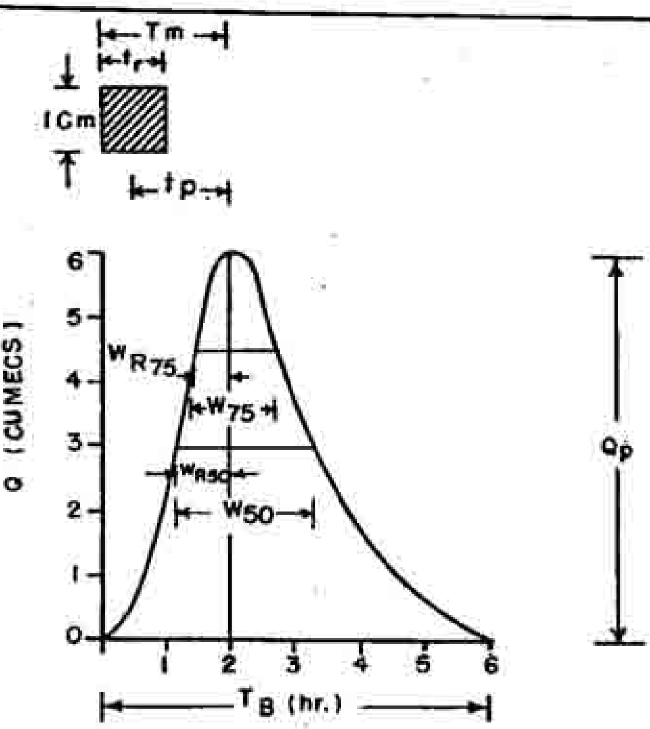
L_C = Length of Longest Stream Course from a point opposit the centre of Gravity of the Catchment to the point of Study (Km.)

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

PHYSIOGRAPHIC PARAMETERS

DRAWN BY-	CHECKED BY-
S. N. MALHOTRA P. N. BHALLA	A. K. GHOSH

FIG. – 2



U.G. = Unit Graph

tr = 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)

tp = 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.)

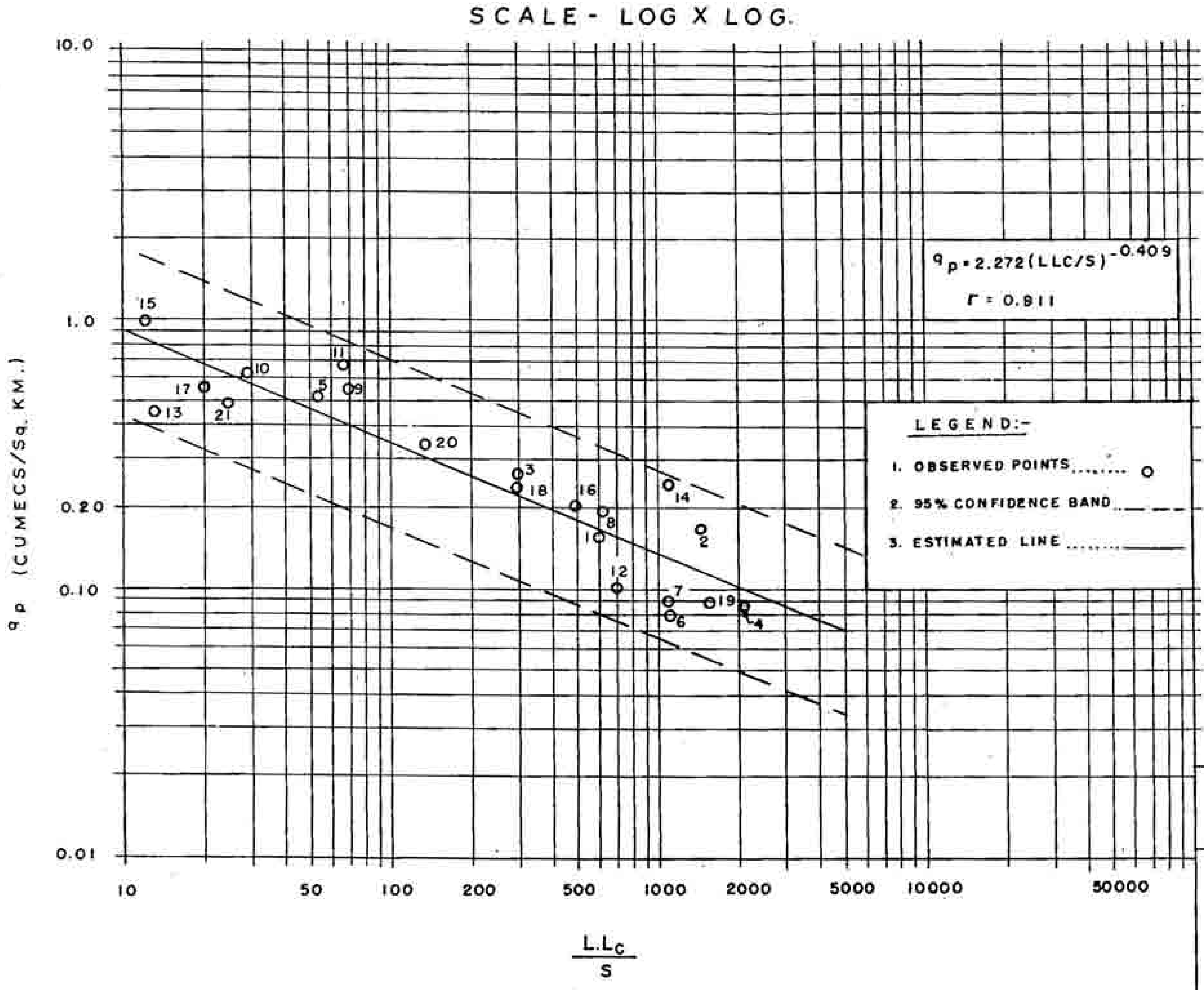
T_B = Base width of Unit Hydrograph (hr.)

A = Catchment Area (Sq. km.)

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

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (SMALL CATCHMENT) DTE.	
UNIT GRAPH PARAMETERS	
DRAWN BY– S.N. MALHOTRA, P.N. BHALLA	CHECKED BY– A. K. GHOSH

FIG.— 3.



