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केन्द्रीय जल आयोग
Central Water Commission

पश्चिमी हिमालय (अंचल - 7) का बाढ़ आकलन रिपोर्ट

FLOOD ESTIMATION REPORT FOR WESTERN HIMALAYAS - ZONE 7

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अनुसंधान अभिकल्प एवं मानक संगठन
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का एक संयुक्त कार्य

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RESEARCH DESIGNS AND
STANDARDS ORGANISATION
INDIA METEOROLOGICAL DEPTT.
AND MIN. OF SURFACE TRANSPORT

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FLOOD ESTIMATION REPORT WESTERN HIMALAYAS

ZONE 7

A METHOD BASED ON UNIT HYDROGRAPH PRINCIPLE
DESIGN OFFICE REPORT NO. WH/22/1994

HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
CENTRAL WATER COMMISSION
NEW DELHI

1994

FOREWORD

Estimation of flood of various return periods for design of waterways and foundations of bridges and culverts having small and medium catchments, where hydrological data are inadequate or totally absent, is extremely difficult. In such a situation, regional method based on hydrometeorological approach involving use of synthetic unit hydrograph and design storm of specific return period has been adopted. For this purpose, the country has been divided into 26 hydrometeorological homogeneous subzones and 20 flood estimation reports covering hydrometeorological studies for 23 subzones have been published.

The present report, 21st in the series deals with estimation of design flood of small and medium catchments in Western Himalayas, (zone - 7). With this report, hydrometeorological studies of 24 subzones covering 91% of total geographical area have been completed. The report gives the method to compute the design flood of 25/50/100 year return period for ungauged catchments which are not located in the snowfed area of the zone.

Recommendations contained in the report are based on study of limited data and these may be judiciously applied till such time sufficient rainfall-runoff data are available for evolving a better and more rational method of arriving at the design flood.

The report is a joint effort of Central Water Commission(CWC), India Meteorological Deptt.(IMD), Research Design and Standards Organisation(RDSO) of Ministry of Railways and Ministry of Surface Transport (MOST).

The cooperative efforts of the officers and staff of the four organisations in producing flood estimation reports of various subzones deserve appreciation.

New Delhi

(A.B. Joshi)
Member (Designs & Research)

PREFACE

Design engineers essentially need the design flood of a specific return period for fixing the waterway vis-a-vis the design HFL and foundation depths of bridges, culverts and cross drainage structures depending on their life and importance to ensure safety as well as economy. A casual approach may lead to underestimation or overestimation of 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 formulae do not take into account the basic meteorologic factor of storm rainfall component and other physiography and hydraulic factors varying from catchment to catchment. Proper selection of constants in these empirical formulae is left to the discretion of design engineer, involving subjectivity.

Recognising the need to evolve a method for estimation of design flood peak of desired frequency, the Committee of engineers headed by Dr. A.N. Khosla had recommended, in its report that the design discharge should be maximum flood on record for a period not less than 50 years. Where adequate records are available extending over a period of not less than 50 years,the design flood should be 50 years flood determined from probability curve on the basis of recorded floods during the period. In case, where the requisite data as above are not available, the design flood should be decided based on the ground and meteorological characteristics . In order to ascertain the effect of these characterstics on the design flood, it is necessary to have the systematic and sustained collection of hydrometeorological data at selected catchments in different climatic zones of India.

Economic constraints do not justify detailed hydrological and meteorological investigations at every new site on a large scale and on a long term basis for estimation of design flood with a desired return period. Regional flood estimation studies thus become necessary for hydro-meteorological homogeneous regions in the country. Broadly, two main regional approaches namely flood frequency and hydro-meteorological 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 run-off data of the representative catchments over a period of 5 to 10 years to develop representative Unit hydrographs of the catchments located in the region, and long term rainfall records at a large number of stations to develop design storm values. This approach has been adopted in the preparation of flood estimation reports under short term and long term plan.

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

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

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

Studies of Rainfall-Depth-Duration-Frequency, point to areal rainfall ratios and time distribution of storms are carried out by Hydro-met Cell of IMD utilising the data collected by RDSO and the long term data collected by IMD from rain-gauge stations maintained by IMD/States.

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

So far, following 20 reports covering 23 sub zones have been published:-

1. Lower Ganga Plains subzone	1(g)	1978
2. Lower Godavari subzone	3(f)	1981
3. Lower Narmada and Tapi subzone	3(b)	1982
4. Mahanadi subzone	3(d)	1982
5. Upper Narmada & Tapi subzone	3(c)	1983
6. Krishna & Penner subzone	3(h)	1983
7. South Brahmaputra subzone	2(b)	1984
8. Upper Indo Ganga Plains subzone	1(e)	1984
9. Middle Ganga Plains subzone	1(f)	1985
10. Kaveri subzone	3(i)	1986
11. Upper Godavari subzone	3(e)	1986
12. Mahi & Sabarmati subzone	3(a)	1987
13. East Coast subzones	4(a)(b) & (c)	1987

14. Sone Subzone	1(d)	1988
15. Chambal subzone	1(b)	1989
16. Betwa subzone	1(c)	1989
17. North Brahmaputra subzone	2(a)	1991
18. West coast subzones	5(a) & (b)	1992
19. Luni subzone	1(a)	1993
20. Indravati subzone	3(g)	1993

The present report deals with the estimation of design flood of 25/50/100 year return periods for small and medium catchments in the Western Himalayas - zone 7 which covers geographical areas of Jammu and Kashmir, Himachal Pradssh and parts of Punjab and Uttar Pradesh.

Hydrometeorological data of 7 catchments having area more than 25 sq.kms. have been collected by the Railways in the zone for the period ranging between 1 to 6 years. All the gauged catchments are situated near the border of the zone with the border of subzone 1(e).The hydrometeorological data of 5 catchments was found suitable for conducting hydrological studies .

Rainfall data of 202 O.R.G stations , 17 maintained by IMD and 185 maintained by State Governments, 20 S.R.R.G stations maintained by IMD in and around the zone and short duration data (hourly/ half hourly rainfall) of 19 stations in 7 bridge catchments of the zone maintained by RDSO have also been utilised for the storm studies conducted by India Meteorological Department.

The Flood Estimation Report for Western Himalayas zone - 7 (WH / 22 / 1994) is recommended for estimation of design flood for small and medium catchments varying in areas from 25 to 1000 sq kmts.

Hydrological studies to develop equations for derivation of SUG , and estimating base flow and loss rate for the ungauged catchments have been carried out from rainfall-runoff data observed from the streams in the southern part of the zone in which floods are caused by rainfall . The recommendations of this report are therefore to be applied with some caution for the northern region of the zone , which has catchments covered by snow and glaciers and differing in flood causing processes ie, in this area the lesser return period floods also can be caused by snow melt either in full or part.

For catchments of areas less than 25 sq Km , the method given in the Report No. RBF- 16 published by RDSO may be used .

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

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

NEW DELHI
Jan, 1994

Sd-
(R.V.Godbole)
Director
Hydrology (RS) Dte
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SYMBOLS

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

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

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

PART -I

INTRODUCTION

Western Himalayas, zone 7 covers Jammu and Kashmir, Punjab, Himachal Pradesh and Uttar Pradseh. The geographical area of the zone is 322170 sq. km. The Flood estimation report of Western Himalayas deals with the method to compute design flood of 25 ,50 and 100 year return period of ungauged catchments located in the zone using SUG approach.

General topography and relief and climatological features of the zone covering river system, soils, land use , rainfall, temperature and communications is given in Part - II. Maps of the zone showing topography and relief ,land use and soils have been extracted from relevant maps of .India contained in the" Irrigation Atlas of India - 1978 ". The maps of the zone showing annual normal rainfall and mean daily temperature have been prepared by India Meteorological Department (IMD) on the basis of available data .

Part III of the report incorporates the unitgraph studies. Equations correlating unit hydrograph parameters with basin parameters of corresponding catchments have been developed to derive SUG for the ungauged catchments in the zone. This part also contains recommendations for adopting values of loss rate per hour and base flow per sq. km. for ungauged catchments on the basis of computed values from observed flood events.

Part IV of the report contains the rainfall studies conducted by India Meteorological Department . The study covers Depth-Duration- Frequency analysis of available daily/short duration rainfall data in and around the subzone. The Design storm components have been derived in the form of (i)25, 50 and 100 year-24 hour isopluvial maps (ii) 24 hours to short duration (1 to 23 hours)rainfall ratios, (iii) Time distribution curves for storms of various durations (2 to 24 hours) and iv) Point to areal rainfall ratios for specific durations (1, 3, 6, 12 and 24 hours). The ORG data of 202 stations, SRRG data of 20 stations and short duration data(hourly / half - hourly) of 19 stations have been used by IMD for rainfall studies . Statistics of heaviest ever recorded one day station rainfall along with date of occurrence at 45 raingauge stations and annual normal rainfall and heaviest 24 hours and short duration rainfall recorded at 17 SRRG stations are also covered in this part.

Part V gives the various criteria and standards in regard to design flood of structures , estimation of design flood by SUG approach along with an illustrative example explaining the procedure to compute design flood of 50 year return period of the ungauged catchment in the zone.

Part VI of the report highlights various assumptions limitations and conclusions of the report .

Procedure to compute the design flood of 25/50/100 year return period by SUG approach is summarized below .

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

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

iii) Determination of 1 - hr. SUG parameters and plotting of SUG.

iv) Estimation of design storm duration (TD).

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

vi) Estimation of effective rainfall increments by subtracting the design loss rate from the areal rainfall increments.

vii) Estimation of base flow.

viii) Computation of design flood peak and flood hydrograph.

PART- II

GENERAL DESCRIPTION OF THE ZONE

2.1 Location :

The Western Himalayas zone 7 is located between Longitudes 73^0 and 81^0 (east) and Latitudes 29^0 and 37^0 30" (north). Plate-1 shows location of the zone in map of India. Annexure 2.1 gives list of subzones in India . The zone is mostly bounded by International boundaries. It is bounded by Indo-China border in the north and north east , Indo-Pakistan border in the west , Indo-Nepal border in the east. It is bounded by the zone 1(e) in the south.The states covered by the zone are Jammu & Kashmir, Punjab, Himachal Pradesh and Uttar Pradesh.

2.2 River System :

Plate -2 depicts the river system . The geographical area is the cradle of all the major rivers of north-west India, which are fed by the snow and rainfall precipitation. The major rivers which flow in the zone are :-

1) The Indus river along with its tributaries Jhelum, Chenab, Ravi, Beas and Sutlaj.

2) The Ganga along with its tributaries Yamuna, the Ramganga and the Sarda .

The catchment area of the various rivers/ tributaries which flow in the the zone is given below :

Sl. No.	Name of the river	catchment area (sq km.)
a)	Indus River system	
1	Indus	171102
2	Jhelum	30749
3	Chenab	31047
4	Ravi	8034
5	Beas	15773
6	Sutlaj	15870
	Sub total	272575
b)	Ganga River system	
1	Ganga	24004
2	Yamuna	12498
3	Ram Ganga	3174
4	Sarda	9919
	Sub total	49595
	Total	322170

2.3 Genearl Features:

2.3.1 Topography and relief

Plate - 3 depicts the general topography and relief of the zone.In Western Himalayas , K2 (8611 mts.) located in Karakoram range is the highest peak . In addition to this , there are many other snow clad peaks within 8000 mts. The areas located in the extreme north and north- east of the zone have elevation ranging between 7500 to 6000 mts. The elevation decreases towards south and in the central portion of the zone it varies between 6000 to 4500 mts.In the areas adjoining the river banks the elevation varies between 4500 to 600 mts.In the plain areas of U.P ,Punjab and Himachal Pradesh, the elevation between 600 to 300 mts.

2.3.2 Soils

Plate - 4 shows the types of soil found over the areas in the zone. In the northern areas of the zone , skeltal soil alongwith saline and alkali soils are found . The areas around Indus river are covered with mountain-meadow soils. Submontain soils are located in the central north-west to north- east areas of the zone . The southern areas are covered with brown hill soil . The areas located in the vicinity of subzone 1(e) are covered with tarai soils.

2.3.3 Land Use :

Plate - 5 shows details of the land use. Nearly 75% of the area located in north , north-east and south-east of the zone is waste . Small pockets towards south and south- west of the zone are covered with scrubs. Forests are located in the areas north-east and south- east of the zone . Rice wheat and millets alongwith fruits of various kinds are grown over the remaining areas.

2.4 Climatological features : (as contributed by I.M.D.)

The zone is fed both by snow and rain . A good percentage of the runoff in the zone is derived from the snow and glaciers which constitute a potential reservoir . Winter precipitation which occurs in the form of snow goes on accumulating till summer.As the summer advances , the accumulations melt and release water in to the stream .

Glaciers are located at an altitude of about 5500 mt. The permanent snow line is at an elevation of about 4500 mts, During winter season the seasonal snowline dips to a height of about 1800 mt. The depth of snow precipitation decreases from west to east and from north to south.

2.4.1 Rainfall features

2.4.1.1 Annual normal rainfall

Western Himalayas, Zone - 7 , has widely varying topographical features; elevation being as low as 300 meters over its southern parts and as high as 7500 meters in the mountainous parts of the zone. The network of rainfall observing stations is fairy dense in plain areas and quite sparse in areas with high elevation, particularly in Gilgit and Ladakh districts of Jammu & Kashmir , Lahul and Spiti, Chamba and Kulu districts of H.P. and Uttarkashi, Chamoli and Pithoragarh districts of U.P.

The isohyetal map of annual normal rainfall for parts of the zone having adequate raingauge network based on normal rainfall of 185 stations, including 45 stations outside the zone along its southern periphery, is shown in Plate 6 . It may be seen that annual normal rainfall over the zone is highly variable, ranging from less than 100 mm over Leh to a maximum of more than 3000 mm at a number of places in H.P. and U.P. The normal rainfall along the southern periphery of the zone is generally of the order of 1000 mm. The isohyetal pattern is cellular in nature with centres of high rainfall around Sonemarg (>1500 mm) in J&K, Dharamshala (>3000mm) and Kothi(>2500mm) in H.P. and Mussoorie(>300mm), Landsdown(>2000mm) and Munsyari(>2500mm) in U.P.