SL.NO.	BRIDGE NO.	$\frac{L.L_c}{S}$	q_p (CUM./KM.^{2})
1.	240	606.0	0.156
2.	521	1456.0	0.165
3.	376	299.0	0.266
4.	373	2095.0	0.086
5.	8(8)	54.0	0.507
6.	486	1139.0	0.080
7.	363	1110.0	0.089
8.	450	625.0	0.190
9.	6/12	70.0	0.540
10.	242	29.0	0.610
11.	210	67.0	0.650
12	22	712.0	0.100.
13.	95	13.0	0.450
14.	285	1099.0	0.244
15.	196	12.0	0.990
16.	429	500.0	0.200
17.	114	20.0	0.550
18.	8(S)	299.0	0.239
19.	385	1535.0	0.087
20.	24	137.0	0.333
21.	201	25.0	0.479

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA

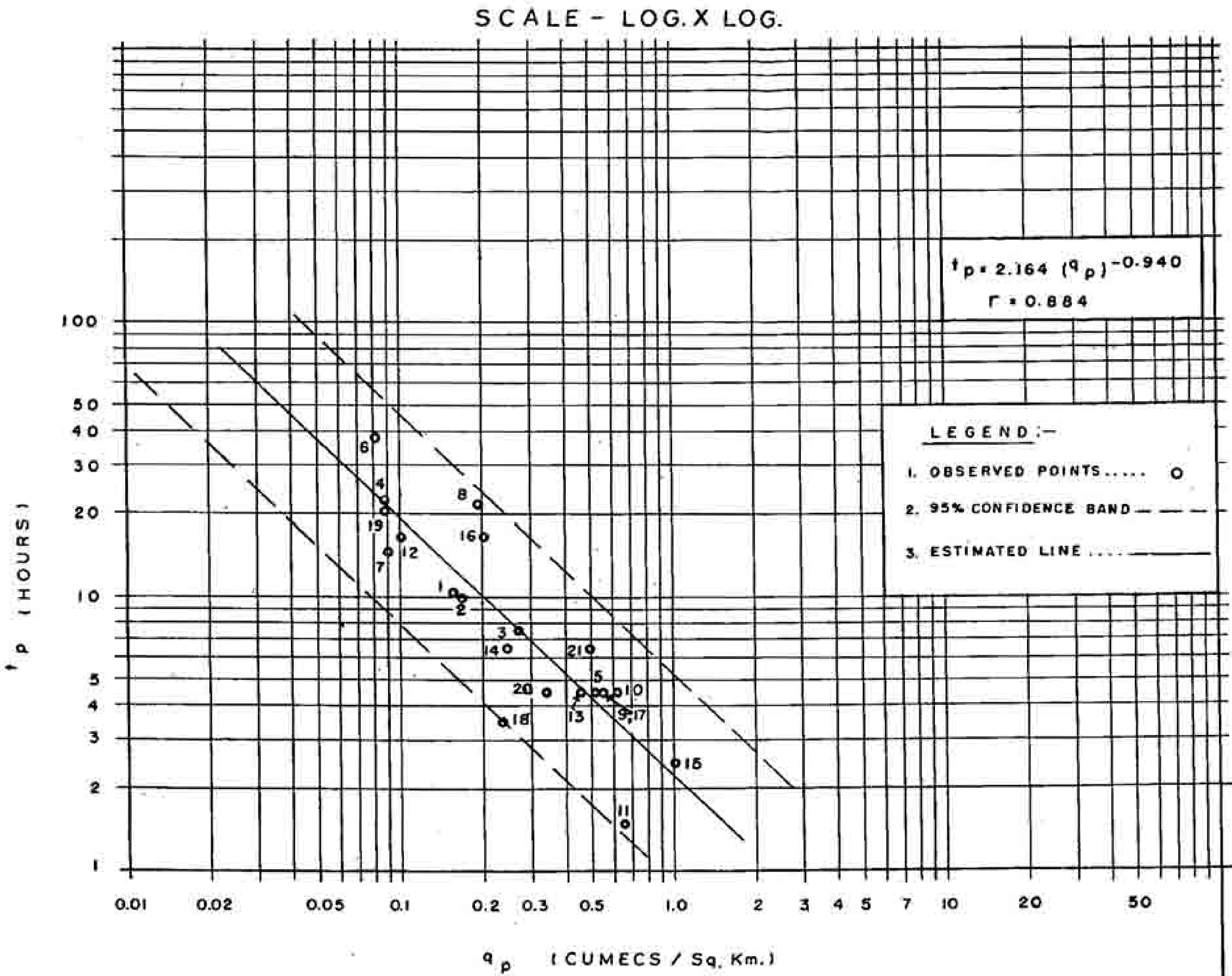
SUB ZONE - 2 (a)

RELATION BETWEEN

LL_c/S AND q_p

DRAWN BY—	CHECKED BY—
S.N. MALHOTRA L.P. NAUTIYAL	R. K. GUPTA.

FIG. – 4.