2.4.1.2 Monthly rainfall distribution.

Monthly rainfall distribution at 6 representative stations viz. Srinagar, Leh, Jammu, Shimla, Dehradun and Pithoragarh is illustrated through bar charts appended to the annual rainfall map (Plate 6) . In the bar charts alphabets along abscissa indicate names of months whereas heights of rectangles are proportional to normal rainfall in respective months. figures at the top of each rectangle indicate the month's rainfall as percent of annual rainfall.

It may be noticed from the bar charts that Jammu, Shimla, Dehradun and Pithoragarh receive most of the rainfall during south west monsoon season (June - Sept.,). Total rainfall during monsoon season at these 4 stations is respectively 74% ,76% , 87% and 75% of the annual rainfall. Srinagar receives only 28% of the annual rainfall during south west monsoon season as against over 55% in the months of December - April in association with western disturbances. Station Leh receives only 94 mm liquid precipitation in the whole year which is more or less uniformly distributed over various months.

2.4.2 Temperature distribution.

2.4.2.1 Mean daily temperatures (annual)

Mean daily temperature distribution over the zone is shown in Plate 7. Mean daily temperatures are worked out as average of mean maximum and mean minimum temperatures over the year.

The map is drawn on the basis of data from 19 observatories of which 14 lie inside the zone and other 5 are located in the vicinity of the zone along its southern periphery . 6 of the observatories viz., Ambala, Amritsar, Jammu, Ludhiana, Pathankot and Patiala are located at an altitude below 500 meters where mean daily temperatures are between 23° c to 25° c . 3 observatories viz., Deharadun, Dharamshala and Tehri are located at an altitude of 500-1500 meters where mean daily temperatures range between 19.6° c to 21.8° c. 9 observatories viz. Dalhousie, Kargil , Mussoorie. Shimla, Srinagar,Mukteswar, Joshimath, Nainital and Mukhim are located at an elevation of 1500-3000 meters with mean daily temperatures ranging between 8.9°c and 15.7° c . The mean daily temperature at Leh , the only observatory at an altitude above 3000 meters (actual 3414 meters) is 5.5° c.

2.4.2.2 Monthly temperature variations at selected stations.

Monthly variations of maximum , minimum and mean daily temperatures of six representative stations, viz, Srinagar , Leh.Jammu, Shimla , Dehradun and Joshimath are shown graphically in Plate-7 appended below the map of mean daily temperatures. It may be seen from there that the highest mean maximum temperatures are observed in the month of May at Dehradun (36.2° c) in the month of June at station Jammu (40.4° c) , Shimla (24.3°c) and Joshimath (27.4° c) and in the month of July at stations Srinagar (30.8° c) and Leh (24.7° c). Lowest mean minimum temperatures are observed in the month of November at Srinagar (0.1° c)and in the month of January at Leh (-14.0° c), Jammu (8.3° c), Shimla (1.9° c) , Dehradun (6.1° c) and Joshimath (2.0° c). Mean daily temperatures are highest in the month of June at Dehradun (29.5° c), Simla (20.3° c) , Jammu (34.1° c) and Joshimath (22.2° c) and in the month of July at Srinagar (24.6° c) and Leh (17.5° c) . They are lowest in the month of January at all the six stations their numerical values being Dehradun (12.6° c), Shimla (5.2° c), Jammu (13.3° c), Srinagar(3.3° c) Leh(-8.4° c) and Joshimath (6.8°c).

2.5 Communications:

2.5.1 Railways :

The basin is served by the network of the northern railway with its head quarters at New Delhi. The Jammu & Kashmir state is served by broad gauge lines up to Jammu.The area lying in Punjab state is served with broad gauge lines with the Delhi- Ambala-Jullandur- Amritsar- Pathankot rail section. Himachal Pradesh is served with Kalka- Simla and the Pathankot-Joginder Nagar narrow gauge lines . Pathankot is the most important railway head quarter for Jammu & Kashmir as well as for western Himachal Pradesh.

2.5.2 Roadways:

The National Highway No. 1 runs from south to north of the zone and connects Delhi with Pathankot. The Hindustan-Tibet road connecting Ambala-Simla-Rampur is other important National Highway. In addition, there are State and District roads such as Tanakpur-Dharchulla, Haldwani-Gangolihat, Kotdwar-Badri Nath, Rishikesh- Yamnotri, Srinagar- Dehradun. These roads run through the portion of the zone lying in Uttar Pradesh .

PART - III

SYNTHETIC UNIT HYDROGRAPH STUDIES

3.1 Synthetic Unit Hydrograph (SUG) :

Hydrometeorological approach has been adopted for developing a regional method for estimating design flood for small and medium catchments in various hydrometeorologically homogeneous sub-zones. In this approach, the design storm after converting it into effective rainfall (input) is applied to the unit hydrograph (transfer function) to obtain a design flood (output). It is possible to develop unit hydrograph if site specific concurrent rainfall runoff data is available for 3-4 years. Collection of adequate concurrent rainfall runoff data for every site, however is neither practicable nor economically feasible.In such a situation the regional method for developing Synthetic Unit Hydograph (SUG) is resorted to. The SUG in the present study is a unit hydrograph of unit duration for a catchment developed from relations established between physiography and unit hydrograph parameters of the representative catchments in hydrometeorologically homogenous regions (sub- zones). Data collected and analysed for obtaining SUG equations are discussed in succeeding paragraphs.

3.2 Data Required:

For conducting the unithydrograph studies for development of equations for derivation of SUG, following concurrent rainfall and runoff data for a number of catchments of small and medium size located uniformilly in a subzone are required for a minimum period of 5 to 8 years during 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 river net-work, location of raingauge stations and gauge and discharge sites, contours, highways and railway network, natural and man made storages, 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.

3.3 Data Collected :

The Northern railways under the supervision and guidance of Research Designs and Standards Organisation (RDSO) has observed and collected data for 7 catchments for a period ranging from 2 to 5 years. Size of the gauged catchment varies from 44 sq.km to 658 sq.km. Concurrent rainfall,gauge and discharge data for 25 bridge catchment years for 26 7 bridge catchments were available for the studies.

Locations of the gauging sites at railway bridges in the zone 7 are shown in Plate-2. Annex.3.1 shows the names of streams, railway bridge numbers with railway sections, catchment areas, number of raingauge stations and the period of availability of concurrent rainfall, gauge and discharge data.

3.4 Analysis of data for obtaining synthetic unit hydrograph equations.

To obtain a synthetic unitgraph, following steps are followed:

i) Analysis of physiography parameters of the catchments.

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

iii) Selection of floods and corresponding storm events.

iv) Computation of 1-hour catchment rainfall.

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

vi) Computation of infiltration loss (ϕ-index) and 1-hour rainfall excess units.

vii) Derivation of 1-hour unitgraph.

viii) Drawing of representative unitgraphs and measuring the parameters.

ix) Establishing relationships between physiography 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:

3.4.1 Physiography parameters of the catchment:

Physiographic parameters indicated in Fig. 1 are discussed in the following paragraphs :

3.4.1.1 Catchment Area(A):

The gauging site is located on a toposheet and the watershed boundary is marked. The area enclosed in this boundary is measured .

3.4.1.2 Length of the Main Stream (L) :

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

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

3.4.1.4 Equivalent Stream Slope (S):

One of the physiography parameters is slope. The slope may be equivalent slope or statistical slope. In this report equivalent stream slope has been used for developing SUG relations. This can be computed by the following methods.

(a) Graphical Method: Longitudinal section (L-section) of the main stream is 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. L section is broadly divided into 3 to 4 segments representing broad ranges of the slopes of the segments . Following formula is used to compute equivalent slope (S) :

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

where Li = Length of the ith segment in km.

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

L = Length of the longest stream as defined in section 3.4.1.2 in km.

Physiography parameters A, L, Lc and S obtained for catchments found suitable for analysis are shown in Annexure 3. and are also indicated on catchment area plans of 5 sites at Fig.A-1.1 to A-1.5.

3.4.2 Unit hydrograph Studies:

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

The data was scrutinised through arithmetical checks and gauge and discharge rating curve(s) were drawn either on linear scale or on log-log scale. The stages for conceivable floods were converted into discharges initially identified with reference to rise and fall in the stages of the river.

3.4.2.2 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 stagnant water levels.

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

Based on the above criteria , 45 flood events for 5 catchments were selected .

3.4.2.3 Computation of hourly catchment rainfall:

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

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

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

3.4.2.5 Separation 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 event.

3.4.2.6 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 method. The iterations were carried out till the observed and estimated direct runoff hydrographs compared favourably. 29 unitgraphs were derived for 5 catchments found suitable.

3.4.2.7 Drawing of representative Unitgraphs and measuring parameters:

Set of unitgraphs as obtained vide para 3.4.2.6 above were superimposed and an average/representative unitgraph (RUG) was derived and tested to check weather observed hydrograph peak discharges can be reasonably reproduced. In addition to these RUGs, one more RUG developed for Sewa Hydro - Electrical project was also considered for developing SUG equations . Annexure 3.3 shows the details of RUGs of these 6 sites. The parameters of these RUGs i.e tp, qp , W50 , W75 , WR50 , WR75 and TB (as illustrated in Fig.2) were measured for each catchment. List showing these parameters for 6 catchments is given in Annexure 3.4

3.4.3 Establishing relationships between physiography and representative unitgraph parameters:

Linear and non-linear equations were tried for establishing the relationship between physiography parameters (Annexure 3.2) and RUG parameters (Annexure 3.4) of the catchments .

Various types of relationships between the physiography parameters and one of the unitgraph parameters (Annexure 3.5) for 6 catchments , considered suitable for the studies were developed. The relationships between L*Lc/S and U.G. parameters were found significant in case of tp , W50 and W75 . qp and TB could be significantly related to tp . WR50 and WR75 were related to W50 and W75 respectively . The principle of least square error was used in the regression analysis to develop following relationships for estimating 1-hr unitgraph parameters .

Relationships	Equation No.
$t_p = 2.498 * (L*Lc/S)^{0.156}$	3.4.3.1
$q_p = 1.048 * (t_p)^{-0.178}$	3.4.3.2
$W_{50} = 1.954 * (L*Lc/S)^{0.099}$	3.4.3.3
$W_{75} = 0.972 * (L*Lc/S)^{0.124}$	3.4.3.4
$WR_{50} = 0.189 * (W_{50})^{1.769}$	3.4.3.5
$WR_{75} = 0.419 * (W_{75})^{1.246}$	3.4.3.6
$TB = 7.845 * (t_p)^{0.453}$	3.4.3.7
$Qp = qp * A$	3.4.3.8

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

These relations are based on the runoff data of only 6 gauged catchments , localized in area near the border of zone 7 and , subzone 1 (f) which constitutes near about 1 % of the total area of the zone . These relations have, therefore inherent limitations,being representative of a vary small fraction of total area of the zone . It is therefore, stressed that at no stage design flood computed by using the above relations for an ungauged catchment of the zone be utilized without verifying the results on the basis of alternate methods . Some of the methods are given in Para 3.7 .

The relations derived from rainfall-runoff data observed on the streams situated in the southern region and floods in these rivers are caused due to rainfall . The relations are not to be used for computation of design flood in the snow covered areas in the northern region of the zone as floods in these rivers are caused by snow melt. These relations are not to be utilised for computation of design flood in the snow fed area of the zone.

3.4.4 Derivation of 1-Hour SUG for an Ungauged catchment:

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

The steps for derivation of 1-hour unitgraph are :

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

ii) Substitute L,Lc and S in the equation 3.4.3.1 , 3.4.3.3 and 3.4.3.4 to obtain tp, W50 and W75 respectively.

iii) Substitute the value of t_p in the equation 3.4.3.2 and 3.4.3.7 to get qp and TB respectively . Obtain Qp by using equation No. 3.4.3.8 .

iv) Substitute W50 and W75 in equations 3.4.3.5 and 3.4.3.6 to get WR50 and WR75 respectively.

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

Sum of discharge ordinates of tr-hr Unitgraph is obtained and compared with the estimates by the following equation:

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

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

d = depth of rainfall (1cm in present study)

A = catchment area in sq.km.

tr = unit duration in hours (1 hour in present study)

Suitable modifications can be made in falling below W_{50} points so that volume of unit hydrograph equals 1cm volume and a smooth Unitgraph be drawn.

3.5 Design Loss Rate:

Direct surface runoff is the end product of storm rainfall after infiltration into surface soils, sub-surface and ground besides abstractions like evaporation,

Loss rate (cm/hr) values computed for 45 flood events analysed for 5 bridge catchments are tabulated in Annexure 3.6. Model value of loss rate was worked out to be 0.6 cm/hour. This value seems to be on higher side, considering the catchment characterstics of the zone . These studies were however based on limited flood events observed at only 5 gauged catchments , localized in a small area of about 1 % of the total geographicl area of the zone and therefore ,do not reflect the basin condtions and are not true representative. From the overall basin features of zone 7 and its neighbouring subzone 1(e) , it is suggested that a loss rate value of 0.5 cm/hour may be adopted for zone 7 . This recommendation , however is not applicable to the catchments in snow fed areas .

Designers can modify this value as per local conditions.

3.6 Design Base Flow :

Base flow values for 45 flood events tabulated in different ranges are shown in Annex 3.7. Out of 45 flood events, 27 flood events fall under the range of 0.00 - 0.10. cumecs/ sq. km . Base flow rate of 0.05 cumecs/sq..km may be adopted for estimating base flow for rainfed catchment in the zone . The recommendation is not applicable to the streams in the snow covered areas as the floods in these rivers are caused due to snow melt .