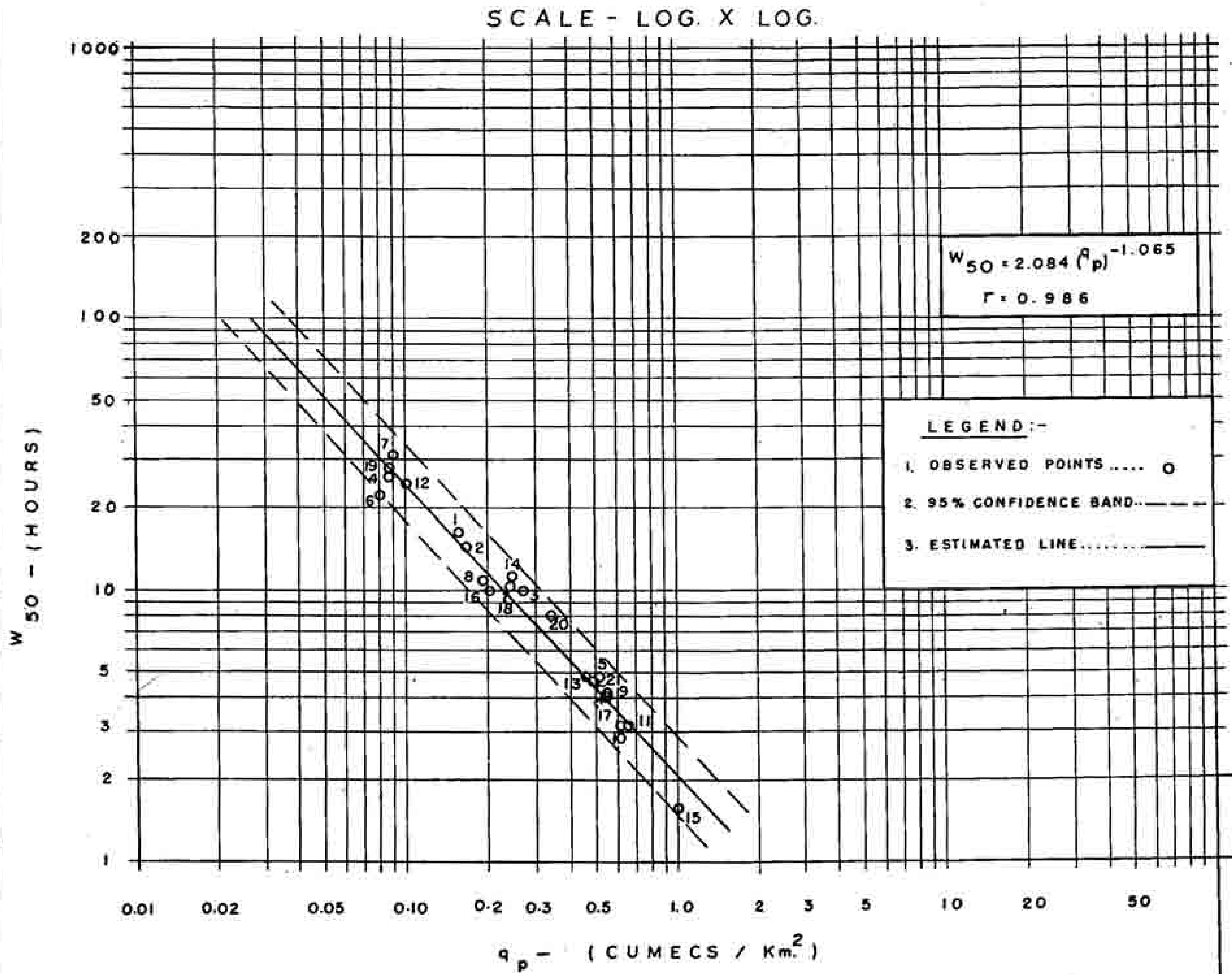
SL. NO	BRIDGE NO.	q_p (CUM./KM.^{2})	t_p (HOURS)
1.	240	0.156	10.50
2.	521	0.165	10.50
3.	376	0.266	7.50
4.	373	0.086	22.50
5.	8 (B)	0.507	4.50
6.	486	0.080	37.50
7.	363	0.089	14.50
8.	450	0.190	21.50
9.	6 /12	0.540	4.50
10.	242	0.610	4.50
11.	210	0.650	1.50
12.	22	0.100	16.50
13.	95	0.450	4.50
14.	285	0.244	6.50
15.	196	0.990	2.50
16.	429	0.200	16.50
17.	114	0.550	4.50
18.	8 (S)	0.239	3.50
19.	385	0.087	20.50
20.	24	0.333	4.50
21.	201	0.479	6.50

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA
SUB ZONE – 2(a)
RELATION BETWEEN q_p AND t_p

DRAWN BY–	CHECKED BY–
S. N. MALHOTRA L. P. NAUTIYAL	A. K. GHOSH.

FIG. - 5.



SL.NO	BRIDGE NO.	q_p (CUM./KM.^{2})	W-50 (HOURS)
1.	240	0.156	16.75
2.	521	0.165	14.50
3.	376	0.266	10.00
4.	373	0.086	26.15
5.	8 (B)	0.507	4.77
6.	486	0.080	22.55
7.	363	0.089	31.20
8.	450	0.190	11.00
9.	6 / 12	0.540	4.20
10.	242	0.610	3.20
11.	210	0.650	3.20
12.	22	0.100	24.75
13.	95	0.450	4.80
14.	285	0.244	11.35
15.	196	0.990	1.60
16.	429	0.200	9.95
17.	114	0.550	4.10
18.	8 (S)	0.239	10.40
19.	385	0.087	28.70
20.	24	0.333	8.15
21.	201	0.479	4.70

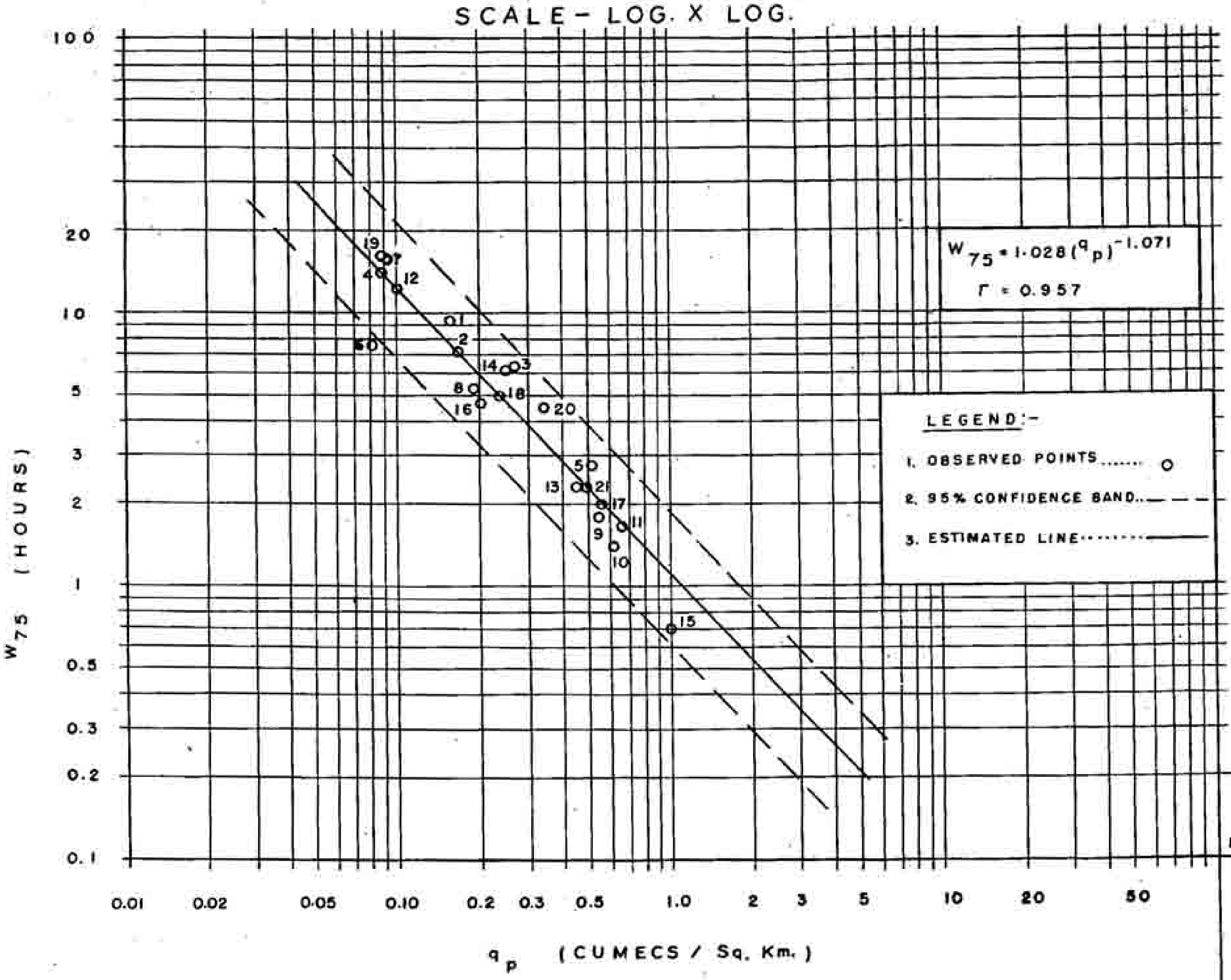
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA
SUB ZONE - 2(a)
RELATION BETWEEN
q_p AND W_{50}

DRAWN BY - S.N. MALHOTRA, L.P. NAUTIYAL

CHECKED BY - K.K. AICH.