3.7 Derivation of SUG of ungauged catchment using RUG of the gauged catchment:-

The SUG equations have been developed using limited data of only six catchments which are also not distributred uniformily over the entire zone . Synthetic unit hydrograph derived using these equations may not be reliable.It is therefore suggested to derive SUG of ungauged catchment using alternate method based on the RUGs developd for six catchments and the known physiography parametres of the ungauged catchment .Few approaches are as under:

a) Synder's approach: The values of Synder's coefficents, C^p and C^t can be obtained from the known unit hydrograph parameters and physiography parametes of the catchment which is similar to the ungauged cathment. The unit hydrograph of the ungauged cathment can be derived using the coefficents and physiography parameters in Synder's equations.

b) Dimensionless unit hydrograph approach: The physiography parameters of the catchment(s) which resemble with the physiography parameters of the ungauged catchment is/are identified . The unit hdrograph(s) of selected catchment(s) is converted to dimensionles unit hydrograph .

In case of selected catchments are more than one, dimensionless unit hydrograph of ungauged catchment is obtained by averaging dimensionless unit hydrographs . This dimensionless unit hydrograph can be converted to synthetic unit hydrograph by using appropriate values of lag ,semi duration and volume. The lag of the ungauged catchment is computed either using Snynder"s equation or equation No. 3.4.3.1.

PART-IV
RAINFALL STUDIES

4.1 Introduction:

The India Meteorological Department (IMD) has conducted detailed rainfall studies for the Western Himalays - zone (7). The study covers Depth - Duration - Frequency analysis of available daily/short duration rainfall data in and around the zone . The Design storm components have been derived in the form of (i) 25, 50 and 100 -year 24 - hour isopluvial maps, (ii) 24 hours to short duration (1 to 23 hours) rainfall ratios, (iii) Time distribution curves for storms of various durations (2 to 24 hours) and (iv) Point to areal rainfall ratios for specific durations (1, 3, 6, 12, and 24 hours). The methodology applied for analysis of each component and the procedure for design storm estimation is discussed in the subsequent paras.

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

4.2 Data Collected:

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

4.2.1 Ordinary raingauge (ORG) data (daily rainfall) of 202 stations, 17 maintained by IMD and 185 maintained by the State Governments, in 40 districts - 13 in Himachal Pradesh, 11 in Uttar Pradesh, 10 in Jammu & Kashmir, 5 in Punjab and 1 in Haryana - covering the zone with 14 districts partly / fully outside the zone. Of these, 98, 24, 73, and 7 stations have respectively 51 - 70 years,31-50 years, 11- 30 years and 7-10 years record . This was necessary in order to cover the areas where the raingauge network is sparse.

4.2.2 Self recording raingauge (SRRG) data (hourly rainfall) of 20 stations maintained by IMD in 17 districts -7 in H.P. 4 in U.P, 3 in Punjab, 2 in J&K and 1 in Haryana. Of these, 9, 4 and 7 stations have respectively 8 - 13 years (88 station-years) (5-7) years (24 station years) and 2-4 years (19 station-years) record.

4.2.3 Short duration data (hourly/half-hourly rainfall) of 19 stations in 7 bridge catchments of the zone specially maintained by RDSO during the period 1962-67.

4.3 Data Used:

The ORG/SRRG data mentioned in paras 4.2.1 and 4.2.2 above available from IMD's National Data Centre have been extensively utilised for analysis. However, the bridge catchment data mentioned in para 4.2.3 procured from RDSO specifically for deriving point to areal rainfall ratios were not usable because except in two bridge catchments, the concurrent data for adequate number of stations/years were not recorded.

4.4 Depth Duration Frequency Analysis:

4.4.1 Isopluvial maps

For each of the 202 ORG stations in and around the zone, a series of annual maximum one-day rainfall was generated. The 202 station series thus formed were subjected to frequency analysis using Gumbel's extreme value distribution for computing one day rainfall estimates for 25, 50 and 100-year return periods. These daily rainfall estimates (202 * 3) were converted into any 24- hour rainfall estimates by using the conversion factor of 1.15. For each return period, the 24-hour estimates for 202 stations were plotted on a base map and isopluvials were drawn. The isopluvial maps of 25, 50 and 100- year 24- hour rainfall are shown in Plates 8,9 and 10 respectively, which can be used to derive 24-hour rainfall estimates for specific return periods at any desired location in the zone.

4.4.2 Short duration ratios

For each of the 9 SRRG stations having at least 8 years record, the hourly rainfall data were subjected to frequency analysis using partial duration series for computing T-year t-hour rainfall estimates for T=2,5,10,25 and 50 years and t=1,3,6,9,12,15,18 and 24 hours. These estimates (9 x 8 x 5) were converted into ratios with respect to the corresponding 24- hour estimates . Average ratios (8 x 5) for the zone as a whole (mean of 9 station ratios) were then computed for each T-year t-hour pair. It was noticed that for a specified duration t, the average ratios beyond T= 5 years were comparable in magnitude. As such the average ratios (8) corresponding to 10-year t-hour rainfall have been recommended to be adopted uniformly for converting 24-hour rainfall into t-hour rainfall. These 8 conversion ratios for t = 1, 3, 6, 9, 12, 15, 18 and 24 hours given below were plotted on a graph and a smooth curve was drawn as shown in graph at Fig. 3, which can be used to derive conversion ratios for any duration t in general, including the intermediate durations (see table alongside graph).

Rainfall Duration (t) in hours	Conversion ratio = 10- year t-hour rainfall / 10-year 24-hour rainfall
1	0.425
3	0.600
6	0.725
9	0.790
12	0.845
15	0.895
18	0.935
24	1.000

Any 25, 50 or 100-year 24-hour point rainfall in the zone, as read from isopluvial maps in Plates 8, 9 and 10, can be converted in to corresponding 25, 50 or 100-year t- hour rainfall by multiplying with t-hour ratio as read from the curve in Fig.3.

4.4.3 Time distribution curves

Based on hourly rainfall data of all the 20 SRRG stations a total of 1507 rainstorms of durations ranging from 2 to 24 hours were analysed and grouped stationwise into the following 5 categories

1) rainstorms of 2 to 3-hour duration (320 of all stations)
2) rainstorms of 4 to 6-hour duration (415)
3) rainstorms of 7 to 12-hour duration (479)
4) rainstorms of 13 to 18-hour duration (184)
5) rainstorms of 19 to 24-hour duration (109)

For each station, 5 different graphs corresponding to each group of rainstorms were prepared by plotting the cumulative percentage of the total storm rainfall against the percentage of the storm duration and the average time distribution curves (20 x 5) were drawn. Average time distribution curves (5) for the zone as a whole were then drawn by plotting 20 station curves on the same graph and these are shown in Fig. 4, which can be used to derive the time distribution coefficients of storm rainfall in the zone for rainstorms of any duration (see Annexure 4.1).

4.4.4 Point to areal rainfall ratios

On account of the non-availability of a dense SRRG network as well as the inadequacy of short durations bridge catchment data, the alternate method of using ORG and SRRG data conjunctively as adopted earlier for subzone 3 (g) has been used in the present study for determining the point to areal rainfall relationship.

The location map of SRRG/ORG stations was scanned to identify one or more groups of stations, each group consisting of a central SRRG surrounded by a close network of ORGs. Two such groups were identified with central SRRGs at Dehradun (U.P.) and Dharmapur (H.P.) surrounded by 18 ORG stations in each group. The hourly rainfall records of central SRRGs and daily rainfall data of surrounding ORGs were carefully examined for storm durations t= 1, 3, 6, 12, and 24 hours to select t-hour representative rainstorms (5) based on the following considerations:

(i) each duration t being entirely contained in the 24-hour period ending 0800 hours;

(ii) a maximum central value of t-hour rainfall being nearest to the corresponding 24-hour rainfall ending 0800 hours; and

(iii) the availability of adequate concurrent data of surrounding ORG stations.

Initially 17 rainstorms (14 for Dehradun and 3 for Dharampur) of different durations were selected and finally 5 representative rainstorms described here under were adopted for analysis.

Central SRRG Station	Duration & No.of storms selected	Representative storm Rainfall (mm)	Date & time of occurence (clock hour)	Correspo-nding 24-hour rain-fall (mm)	Concu-rrent ORG data (No. of stations)
Dehradun	1-hr(5)	31.5	8.9.78(19-20)	41.7	16
	3-hr(6)	57.4	8.7.78(02-05)	68.7	15
	6-hr(1)	90.1	28.7.76(00-06)	91.3	16
	24-hr(2)	129.7	2-3.9.78(08-08)	129.7	16
Dharampur	1-hr(1)	-	-	-	-
	6-hr(1)	-	-	-	-
	12-hr(1)	137.0	28-29.6.78(20-08)	155.7	18

For each representative storm, the ratio of storm rainfall to corresponding 24-hour rainfall was computed and the daily rainfall values of surrounding ORG stations were reduced in the same proportion. Isohyetal maps of 5 representative storms were then prepared using concurrent rainfall values of central SRRG stations and surrounding ORG stations (reduced values) corresponding to the date and time of each representative storm. By planimetering each isohyetal map around the storm centre and plotting the percentage ratios of areal rainfall depth to representative point rainfall against the areas, the best fit curves (5) were drawn as shown in the graphs at Fig .5(a) and 5 (b), which can be used to derive the percentage areal reduction factors for converting point rainfall of any duration in the zone into corresponding areal rainfall for any particular small catchment in the zone (Annexure 4.2).

4.5 Heaviest rainfall records:

4.5.1 ORG Data : The highest ever recorded one-day station rainfall (24 hours rainfall ending 0830 hrs of date) along with date of occurrence in each of the 45 stations in 40 districts covering zone (7) have been compiled from the ORG data and presented in Annexure 4.3. Normal annual rainfall for each selected station is also given in Annexure .

4.5.2 SRRG Data: The heaviest storm rainfall in durations of 24, 12, 6, 3, and 1 hour alongwith date and time of occurrence in each of the 17 districts covering all the 20 SRRG stations have been compiled from the available autographic records and are presented in Annexure 4.4 .

4.6 Procedure for design storm rainfall estimation:

For a specified design storm duration T_D hours (time of concentration for a particular bridge catchment in the zone, the design storm rainfall and its temporal distribution in the catchment can be computed by adopting the following procedure.

Step-1 : Locate bridge catchment under study on the 50 - year 24- hour isopluvial map in Plate 9 and obtain the 50-year 24-hour point rainfall value in cm. For a catchment covering more than one isopluvial, compute the average point rainfall.

Step-2 : Read the conversion ratio for storm duration T_D from Fig 3 and multiply the 50- year 24-hour point rainfall in step -1 to obtain 50 year T_D hour point rainfall.

Step-3 : Read the areal reduction factor corresponding to storm duration T_D and the given area of catchment from Fig 5(a) & (b) or Annexure-4.2 and multiply the 50-year T_D point rainfall in step- 2 by this factor to obtain the 50-year T_D - hour areal rainfall over the catchment

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

Step-5 : Obtain the depths of storm rainfall occuring every hour in the bridge catchment by substraction of successive cumulative depths of 1,2,...... (T_D-1) and T_D hours in step-4.

PART-V

DESIGN FLOOD ESTIMATION

5.1. Criteria and Standards in regard to Design Flood of Structures of small and Medium Catchments:

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

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

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

b) Indian Road Congress-IRC 5-1985, clause 103 of Section I "General Features of Design" Specifies that the water way of a bridge is to be designed for a maximum flood of 50-yr return period. To provide for adequate margin of safety, the foundation and protection works should be designed for larger discharge. The recommended percentage increase over the design discharge specified in clause 103 is same as suggested by the committee of Engineers.

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

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

e) Indian Standards Guidelines for "Fixing spillway capacity of dams under clauses 3.1.2. and 3.1.3 of IS: 11223-1985" recommends 100-yr return period flood as inflow design flood for small dams having either gross storage of the dam between 0.5 and 10 Mm^3 or hydraulic head between 7.5 Mm^3. and 12 m.

5.2 Estimation of Design Flood:

To obtain design flood of required return period the effective rainfall for design storm duration is to be applied to the unit hydrograph of a catchment.

Procedure for computing design flood peak and design flood hydrograph for T year return period by SUG approach is as under:

a) Computation of design flood peak

Step-1 Synthetic unit hydrograph

Derive the synthetic unit hydrograph as per section 3.5 and tabulate 1 hour U.G. ordinates.

Step-2 Design storm duration

The duration of storm,which causes maximum flow in a river at a specified location is called "Design Storm Duration". . To obtain Design Stotm Duration for the catchments in the the subzone, flood peaks of 25 ,50 , and 100 year return period for gauged catchments were computed using different values of TD as Td=1.1*tp and TD=TB. and shown in Annex. 5.1. The value of TD as 1.1 * tp produced maximum flood peaks in all the catchments. It is therefore suggested to adopt the value of TD as 1.1 *tp . The design engineer may adopt the value of TD as 1.1 * tp or any other value which gives the mximuum value of dicharge .

Step-3 Design storm rainfall.

i) Adopt suitable design storm durartion (T_D) as explained in Step- 2.

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

iii) Adopt design loss rate as recommended in section 3.5

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

Step-4 Design flood peak:-

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

(ii) Obtain the base flow for the catchment area under study vide section 3.6.

(iii) Obtain total surface runoff by summing the product of unit hydrograph ordinates as tabulated in Step 1 and the effective rainfall values as tabulated in Step 3.(iv)

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

b) Design flood hydrograph

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

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

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

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

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

5.2.1 Illustrative Example:-

An example , taking bridge number 629 as ungauged catchment has been worked out for illustrating the procedure to compute 50 yr design flood. The catchment plan is enclosed at Fig. A-1.1 . The particulars of the catchment under study are given below :

i) Name of zone	Western Himalayas
ii) Name of Tributary	Banu Khad
iii) Name of Rail Section	Pathankot-Joginder
iv) Shape of catchment	Leaf
v) Location	Lat 32^0-04'-55" Long 76^0-28'-15"
vii) Topography	Steep slope

Procedure is explained stepwise:

Step-1:- Physiographic parameters:

Physiographic parameters obtained are given below:

1)	Area (A)(refer Fig. A-1.1)	103.60 sq km
2)	Length of the longest stream (L)	21.32 km
3)	Length of the longest stream from a point opposite to C.G. of catchment to point of study (Lc)	11.58 km
4)	Equivalent stream slope (S) (Refer Annexure 5.2)	69.21m/km

Step-2:- 1-hr Synthetic Unitgraph:

Synthetic Unitgraph Parameters as given below were computed using equations in para 3.4.3.