FIG. 6.



SL. NO	BRIDGE NO.	q_p (CUM./KM.^{2})	W_{75} (HOURS)
1.	240	0.156	9.25
2.	521	0.165	7.20
3.	376	0.266	6.30
4.	373	0.086	14.00
5.	8 (B)	0.507	2.77
6.	486	0.080	7.50
7.	363	0.089	15.90
8.	450	0.190	5.20
9.	6/12	0.540	1.80
10.	242	0.610	1.40
11.	210	0.650	1.66
12.	22	0.100	12.25
13.	95	0.450	2.30
14.	285	0.244	6.10
15.	196	0.990	0.70
16.	429	0.200	4.65
17.	114	0.550	2.00
18.	8 (S)	0.239	5.00
19.	385	0.087	16.20
20.	24	0.333	4.55
21.	201	0.479	2.30

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA

SUB ZONE - 2(a)

RELATION BETWEEN q_p AND W_{75}

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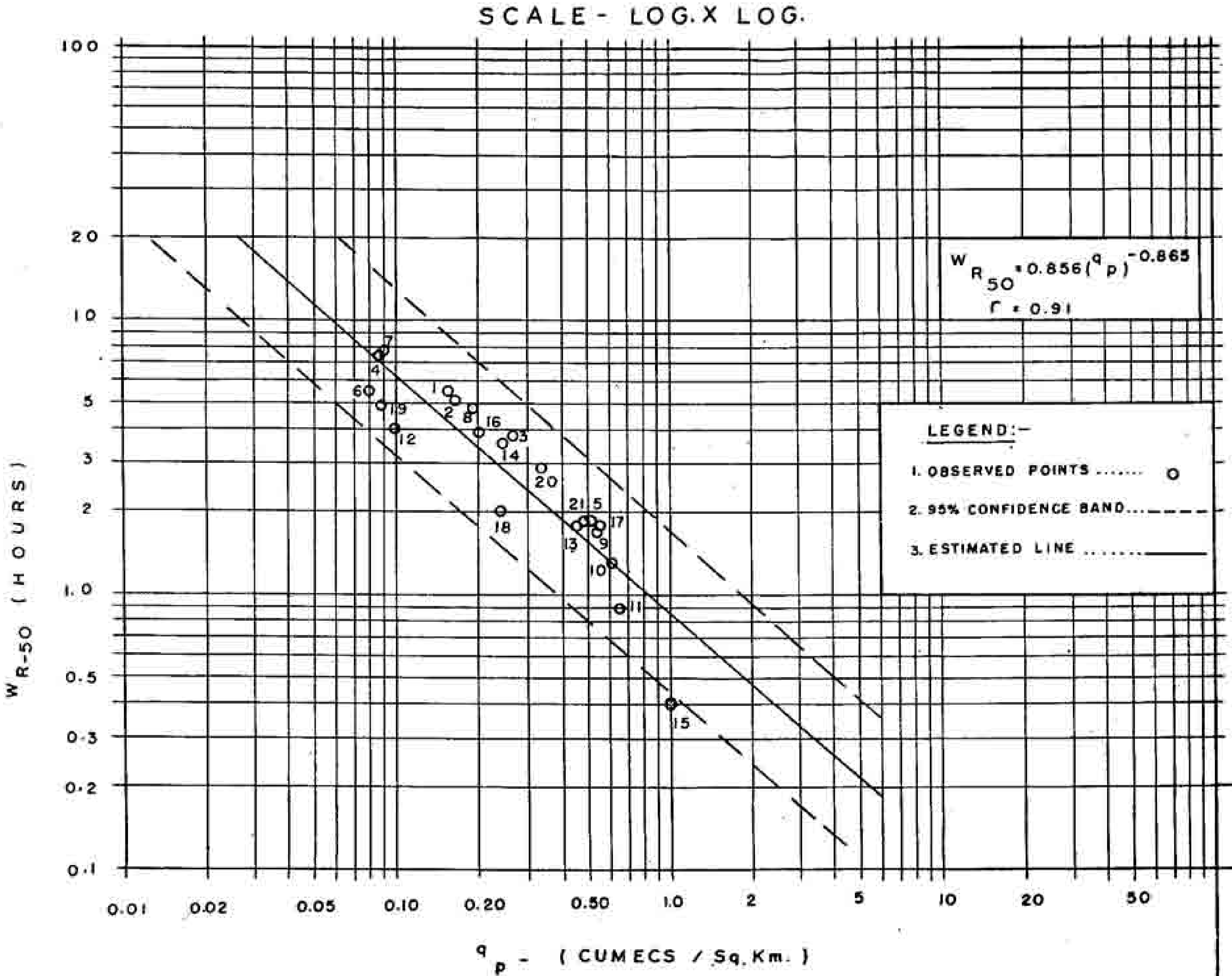
FIG.— 7.