---

t_p = 2.5 hr.

q_p = 0.86 cumecs/sq.km

W_{50} = 2.26 hr.

W_{75} = 1.14 hr.

WR_{50} = 0.77 hr.

WR_{75} = 0.47 hr.

TB = 13.0 hr.

Q_p = 89.02 cumecs

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

Where A = Catchment area in Sq. Km.

d = 1.0 cm depth

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

$$Q = \frac{A * d}{0.36*tr} = \frac{103.60 * 1}{0.36 * 1} = 287.78 \ m^3/s$$

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

Step-3: Estimation of Design Storm:

(a) Design storm duration:

The Design Storm Duration (TD) has been adopted as 1.1 * tp as this value of storm duration gave higher value of flood peak (refer Section 5.2.[illegible]). Rounding of the design storm duration to nearest hour, its value came as 3 hrs.

(b) Estimation of Point Rainfall and Areal Rainfall for storm duration:

Catchment under study was located on Plate -9 showing 50-yr 24-hr point rainfall. The point rainfall was found to be 32.00 cm. The Conversion factor of 0.600 was read from Fig - 3 to convert the 50-yr 24-hr point rainfall to 50-yr 3-hr point rainfall (since TD = 3 hrs). 50-yr 3-hr point rainfall was 19.20 cm.

Areal reduction factor of 0.926 corresponding to the catchment area of 103.60 sq.km for TD = 3-hr. was interpolated from Annex.4.2 or Fig 5(a) for conversion of point rainfall to areal rainfall. 50-yr 3-hr areal rainfall thus worked out to be 17.78 cm.

The 50-yr, 3-hr areal rainfall was split in to 1-hour rainfall increments using time distribution coefficients given in Annexure 4.1 or Fig 4.

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

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

Table - 1
(Hourly rainfall Increments)

Dura-ation 1	Distribu-tion coef-ficient 2	Storm rainfall 3 (cm)	Rainfall increments 4 (cm)	Loss per hr. 5 (cm)	Effective rainfall increments 6 (cm)
1	0.73	12.98	12.98	0.2	12.78
2	0.92	16.36	3.38	0.2	3.18
3	1.00	17.78	1.42	0.2	1.22

Step-4: Estimation of base flow:

Taking design base flow of 0.05 cumecs per sq km as recommended in para 3.6, the base flow was estimated to be 5.18 cumecs for the catchment area of 103.60 sq.km.

Step-5: Estimation of 50-yr flood.

(a) Computation of flood peak

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

Table - 2

(50 year flood peak)

Time (hrs)	U.G. ordinate cumecs	1-hr effec. rainfall (cms)	direct runoff (cumecs)
1	2	3	4
3	89.02	12.78	1137.67
4	56.50	3.18	179.67
5	35.00	1.22	42.70
		Total	1360.04
		Base flow	5.18
		50-yr flood Peak	1365.22

(b) Computation of design flood hydrograph:

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

Table - 3
(Critical sequence of rainfall)

Time in hrs	Critical 1-hr effective rainfall sequence cms
1	1.22
2	3.18
3	12.78

For computation of design flood hydrograph, the U.G. ordinates were tabulated in col(2) of Annex. 5.3. The critical sequence of effective rainfall increments were entered in col.3 to 5 horizontally. Direct runoff resulting from each of the effective rainfall increments was obtained by multiplying effective rainfall depths with the synthetic U.G. ordinate in col. (2) and direct runoff values were entered in columns against each unit with a successive lag of 1-hr since the unit duration of S.U.G. is 1-hr. Direct runoff values are shown in col (3) to (5). Direct runoff values were added horizontally and total direct runoff is shown in col. (6) Adding total base flow of 5.18 m^3 /sec. (col. 7), design flood hydrograph ordinates (Col 8) were obtained. Design flood hydrograph was plotted against time as shown in Fig A-3. The peak obtained was 1365.22m^3/s which tallies with the peak shown in table-2.

5.3 Computation of Design H.F.L:

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

Stage discharge relationship is represented by stage vs. discharge rating curve of a river at the point of study. The most acceptable method for establishing stage discharge rating curve is based on observed gauges and discharges covering satisfactorily the lower to upper elevation ranges. Stage discharge relation defines the complex interaction of channel characteristics inclu- ding 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.

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

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

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

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

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

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

PART VI

ASSUMPTIONS, LIMITATIONS AND CONCLUSIONS

6.1 Assumptions:

6.1.1 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.

6.1.2 A generalized value of loss rate and base flow is assumed to hold good for a catchment of river in which flood is caused by rainfall only .

6.2 Limitations:

The RUGs of 5 gauged catchments and of Sewa Hydel project have been considered for developing SUG equations for the zone . The gauged catchments are not only too meagre to develop reliable SUG equations, but their distribution is also not uniform. All the gauged catchments are clustered near the border of the zone with subzone 1(e) and represent only about 1 % of the area of the zone. Similarly , the recommended values of loss rate , base flow and design storm have been obtained on the basis of only 45 flood events at 5 gauged catchments.It is therefore important to empathize that all the complexities present in the estimation of design flood at all the locations of the zone can't possibly be compressed in few equations and values obtained on the basis of such a limited data . The design engineers may verify the results by alternative methods . The recommendations are not applicable to the ungauged catchments of the streams in the snow covered areas as floods in these rivers are due to snow melt .

For more reliable relationships, the data of more-suitable catchments spread uniformly in the zone zone would be desirable.

The base flow and loss rate values for the zone may hold good only in a limited way due to the limitations and assumptions explained above. The designer may adopt other suitable values as per site conditions.

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.

6.3 Conclusions :

6.3.1 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.

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

6.3.3 25-yr, 50-yr and 100-yr flood may be estimated using design loss rate of cm/hr.

6.3.4 The report is applicable for the catchment areas ranging from 25 sq km to 1000 sq km. located in the rainfed area of the zone.

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ANNEXURE 2.1

LIST OF HYDRO-METEOROLOGICAL SUB-ZONE

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

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

ZONE-7

ANNEXURE 3.1

LIST OF RAILWAY BRIDGE CATCHMENTS AND AVAILABILITTY OF GAUGE DISCHARGE AND RAINFALL DATA

S.N.	NAME OF STREAM	NAME OF SECTION	BRIDGE NO.	LOCATION LON. Dg Mt Sec	LOCATION LAT. Dg Mt Sec	C.A. Sq.km.	NO OF RAIN-GAUGES	DATA AVAIL-BILITY	NO.OF YEARS
1	CHAKKI KHAD	JALANDHER-PAT	232	75-46-00	32-17-00	657.86	7	1963-67	5
2	SUSWA NADI	LAKSAR-DEHRAD	139	78-07-00	30-07-00	296.84	3	1966-67	2
3	NEOGAL KHAD	AMRITSAR-JOGI	821	76-38-30	32-03-20	151.98	2	1966	1
4	BANU KHAD	PATHANKOT-JOG	629	76-28-15	32-04-55	103.60	4	1963-66	4
5	JHALUM (Tri.)	SIR-NLDM	154	76-35-05	31-08-00	43.82	1	1962-67	6
6	SEWA	PATHANKOT-GAT	SEWA HE PROJECT	75-49-20	32-41-10	383.00	-	-	-
	BRIDGES NOT CONSIDERED FOR REGRESSION ANALYSIS								
7	BANNAR KHAD	PATHANKOT-JOG	357	76-14-45	32-01-15	170.00	1	1962-65	4
8		LAKSAR-DEHRAD	213	78-03-30	30-17-20	45.00	1	1962-66	5

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ANNEXURE-3.2

PHYSIOGRAPHY PARAMETERS OF SELECTED CATCHMENTS

S.N.	BR.No.	C.A. sq.km	L km.	LC km.	SEQ m/km.
1	232	657.86	51.49	24.13	9.90
2	139	296.84	46.50	20.50	13.95
3	821	151.98	21.35	12.00	84.04
4	629	103.60	21.32	11.58	69.21
5	154	43.82	13.10	7.50	13.85
6	SEWA HE PROJECT	383.00	40.22	16.00	20.59

ZONE-7 ANNEXURE-3.3

1-Hr.R.U.G.ORDINATES OF SELECTED CACHMENTS

HOURS/BR.NO.---	232	139	821	629	154
0	0.00	0.0	0.0	0.0	0.0
1	3.41	5.0	2.8	5.0	0.4
2	6.75	22.0	10.0	35.0	2.8
3	26.98	59.0	46.0	95.0	11.9
4	67.65	133.0	123.6	53.0	34.9
5	206.42	225.0	76.0	38.0	23.0
6	507.96	148.0	49.5	27.0	15.8
7	360.64	94.0	34.0	17.0	10.9
8	239.40	62.0	25.6	10.0	7.4
9	154.59	40.0	19.0	5.0	5.3
10	100.30	22.0	14.0	2.8	3.7
11	59.83	10.0	9.8	0.0	2.4
12	35.64	4.56	6.3		1.5
13	23.60	0.00	3.7		0.9
14	15.82		1.8		0.4
15	9.87		0.0		0.3
16	6.00				0.0
17	2.53				
18	0.00				

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ANNEXURE-3.4

1-HR REPRESENTATIVE UNIT GRAPH(RUG) PARAMETERS OF SELECTED CATCHMENTS

Sl. No.	Br.No.	C.A. sq.km	Tp hrs	qp cumecs/ sq.km.	Qp cumecs	tr hrs	TB hrs	W50 hrs	W75 hrs	WR50 hrs	WR75 hrs
1	232	657.86	5.5	0.77	507.96	1	18	2.6	1.6	0.8	0.6
2	139	296.84	4.5	0.76	225.00	1	13	2.8	1.5	1.2	0.7
3	821	151.98	3.5	0.81	123.64	1	15	2.0	1.0	0.7	0.5
4	629	103.60	2.5	0.92	95.00	1	11	2.2	1.2	0.9	0.6
5	154	43.82	3.5	0.80	34.86	1	16	2.4	1.2	0.8	0.4
6	SEWA HE PROJECT	383.00	4.5	0.89	340.00	1	15	2.4	1.1	1.0	0.5

ZONE 7 ANNEXURE - 3.5

PHYSIOGRAPHY AND UNIT HYDROGRAPH PARAMETERS STUDIED TO ESTABLISH THEIR RELATIONS

Sl.No	Dependant Variable	Independant Variable	A	B	R	S.E
1	qp	A,L*Lc/S	0.758	0.004 0.004	0.385	1.085
2	qp*	tp	1.048	-0.178	0.631	1.069
3	tp	$L/S^{0.5}$	2.330	0.288	0.894	1.148
4	tp	L/S	3.756	0.195	0.886	1.153
5	tp	$L*LC/S^{0.5}$	1.215	0.194	0.872	1.163
6	tp*	LLc/S	2.498	0.156	0.897	1.146
7	W50	tp	1.304	0.520	0.517	1.303
8	W50*	L*Lc/S	1.954	0.099	0.558	1.290
9	W75	tp	0.612	0.599	0.665	1.231
10	W75	$L*LC^{0.5}$	0.685	0.158	0.786	1.187
11	W75	$L/S^{0.5}$	0.901	0.241	0.621	1.275
12	W75*	L*Lc/S	0.972	0.124	0.792	1.185
13	WR50	$L/S^{0.5}$	0.665	0.258	0.432	1.677
14	WR50	tp	0.501	0.547	0.294	1.730
15	WR50	$L*Lc/S^{0.5}$	0.512	0.163	0.392	1.695
16	WR50*	W50	0.189	1.769	0.951	1.290
17	WR75	$L/S^{0.5}$	0.419	0.227	0.524	1.425
18	WR75	tp	0.322	0.489	0.363	1.473
19	WR75	L*Lc/S	0.461	0.108	0.462	1.445
20	WR75*	W75	0.419	1.246	0.834	1.257
21	TB	LLc*/S	12.692	0.435	0.435	1.185
22	TB *	tp	7.845	0.453	0.728	1.140

NOTE - "A" stands for Constant

"B" stands for Regreesion Coefficient

"R" stands for Crrelation Coefficient

* Relations recommended for adoption

ZONE-7

ANNEXURE-3.6

LOSS RATE RANGES (cm/hr.)) OF OBSEREVD FLOOD EVENTS

S.N.BR.NO.			232	139	821	629	154	
C.A. sq.km.			657.86	296.84	151.98	103.6	43.82	
LOSSRATE RANGES cms/hr	LB	UB	NUMBER OF OBSERVED FLOODS					TOTAL
1	0.00	0.10	-	-	-	-	-	-
2	0.11	0.30	3	-	-	2	-	5
3	0.31	0.50	3	-	-	1	2	6
4	0.51	0.70	7	2	2	-	1	12
5	0.71	0.90	1	-	1	1	2	5
6	0.91	1.10	5	3	1	-	1	10
7	1.11	1.30	2	-	-	-	1	3
8	1.31	1.50	-	-	-	-	-	-
9	1.51	1.70	1	1	-	-	-	2
10	1.71	1.90	-	-	-	-	-	-
11	1.91	2.10	1	1	-	-	-	2
12	2.11	2.30	-	-	-	-	-	-
13	2.31	2.50	-	-	-	-	-	-
14	2.51	2.70	-	-	-	-	-	-
15	2.71	2.90	-	-	-	-	-	-
16	2.91	& above	-	-	-	-	-	-
		TOTAL	23	7	4	4	7	45

ZONE-7

ANNEXURE-3.7

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

S.N.	BR.NO.		232	139	821	629	154	
	C.A. sq.km.		657.86	296.84	151.98	103.6	43.82	
	BASE FLOW RANGES cumecs/sq.km. LB	UB	NUMBER OF OBSERVED FLOODS					TOTAL
1	0.0	0.10	12	7	1			27
2	0.11	0.20	7	-	1		-	9
3	0.21	0.30	2	-	-		-	2
4	0.31	0.40	1	-	1		-	5
5	0.41	& Above	-	-	1		-	2
		TOTAL	23	7	4		7	45

ANNEXURE - 4.1

TIME DISTRIBUTION CO-EFFICIENTS OF CUMULATIVE HOURLY RAINFALL - ZONE(7)

INTER-MEDIATE HOURS	DESIGN STORM DURATION (HOURS)																								INTER-MEDIATE HOURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	1.00	0.85	0.73	0.62	0.56	0.52	0.46	0.43	0.41	0.38	0.37	0.34	0.32	0.30	0.28	0.26	0.25	0.23	0.21	0.20	0.19	0.18	0.17	0.17	1
2		1.00	0.92	0.82	0.75	0.69	0.63	0.60	0.57	0.54	0.52	0.49	0.44	0.43	0.41	0.40	0.39	0.37	0.33	0.32	0.31	0.30	0.28	0.27	2
3			1.00	0.94	0.87	0.82	0.75	0.71	0.68	0.65	0.62	0.60	0.55	0.53	0.51	0.50	0.48	0.46	0.43	0.41	0.39	0.38	0.37	0.36	3
4				1.00	0.96	0.91	0.85	0.81	0.76	0.73	0.71	0.67	0.63	0.61	0.59	0.57	0.56	0.54	0.50	0.48	0.46	0.45	0.44	0.43	4
5					1.00	0.97	0.92	0.88	0.84	0.81	0.77	0.74	0.70	0.68	0.66	0.64	0.62	0.60	0.56	0.54	0.52	0.51	0.50	0.48	5
6						1.00	0.97	0.94	0.90	0.87	0.83	0.81	0.77	0.74	0.72	0.69	0.68	0.66	0.61	0.59	0.57	0.56	0.55	0.53	6
7							1.00	0.97	0.95	0.92	0.88	0.86	0.82	0.79	0.77	0.74	0.73	0.71	0.66	0.64	0.62	0.61	0.60	0.58	7
8								1.00	0.98	0.95	0.93	0.90	0.86	0.84	0.81	0.79	0.77	0.75	0.71	0.69	0.67	0.66	0.65	0.63	8
9									1.00	0.98	0.96	0.94	0.90	0.87	0.85	0.83	0.81	0.79	0.75	0.73	0.71	0.70	0.69	0.67	9
10										1.00	0.98	0.96	0.93	0.90	0.88	0.87	0.85	0.83	0.79	0.77	0.74	0.73	0.72	0.70	10
11											1.00	0.98	0.96	0.93	0.91	0.90	0.88	0.86	0.82	0.80	0.77	0.76	0.75	0.73	11
12												1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.85	0.83	0.80	0.79	0.78	0.76	12
13													1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.86	0.83	0.82	0.81	0.79	13
14														1.00	0.98	0.96	0.94	0.92	0.90	0.89	0.86	0.85	0.83	0.82	14
15															1.00	0.98	0.96	0.94	0.92	0.91	0.89	0.87	0.85	0.84	15
16																1.00	0.98	0.96	0.94	0.93	0.91	0.89	0.87	0.86	16
17																	1.00	0.98	0.96	0.95	0.93	0.91	0.89	0.88	17
18																		1.00	0.98	0.97	0.95	0.93	0.91	0.90	18
19																			1.00	0.99	0.97	0.95	0.93	0.92	19
20																				1.00	0.99	0.97	0.95	0.94	20
21																					1.00	0.99	0.97	0.96	21
22																						1.00	0.99	0.98	22
23																							1.00	0.99	23
24																								1.00	24

ANNEXURE - 4.2

AREAL REDUCTION FACTORS (%) FOR POINT TO AREAL RAINFALL

ZONE - 7

CATCHMENT AREA (Km²)	DESIGN STORM DURATION (HOURS)																								CATCHMENT AREA (Km²)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0000
50	94.00	95.20	96.40	96.83	97.27	97.70	97.79	97.88	97.97	98.07	98.16	98.25	98.31	98.38	98.44	98.50	98.56	98.62	98.69	98.75	98.81	98.88	98.94	99.00	50
100	89.00	90.95	92.90	93.73	94.57	95.40	95.58	95.77	95.95	96.13	96.32	96.50	96.62	96.75	96.88	97.00	97.12	97.25	97.38	97.50	97.62	97.75	97.87	98.00	100
150	84.50	87.00	89.50	90.70	91.90	93.10	93.42	93.73	94.05	94.37	94.68	95.00	95.17	95.33	95.50	95.67	95.83	96.00	96.17	96.33	96.50	96.67	96.83	97.00	150
200	80.75	83.47	86.20	87.40	88.60	89.80	90.42	91.03	91.65	92.27	92.88	93.50	93.71	93.92	94.12	94.33	94.54	94.75	94.96	95.17	95.37	95.58	95.79	96.00	200
250	77.25	80.12	83.00	84.83	86.67	88.50	89.08	89.67	90.25	90.83	91.42	92.00	92.27	92.53	92.80	93.07	93.33	93.60	93.87	94.13	94.40	94.67	94.93	95.20	250
300	74.25	77.12	80.00	82.07	84.13	86.20	86.92	87.63	88.35	89.07	89.78	90.50	90.82	91.15	91.47	91.80	92.12	92.45	92.77	93.10	93.42	93.75	94.07	94.40	300
350			77.20	79.43	81.67	83.90	84.77	85.63	86.50	87.37	88.23	89.10	89.48	89.87	90.25	90.63	91.02	91.40	91.78	92.17	92.55	92.93	93.32	93.70	350
400			74.50	76.87	79.23	81.60	82.62	83.65	84.67	85.70	86.72	87.75	88.19	88.62	89.06	89.50	89.94	90.37	90.81	91.25	91.69	92.12	92.56	93.00	400
450			72.00	74.50	77.00	79.50	80.67	81.83	83.00	84.17	85.33	86.50	86.98	87.47	87.95	88.43	88.92	89.40	89.88	90.37	90.85	91.33	91.82	92.30	450
500			70.00	72.40	74.80	77.20	78.54	79.88	81.22	82.57	83.91	85.25	85.78	86.31	86.84	87.37	87.90	88.42	88.95	89.48	90.01	90.54	91.07	91.60	500
600												83.00	83.60	84.21	84.81	85.42	86.02	86.62	87.23	87.83	88.44	89.04	89.65	90.25	600
700												81.00	81.67	82.33	83.00	83.67	84.33	85.00	85.67	86.33	87.00	87.67	88.33	89.00	700
800												79.60	80.30	81.00	81.70	82.40	83.10	83.80	84.50	85.20	85.90	86.60	87.30	88.00	800
900												78.40	79.12	79.83	80.55	81.27	81.98	82.70	83.42	84.13	84.85	85.57	86.28	87.00	900
1000												77.20	77.95	78.71	79.46	80.22	80.97	81.72	82.48	83.23	83.99	84.74	85.50	86.25	1000
1100												76.20	76.97	77.75	78.52	79.30	80.07	80.85	81.62	82.40	83.17	83.95	84.72	85.50	1100
1200												75.50	76.29	77.08	77.87	78.67	79.46	80.25	81.04	81.83	82.62	83.42	84.21	85.00	1200
1300																								84.50	1300
1400																								84.00	1400
1500																								83.50	1500
2000																								82.70	2000

Annexure-4.3

Statistics of Heaviest Rainfall & Annual Normal Rainfall in Zone - 7.

SN.	STATE/District	Station	Heaviest Rainfall 35≥cm	35<cm	Date of occurrence.	Annual Normal R/F in cm.
1	2	3	4	5	6	7
	Himachal Pradesh					
1.	Kinnaur	1.Kilba	61.0	-	27.12.1958	70.3
		2.Sangla	55.9	-	21.12.1958	83.8
2.	Kangra	3.Dharamshala	60.0	-	18.07.1967	309.9
3.	Shimla	4.Barauli	41.9	-	21.08.1901	123.7
4.	Mandi	5.Joginder-Nagar.	39.4	-	18.08.1954	224.5
5.	Chamba	6.Batheri	-	28.5	04.10.1955	150.8
6.	Una	7.Una	-	27.6	26.09.1947	109.4
7.	Mahasu	8.Nichar	-	26.8	10.10.1956	98.5
8.	Solan	9.Solan	-	26.4	21.08.1951	140.4
9.	Hamirpur	10.Hamirpur	-	24.8	19.07.1907	137.7
10.	Sirmur	11.Rainka	-	24.6	12.10.1956	173.0
11..	Kullu	12.Kullu	-	23.6	04.10.1888	98.4
12.	Bilaspur	13.Bilaspur	-	22.6	07.08.1971	128.9
13.	Lahul & Spiti	14.Keylong	-	12.8	17.09.1950	62.2
	Uttar Pradesh					
14.	Nainital	15.Nainital	50.9	-	22.09.1958	264.7
		16.Bazpur	40.6	-	03.10.1954	129.0
15.	Saharanpur	17.Hardwar	49.5	-	18.09.1880	125.6
16.	Dehradun	18.Dehradun	48.7	-	25.07.1966	216.8
		19.Rajpur	44.0	-	25.08.1954	301.6
17.	Pithoragarh	20.Askote	45.0	-	05.09.1982	185.3
18.	Uttarkashi	21.Kharsali	40.0	-	15.09.1963	193.4
19.	Almora	22.Champawat	39.0	-	27.09.1897	140.7
20.	Garhwal	23.Kotdwara	-	34.9	27.08.1892	175.6

Contd..2/-

1	2	3	4	5	6	7
21.	Pilibhit*	24.Pilibhit City	-	34.5	02.08.1879	130.2
22.	Bijnor*	25.Bijnor	-	31.9	15.09.1957	98.4
23.	Chamoli	26.Joshimath	-	27.3	21.07.1970	124.7
24.	Tehri Garhwal	27.Mukhim	-	12.1	16.09.1963	174.2
	Punjab					
25.	Gurdaspur	28.Batala	47.5	-	05.10.1955	71.9
		29.Tibri	38.6	-	04.09.1950	94.8
		30.Gurdaspur	37.0	-	05.10.1955	91.2
26.	Hoshiarpur	31.Hoshiarpur	36.1	-	19.08.1878	89.9
27.	Rupar	32.Rupar	-	31.0	30.07.1951	82.8
28.	Jullundar*	33.Jullundar	-	30.5	18.08.1878	69.7
29.	Patiala*	34.Patiala	-	23.8	14.07.1949	72.6
	Jammu & Kashmir					
30.	Reasi	35.Gulabgarh	37.1	-	14.09.1906	190.2
31.	Kashmir(North)	36.Partapsinghpura	-	30.5	11.09.1941	58.4
32.	Ladakh	37.Sonemarg	-	30.0	27.02.1936	178.5
33.	Mirpur	38.Kotli	-	27.7	02.07.1914	110.4
34.	Poonch	39.Poonch	-	26.8	31.08.1928	149.3
35.	Jammu	40.Akhnur	-	24.9	25.09.1917	115.1
36.	Kathua	41.Basohli	-	22.9	14.10.1955	156.7
37.	Kashmir(South)	42.Babapura	-	22.9	27.02.1958	52.8
38.	Udhampur	43.Ramnagar	-	22.4	18.09.1950	176.9
39.	Muzaffarabad	44.Karnah	-	20.3	24.05.1901	114.3
	Haryana					
40.	Ambala	45.Ambala	-	22.9	10.08.1896	79.7

Note: Col.2 Districts underlined/asterisked* are partly/fully outside the zone.

ANNEXURE 4.4

Heaviest 24 hours' & shorter durations' rainfall recorded in Zone (7)

	STATE/ District	SRRG Station	Highest Storm Rainfall (mm) & Duration (hrs.)	Date & Time of Occurrence (Clock hr.)
	(1)	(2)	(3)	(4)
	UTTAR PRADESH			
1.	Dehradun (2)	1. Dehradun	331 (24)	24-25.7.73 (03-03)
			215 (12)	24.7.73 (02-14)
			189 (6)	(07-13)
			143 (3)	14.6.70 (07-10)
			98 (1)	(08-09)
2.	Nainital (2)	2. Nainital	237 (24)	3-4.7.72 (17-17)
			208 (12)	18-19.7.72 (17-05)
			183 (6)	(22-04)
			125 (3)	(22-01)
			79 (1)	3.7.72 (18-19)
3.	Uttarkashi (1)	3. Uttarkashi*	123 (24)	12-13.7.79 (14-14)
			108 (12)	(14-02)
			106 (6)	12.7.79 (14-20)
			103 (3)	(14-17)
			100 (1)	(14-15)
4.	Tehri Garhwal (2)	4. Tehri	91 (24)	21-22.7.71 (01-01)
			90 (12)	(22-10)
			90 (6)	(22-04)
			90 (3)	(22-01)
			50 (1)	21.7.71 (22-23)
	PUNJAB			
5.	Gurdaspur (1)	5. Madhopur	329 (24)	23-24.7.74 (23-23)
			329 (12)	24.7.74 (04-16)
			287 (6)	(07-13)
			217 (3)	(07-10)
			100 (1)	16.9.75 (19-20)
6.	Patiala* (1)	6. Patiala	210 (24)	21-22.7.79 (09-09)
			210 (12)	(21-09)
			181 (6)	21.7.82 (06-12)
			153 (3)	(09-12)
			93 (1)	(10-11)
7.	Hoshiarpur (1)	7. Hoshiarpur	138 (24)	4-5.8.82 (11-11)
			138 (12)	5.8.82 (04-16)
			138 (6)	(04-10)
			133 (3)	(04-07)
			81 (1)	(06-07)
	JAMMU & KASHMIR			
8.	Kashmir(North) (1)	8. Gulmarg	99 (24)	9-10.9.80 (12-12)
			84 (12)	(21-09)
			65 (6)	9.9.80 (16-22)
			63 (3)	(19-22)
			62 (1)	(21-22)
9.	Kashmir(South) (1)	9. Srinagar	67 (24)	16-17.5.75 (03-03)
			66 (12)	28.8.75 (04-16)
			64 (6)	(08-14)
			54 (3)	(09-12)
			32 (1)	(09-10)

contd.....