SL. NO.	BRIDGE NO.	q_p (CUM./KM.^{2})	W_{R-50} (HOURS)
1.	240	0.156	5.55
2.	521	0.165	5.10
3.	376	0.266	3.77
4.	373	0.086	7.40
5.	8 (B)	0.507	1.87
6.	486	0.080	5.50
7.	363	0.089	7.60
8.	450	0.190	4.80
9.	6/12	0.540	1.70
10.	242	0.610	1.30
11.	210	0.650	0.90
12.	22	0.100	4.00
13.	95	0.450	1.80
14.	285	0.244	3.55
15.	196	0.990	0.40
16.	429	0.200	3.95
17.	114	0.550	1.80
18.	8 (S)	0.239	2.00
19.	385	0.087	4.90
20.	24	0.333	2.90
21.	201	0.479	1.87

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA
SUB ZONE - 2 (a)
RELATION BETWEEN
q_p AND $W_{R.50}$

DRAWN BY—	CHECKED BY—
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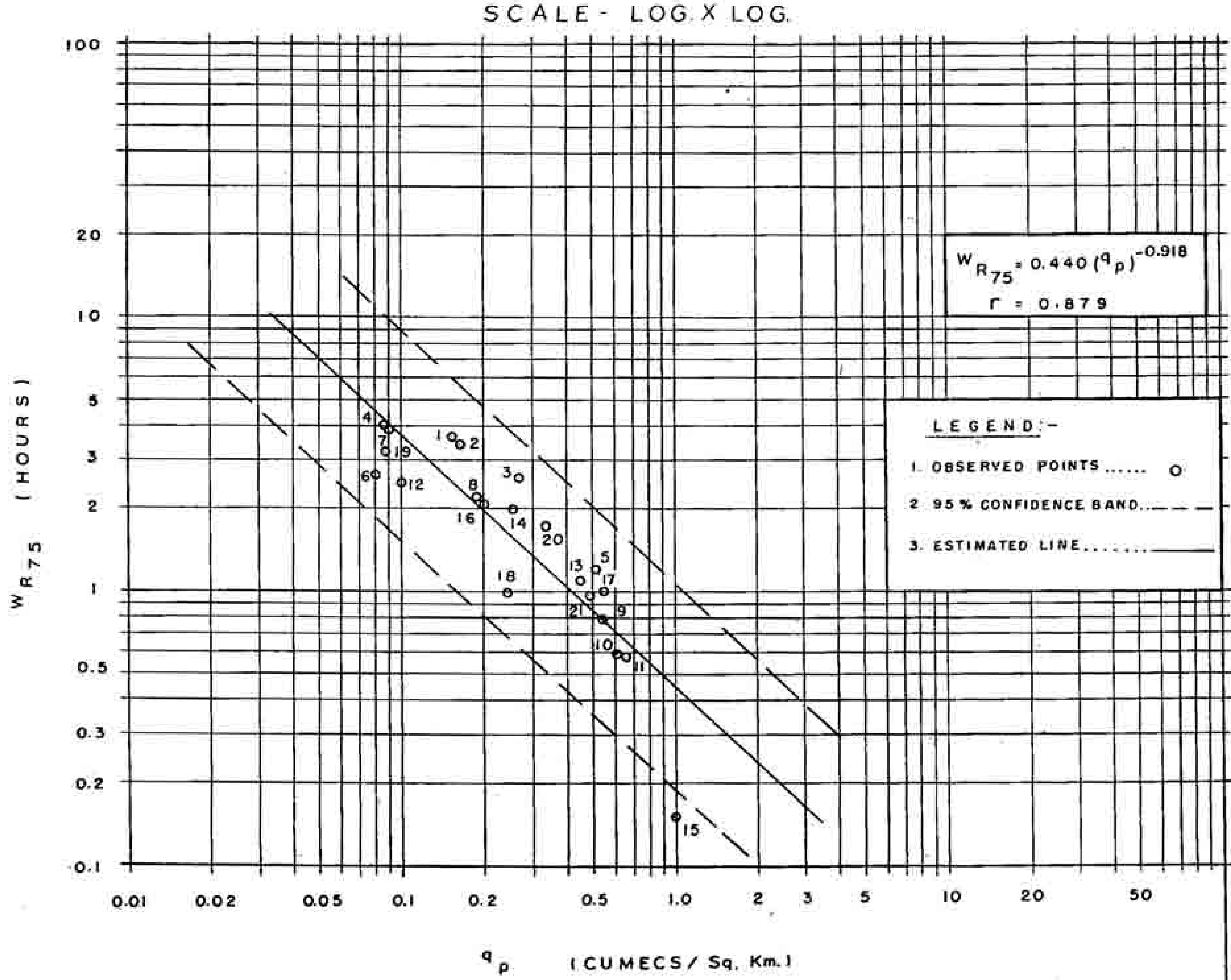
FIG. — 8.



SL.NO	BRIDGE NO.	q_p (CUM./KM.^{2})	$W_{R.75}$ (HOURS)
1.	240	0.156	3.60
2.	521	0.165	3.40
3.	376	0.266	2.60
4.	373	0.086	4.00
5.	8 (B)	0.507	1.20
6.	486	0.080	2.70
7.	363	0.089	3.90
8.	450	0.190	2.20
9.	6/12	0.540	0.80
10.	242	0.610	0.60
11.	210	0.650	0.58
12.	22	0.100	2.50
13.	95	0.450	1.10
14.	285	0.244	2.00
15.	196	0.990	0.15
16.	429	0.200	2.10
17.	114	0.550	1.00
18.	8 (S)	0.239	1.00
19.	385	0.087	3.20
20	24	0.333	1.75
21.	201	0.479	0.97

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA

SUB ZONE - 2 (a)