(1)	(2)	(3)	(4)
HIMACHAL PRADESH			
10. Kangra	10. Dharamshala	270 (24)	13-14.7.76 (23-23)
(1)		205 (12)	24-25.7.80 (21-09)
		187 (6)	8.8.78 (16-22)
		123 (3)	(19-22)
		73 (1)	4.8.75 (21-22)
11. Chamba	11. Dalhousie*	182 (24)	9-10.6.71 (19-19)
(1)		133 (12)	(19-07)
		128 (6)	(20-02)
		120 (3)	9.6.71 (20-23)
		59 (1)	(21-22)
12 Solan	12. Dharampur	157 (24)	28-29.6.78 (08-08)
(1)		138 (12)	12.8.85 (04-16)
		124 (6)	(04-10)
		114 (3)	(05-08)
		100 (1)	9.8.85 (08-09)
13. Shimla	13. Shimla	127 (24)	17-18.7.70 (02-02)
(1)		105 (12)	(16-04)
		103 (6)	(21-03)
		86 (3)	12.7.79 (14-17)
		50 (1)	(16-17)
14. Mandi	14. Sundernagar*	120 (24)	20.8.85 (00-24)
(1)		80 (12)	18-19.8.85 (17-05)
		72 (6)	7.7.85 (05-11)
		68 (3)	(05-08)
		50 (1)	25.7.82 (18-19)
15. Sirmur	15. Nahan*	97 (24)	1-2.8.80 (21-21)
(1)		97 (12)	(21-09)
		89 (6)	(21-03)
		86 (3)	1.8.80 (21-24)
		84 (1)	(21-22)
16. Kullu	16. Bhuntar*	38 (24)	12-13.12.84 (13-13)
(1)		27 (12)	23-24.3.85 (19-07)
		20 (6)	(21-03)
		20 (3)	15.8.84 (01-04)
		19 (1)	(01-02)
HARYANA			
17. Ambala	17. Ambala	150 (24)	13-14.7.80 (09-09)
(1)		108 (12)	28.7.81 (02-14)
		101 (6)	(03-09)
		85 (3)	17.8.72 (12-15)
		74 (1)	20.8.82 (12-13)

Note :

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

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

ZONE 7 ANNEXURE-5.1

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

SL.NO.	BRIDGE No.	TD=1.1*tp			TD=TB		
		Q25	Q50	Q100	Q25	Q50	Q100
1	232	4450.89	4802.17	5462.63	3814.87	4004.38	6415.88
2	139	2703.27	3452.52	3637.97	2339.20	3163.93	3187.44
3	821	1645.24	1728.76	2277.01	1306.52	1558.63	1842.79
4	629	1265.87	1345.28	1718.87	1170.41	1252.82	1599.27
5	154	374.89	500.28	540.27	259.11	406.23	391.82

ZONE-7

ANNEXURE 5.2

COMPUTAION OF EQUIVALENT SLOPE OF BRIDGE CATCHMENT NO-629

SL. No.	REDUCED DISTANCE RD KM	REDUCED LEVEL RL M	LENGTH OF EACH SEGMENT Li KM	HEIGHT ABOVE DATUM Di M	(Di-1+Di) M	Li*(Di-1+Di) KM*M
1	0.00	945.00	0.00	0.00	0.00	0.00
2	1.25	960.00	1.25	15.00	15.00	18.75
3	2.00	980.00	0.75	35.00	50.00	37.50
4	2.50	1000.00	0.50	55.00	90.00	45.00
5	5.00	1100.00	2.50	155.00	210.00	525.00
6	6.50	1200.00	1.50	255.00	410.00	615.00
7	12.00	1400.00	5.50	455.00	710.00	3905.00
8	14.00	1600.00	2.00	655.00	1110.00	2220.00
9	15.25	1800.00	1.25	855.00	1510.00	1887.50
10	16.75	2000.00	1.50	1055.00	1910.00	2865.00
11	17.25	2200.00	0.50	1255.00	2310.00	1155.00
12	18.00	2400.00	0.75	1455.00	2710.00	2032.50
13	18.50	2600.00	0.50	1655.00	3110.00	1555.00
14	19.00	2800.00	0.50	1855.00	3510.00	1755.00
15	19.25	3000.00	0.25	2055.00	3910.00	977.50
16	19.50	3200.00	0.25	2255.00	4310.00	1077.50
17	19.75	3400.00	0.25	2455.00	4710.00	1177.50
18	20.00	3600.00	0.25	2655.00	5110.00	1277.50
19	20.25	3800.00	0.25	2855.00	5510.00	1377.50
20	20.50	4000.00	0.25	3055.00	5910.00	1477.50
21	20.75	4200.00	0.25	3255.00	6310.00	1577.50
22	21.32	4400.00	0.57	3455.00	6710.00	3824.70
						31383.45

$$S = \frac{Li*(Di-1+Di)}{L^2} = \frac{31383.45}{454.54} = 69.21 \text{ MT/KM.}$$

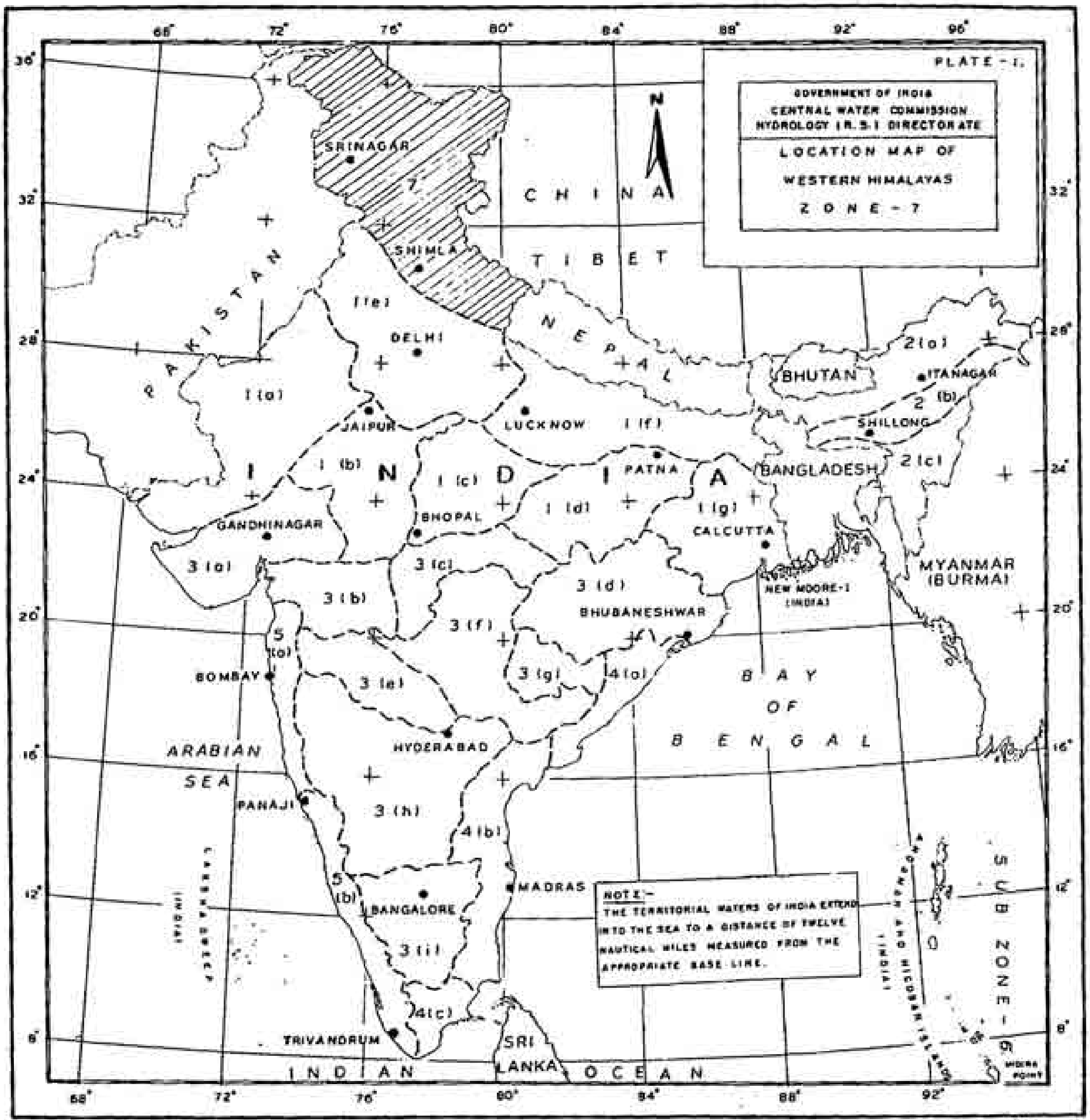
DATUM = 945m , i.e. R.L of river bed at point of study.

ZONE - 7

ANNEXURE - 5.3

COMPUTATUION OF DESIGN FLOOD HYDROGRAPH OF BRIDGE CATCHMENT NO 629

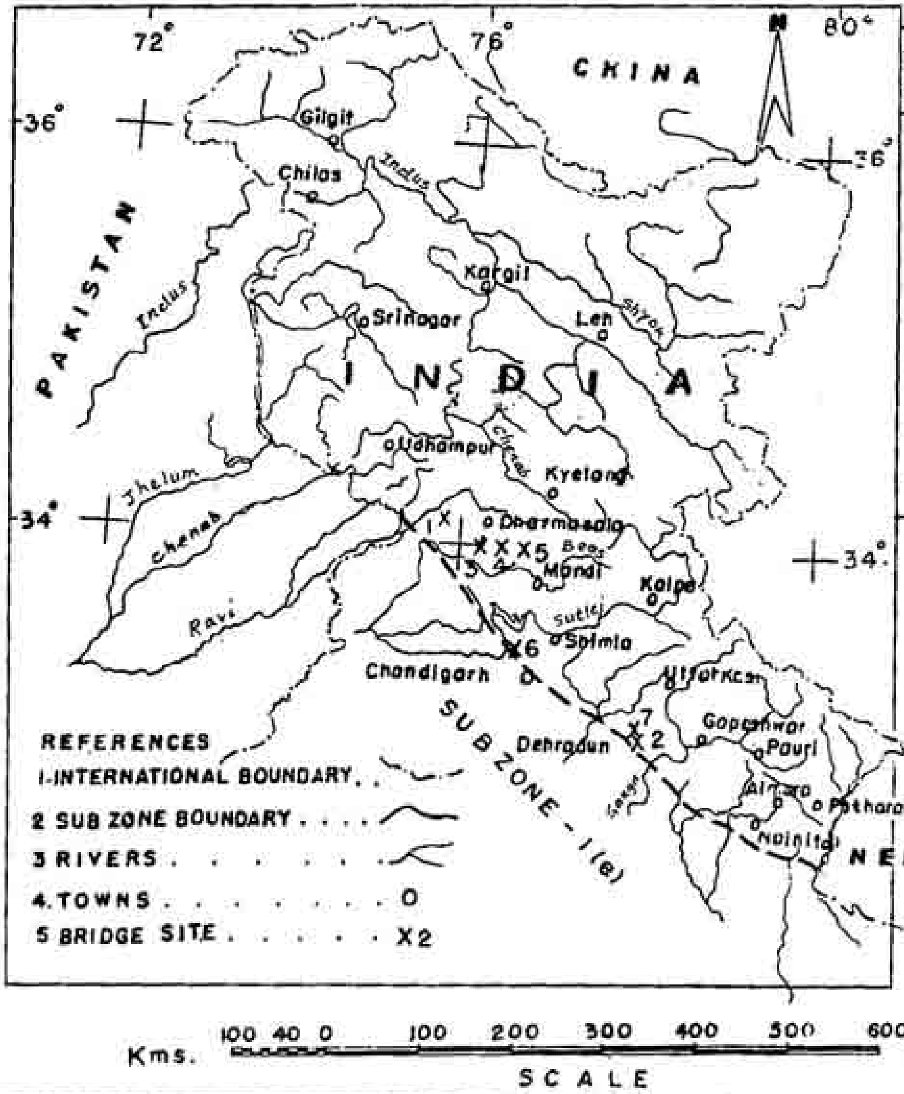
TIME HRS.	S.U.H ORDINATES CUMECS	RAINFALL EXCESS IN CMS 1.22	3.18	12.78	TOTAL D.S.R.O. IN CUMECS	BASE FLOW IN CUMECS.	TOTAL FLOW IN CUMECS
		DIRECT RUNOFF (CUMECS)					
1	2	3	4	5	6	7	8
1	0.00	0.00			0.00	5.18	5.18
2	4.00	4.88	0.00		4.88	5.18	10.06
3	23.26	28.38	12.72	0.00	41.10	5.18	46.28
4	89.02	108.60	73.97	51.12	233.69	5.18	238.87
5	56.50	68.93	283.08	297.26	649.28	5.18	654.46
6	35.00	42.70	179.67	1137.68	1360.05	5.18	1365.23 ------) PEAK
7	26.00	31.72	111.30	722.07	865.09	5.18	870.27
8	19.00	23.18	82.68	447.30	553.16	5.18	558.34
9	14.00	17.08	60.42	332.28	409.78	5.18	414.96
10	10.00	12.20	44.52	242.82	299.54	5.18	304.72
11	6.00	7.32	31.80	178.92	218.04	5.18	223.22
12	3.50	4.27	19.08	127.80	151.15	5.18	156.33
13	1.50	1.83	11.13	76.68	89.64	5.18	94.82
14	0.00	0.00	4.77	44.73	49.50	5.18	54.68
15			0.00	19.17	19.17	5.18	24.35
16				0.00	0.00	5.18	5.18
17					0.00	5.18	5.18
18						5.18	5.18
19							0.00



NOTES:- i) BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.
ii) RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS SHOWN ON THE MAP RESTS WITH THE PUBLISHER.

L.P. NAUTIYAL.
L.R. PANT

PLATE-2



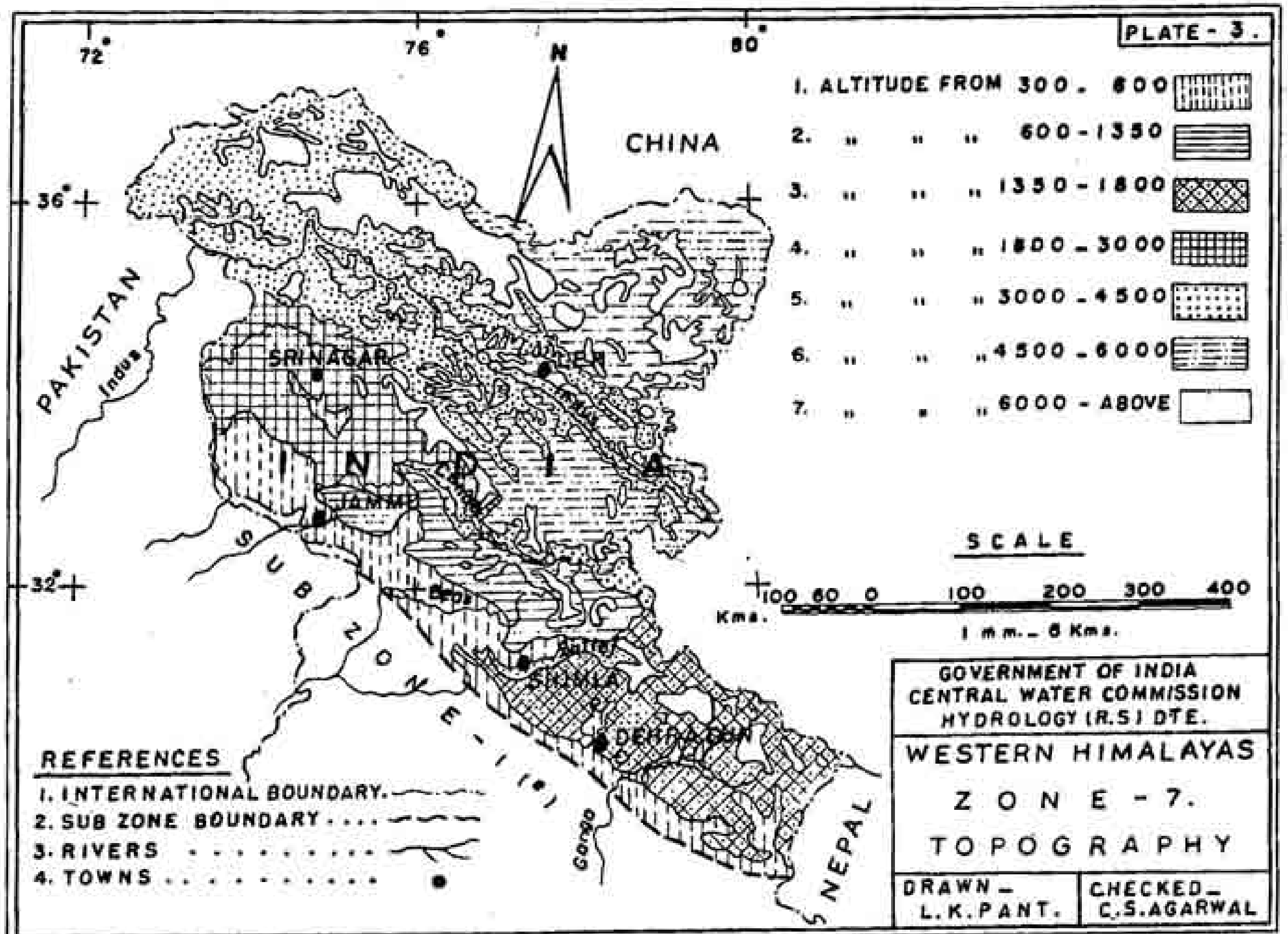
Sl. NO.	BR. NO.	LOCATION		C.A Km².
		LONG.	LATI.	
1.	232	75°46' 00"	32°17' 00"	657.86
2.	139	78°07' 00"	30°07' 00"	296.84
3.	357	76°14' 45"	32°01' 15"	170.00
4.	629	76°28' 15"	32°04' 55"	103.60
5.	821	76°38' 30"	32°03' 20"	151.98
6.	154	76°35' 05"	31°08' 00"	43.88
7.	213	78°03' 30"	30°17' 20"	45.00

Government of India
Central Water Commission
Hydrology (R.S) Directorate.

WESTERN HIMALAYAS
ZONE - 7
INDEX MAP
SHOWING RIVER SYSTEM & G & D SITES

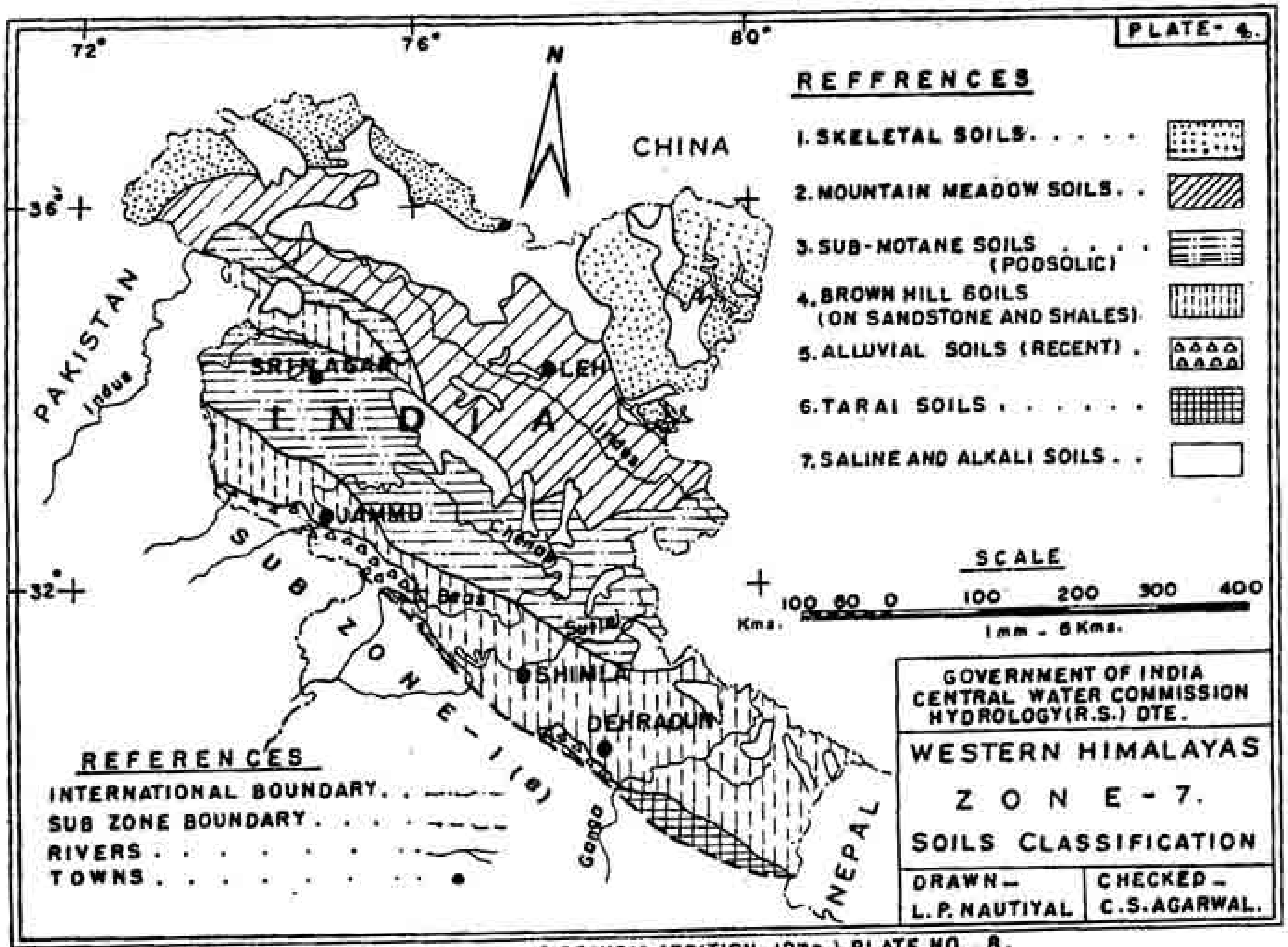
DRAWN - L. K. PANT | CHECKED - C.S. AGARWAL

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



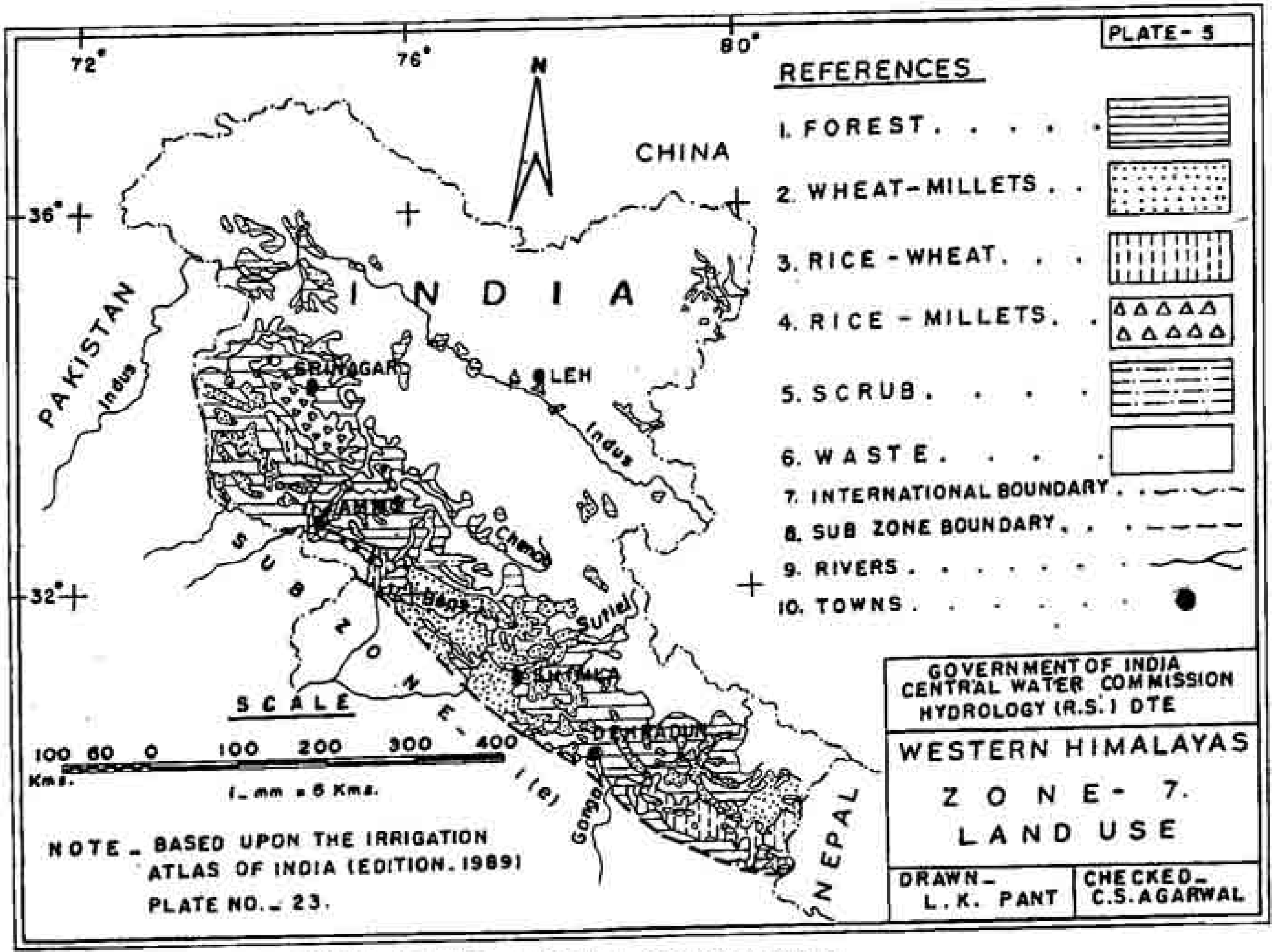
NOTE - BASED UPON THE IRRIGATION ATLAS OF INDIA (EDITION - 1989) PLATE NO. 18.