RELATION BETWEEN

q_p AND $W_{R\text{-}75}$

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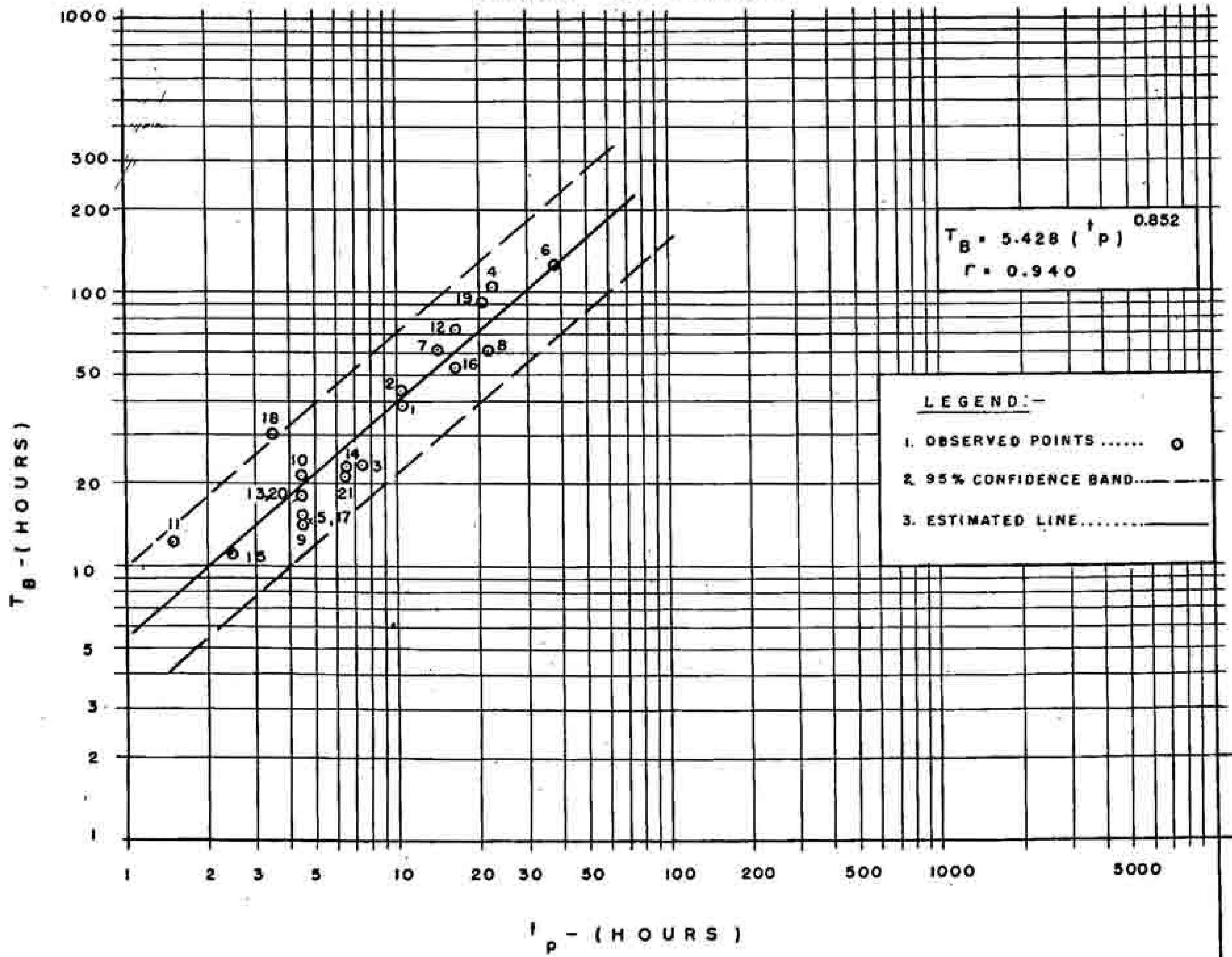
CHECKED BY— K. K. AICH.

FIG. – 9.

SCALE - LOG. X LOG.



SL.NO.	BRIDGE NO.	t_p (HOURS)	T_B (HOURS)
1.	240	10.50	38
2.	521	10.50	43
3.	376	7.50	23
4.	373	22.50	103
5.	8 (B)	4.50	15
6.	486	37.50	125
7.	363	14.50	62
8.	450	21.50	60
9.	6/12	4.50	14
10.	242	4.50	21
11.	210	1.50	12
12.	22	16.50	72
13.	95	4.50	18
14.	285	6.50	23
15.	196	2.50	11
16.	429	16.50	52
17.	114	4.50	15
18.	8 (S)	3.50	30
19.	385	20.50	91
20.	24	4.50	18
21.	201	6.50	21

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (SMALL CATCHMENTS) DTE.

NORTH BRAHMAPUTRA
SUB ZONE - 2 (a)
RELATION BETWEEN
t_p AND T_B

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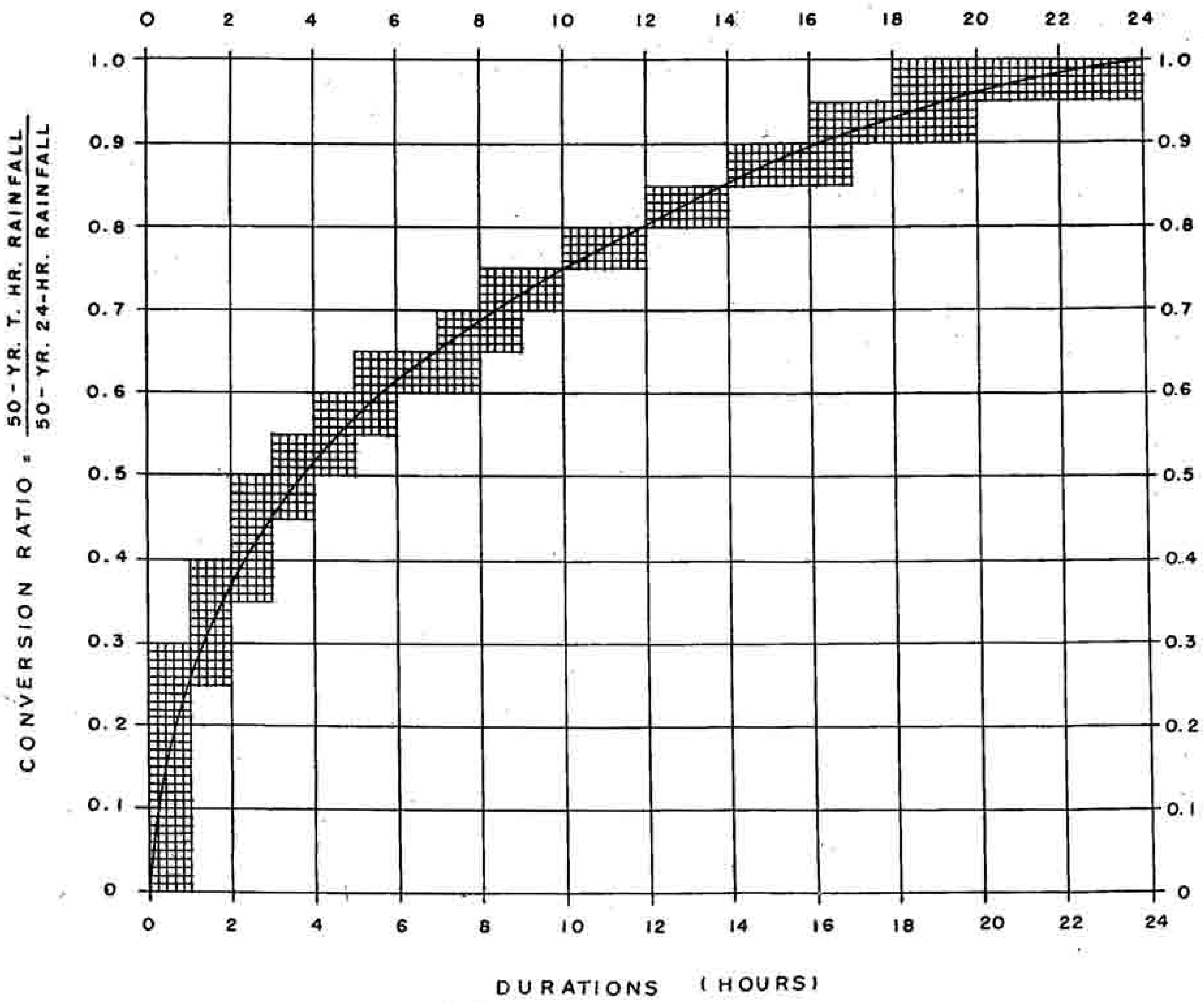
FIG.- 10.



RATIOS OF 24-HR. POINT RAINFALL TO SHORT DURATION RAINFALL

DURATION (HR.)	RATIO
0	0.0
1	0.260
2	0.370
3	0.457
4	0.520
5	0.570
6	0.615
7	0.656
8	0.687
9	0.720
10	0.747
11	0.775
12	0.805
13	0.830
14	0.850
15	0.875
16	0.895
17	0.912
18	0.930
19	0.945
20	0.960
21	0.973
22	0.983
23	0.992
24	1.000

NOTE :- CURVES SUPPLIED BY I.M.D.

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HYDROLOGY (SMALL CATCHMENTS) DTE

NORTH BRAHMAPUTRA
SUB ZONE 2 (a)

DURATION Vs. CONVERSION RATIO

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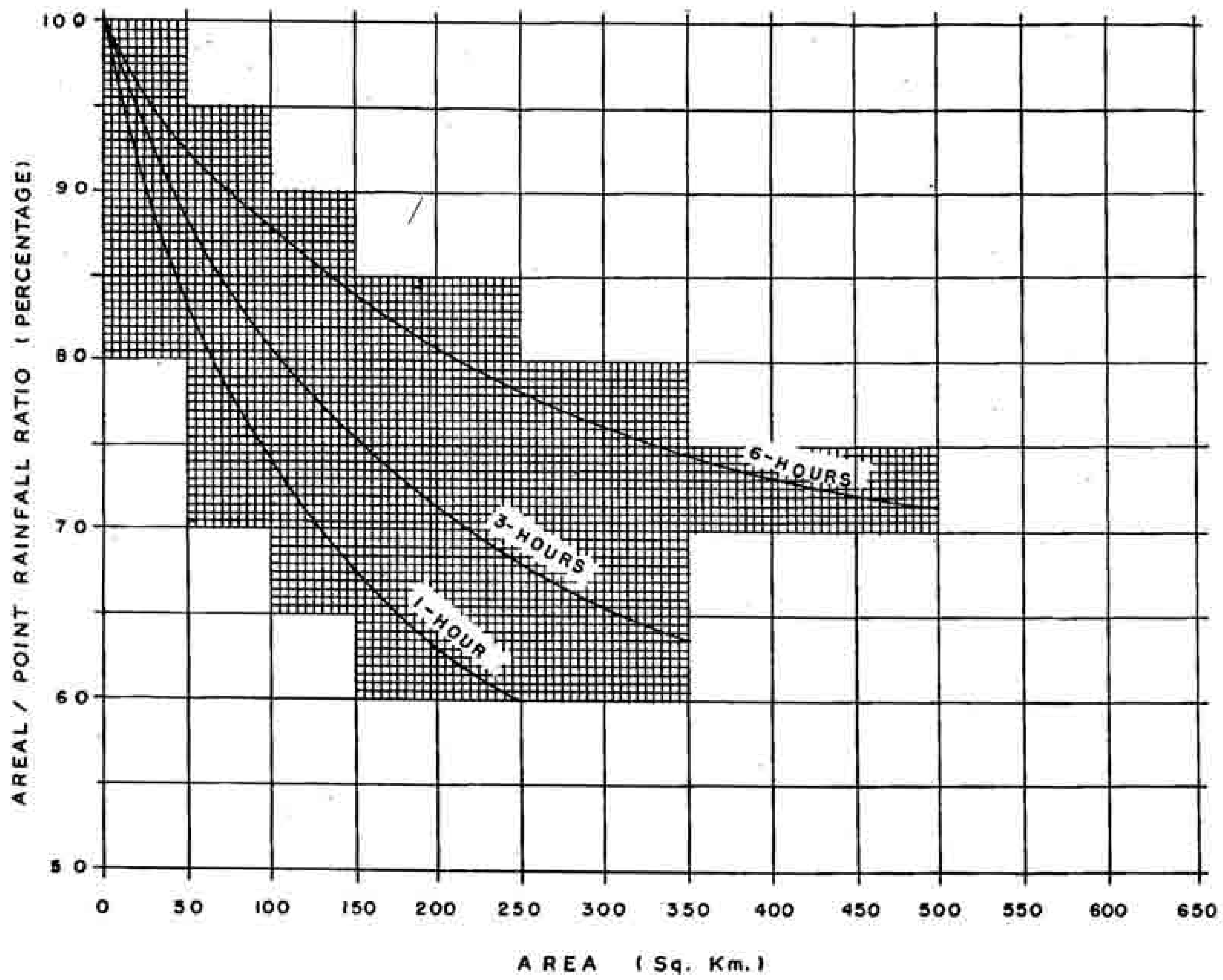
FIG.- 11. (a)



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NORTH BRAHMAPUTRA
SUB ZONE 2 (a)
AREAL TO POINT RAINFALL RATIO
(PERCENTAGE)

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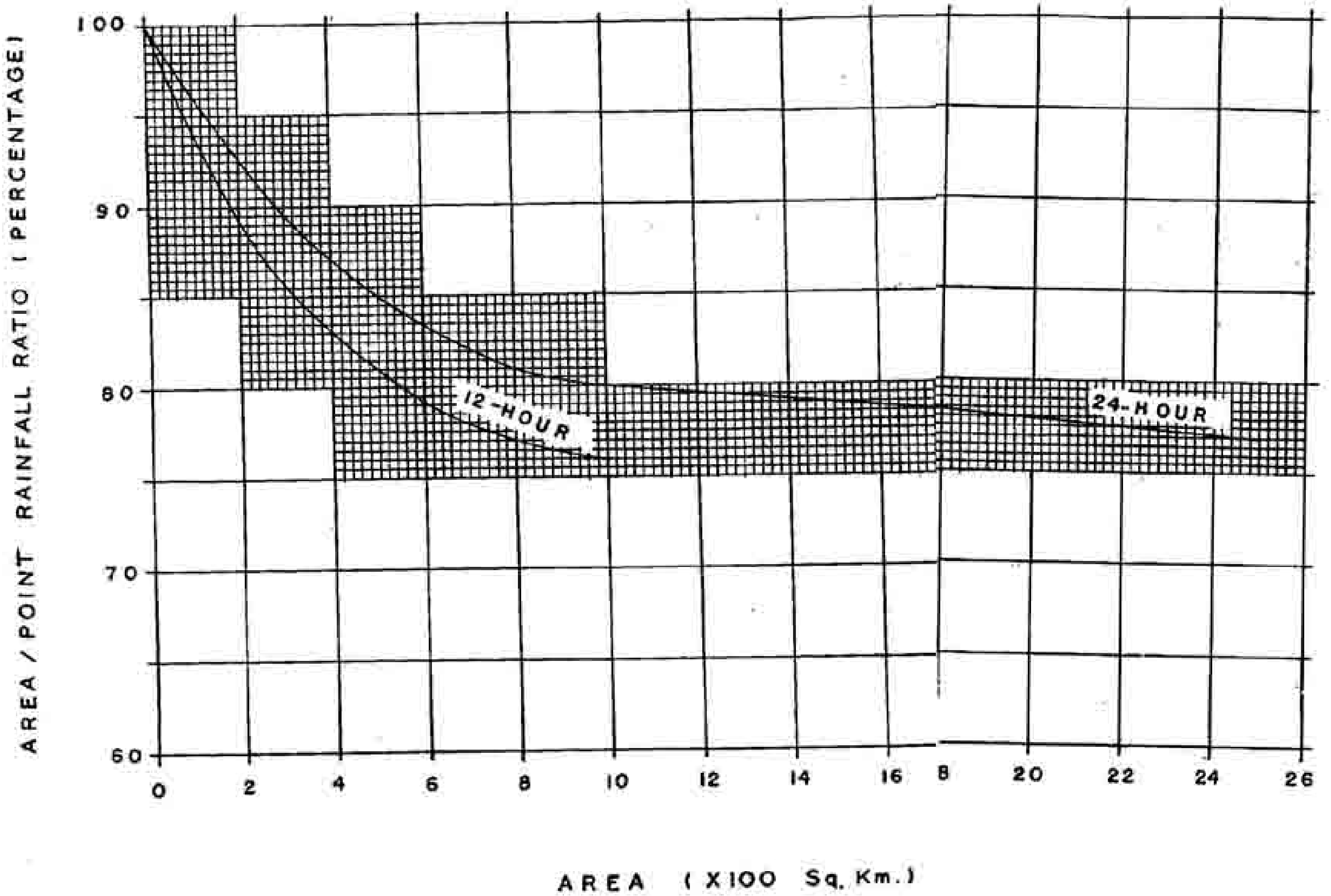
FIG.- 11. (b)



NOTE:-

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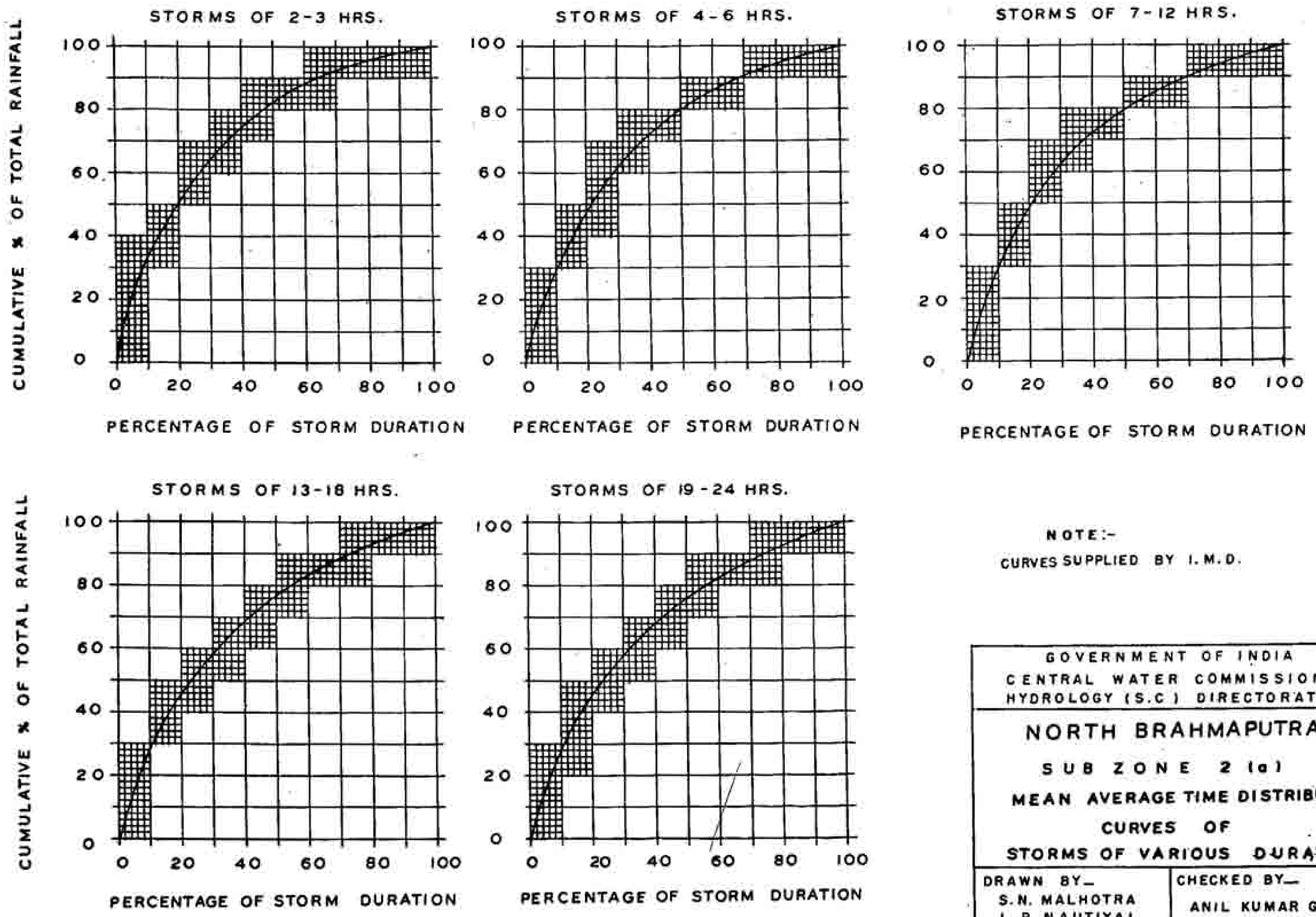
NORTH BRAHMAPUTRA

SUB ZONE 2 (a)

AREAL TO POINT RAINFALL RATIO
(PERCENTAGE)

DRAWN BY_	CHECKED BY_
S. N. MALHOTRA L. P. NAUTIYAL	R. K. GUPTA

FIG.- 12.



NOTE:-
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NORTH BRAHMAPUTRA
SUB ZONE 2 (a)
MEAN AVERAGE TIME DISTRIBUTION
CURVES OF
STORMS OF VARIOUS DURATIONS

DRAWN BY_	CHECKED BY_
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