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

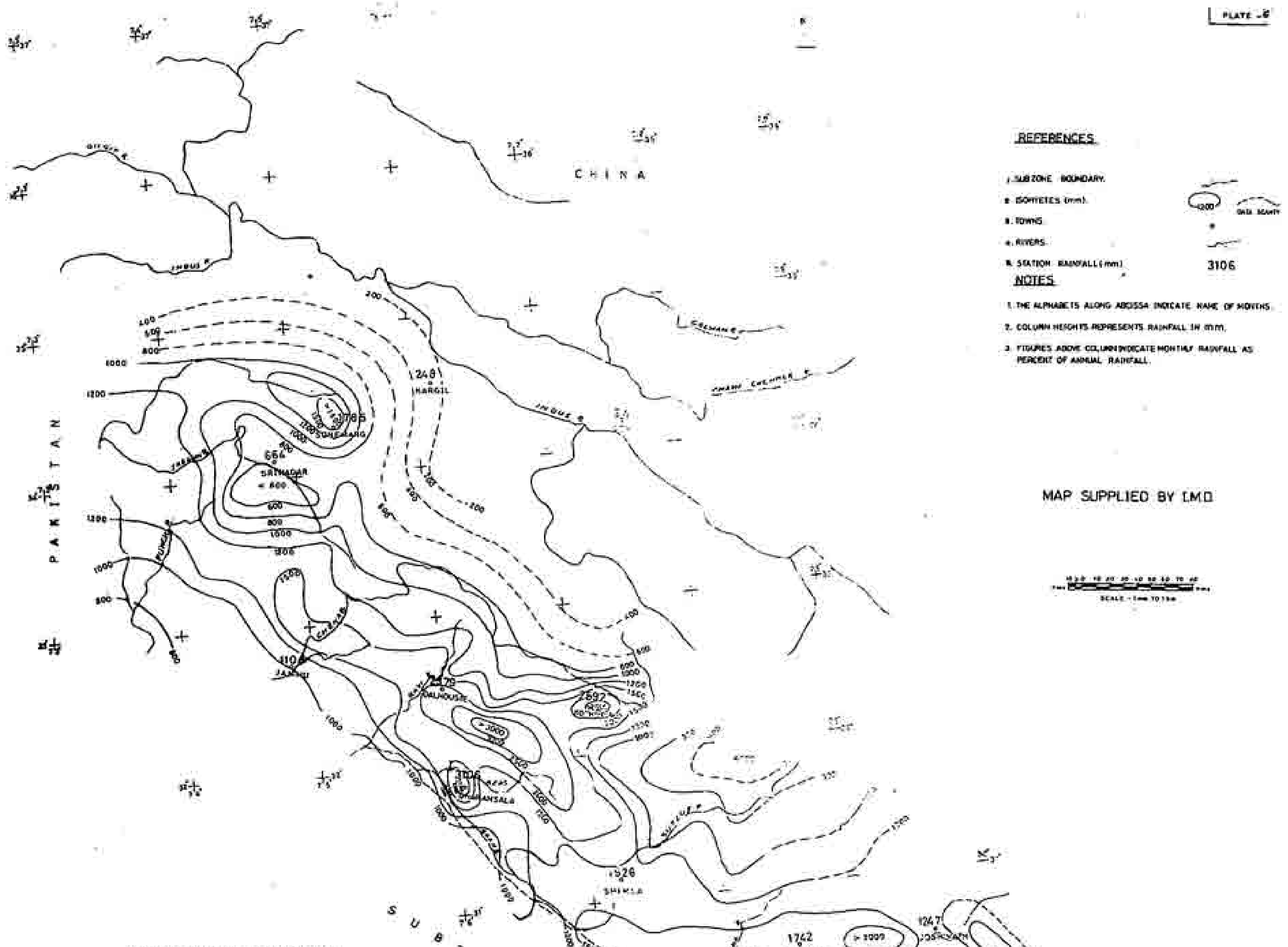


NOTE:- BASED UPON THE IRRIGATION ATLAS OF INDIA (EDITION-1972) PLATE NO.- 8.

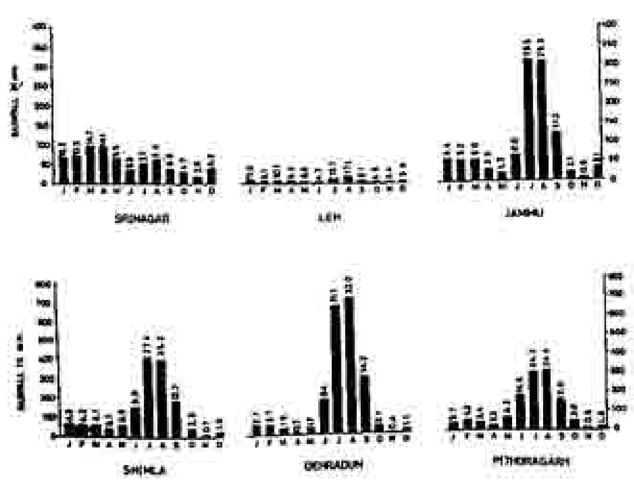
BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA



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



MONTHLY RAINFALL DISTRIBUTION



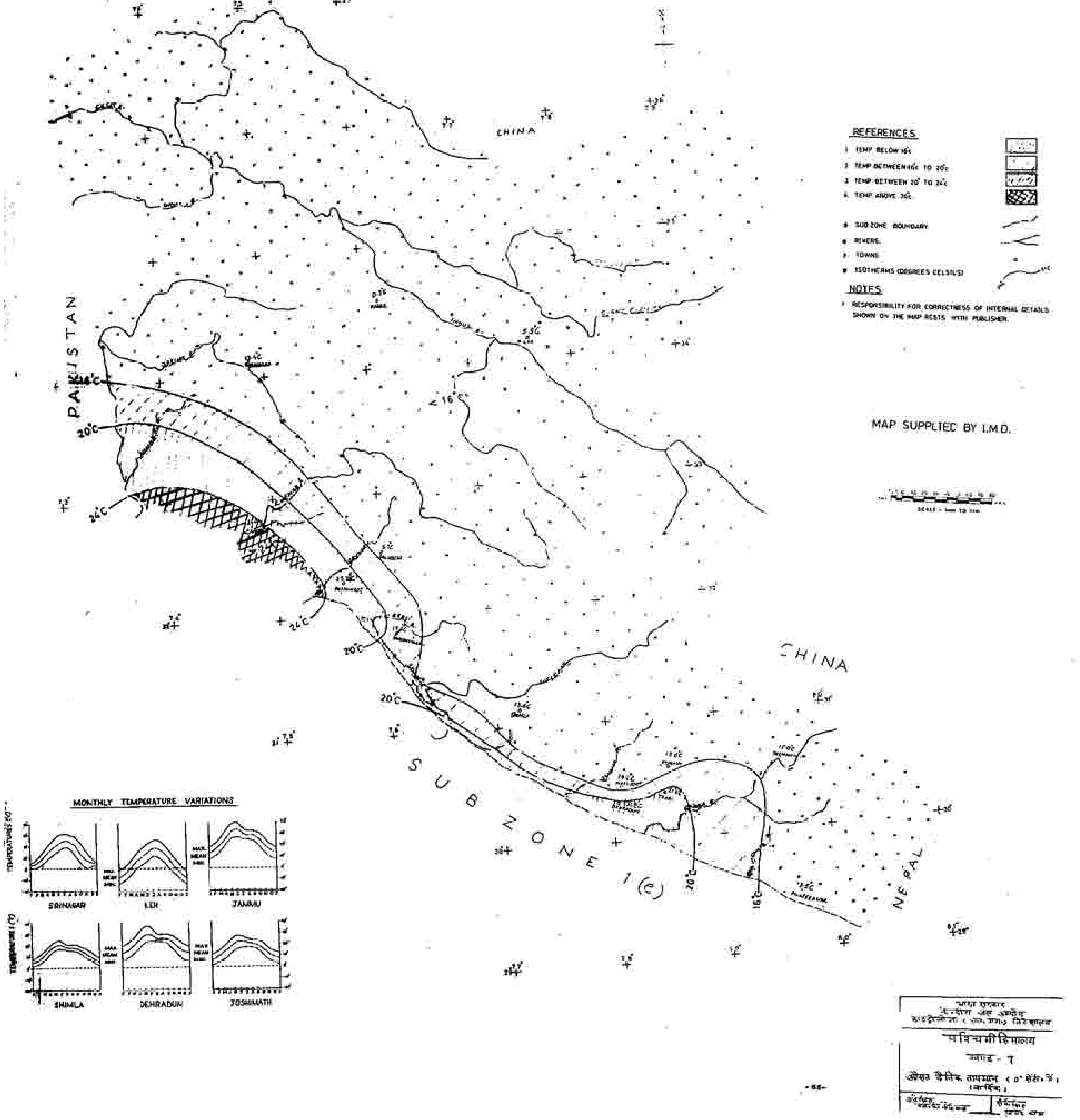
भारत सरकार
केन्द्रीय जल आयोग
जल विज्ञान (आर. एस.) निदेशालय

पश्चिमी हिमालय

खण्ड - 7

वार्षिक सामान्य वर्षा (मिलीमीटर)

PLATE - 4.



REFERENCES
1 TEMP BELOW 16°C
2 TEMP BETWEEN 16°C TO 20°C
3 TEMP BETWEEN 20° TO 24°C
4 TEMP ABOVE 24°C
SUB ZONE BOUNDARY
RIVERS.
TOWNS.
ISOTHERMS (DEGREES CELSIUS)
NOTES
RESPONSIBILITY FOR CORRECTNESS OF INTERNAL DETAILS SHOWN ON THE MAP RESTS WITH PUBLISHER.
MAP SUPPLIED BY I.M.D.
CHINA
CHINA
PAKISTAN
NEPAL
SUB ZONE 1(e)
< 16°C
20°C
24°C
16°C
MONTHLY TEMPERATURE VARIATIONS
SRINAGAR
LEH
JAMMU
SHIMLA
DEHRADUN
JOSHIMATH
MAX
MEAN
MIN
पश्चिमी हिमालय

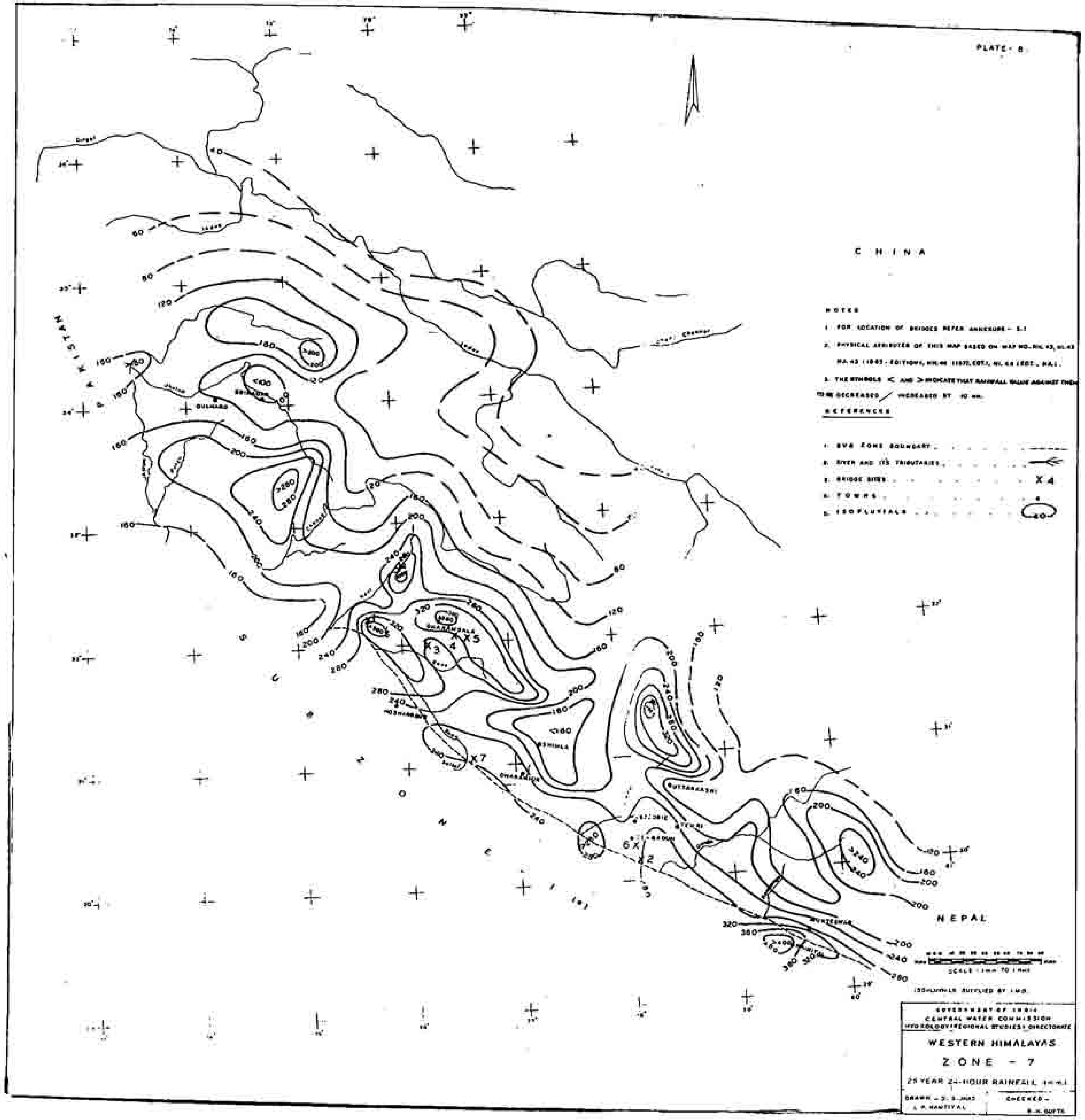


PLATE- 8
CHINA
NOTES
1. FOR LOCATION OF BRIDGES REFER ANNEXURE - 5.1
REFERENCES
ZONE BOUNDARY
RIVER AND ITS TRIBUTARIES
BRIDGE SITES
TOWNS
ISOPLUVIALS
PAKISTAN
SUB ZONE 7
NEPAL
SRINAGAR
DHARAMSALA
SHIMLA
UTTARKASHI
MUSSOORIE
DEHRADUN
TEHRI
NAINITAL
SCALE 1 mm TO 1 Km
ISOPLUVIALS SUPPLIED BY IMD
GOVERNMENT OF INDIA
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HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
WESTERN HIMALAYAS
ZONE - 7
25 YEAR 24-HOUR RAINFALL (mm)
CHECKED -

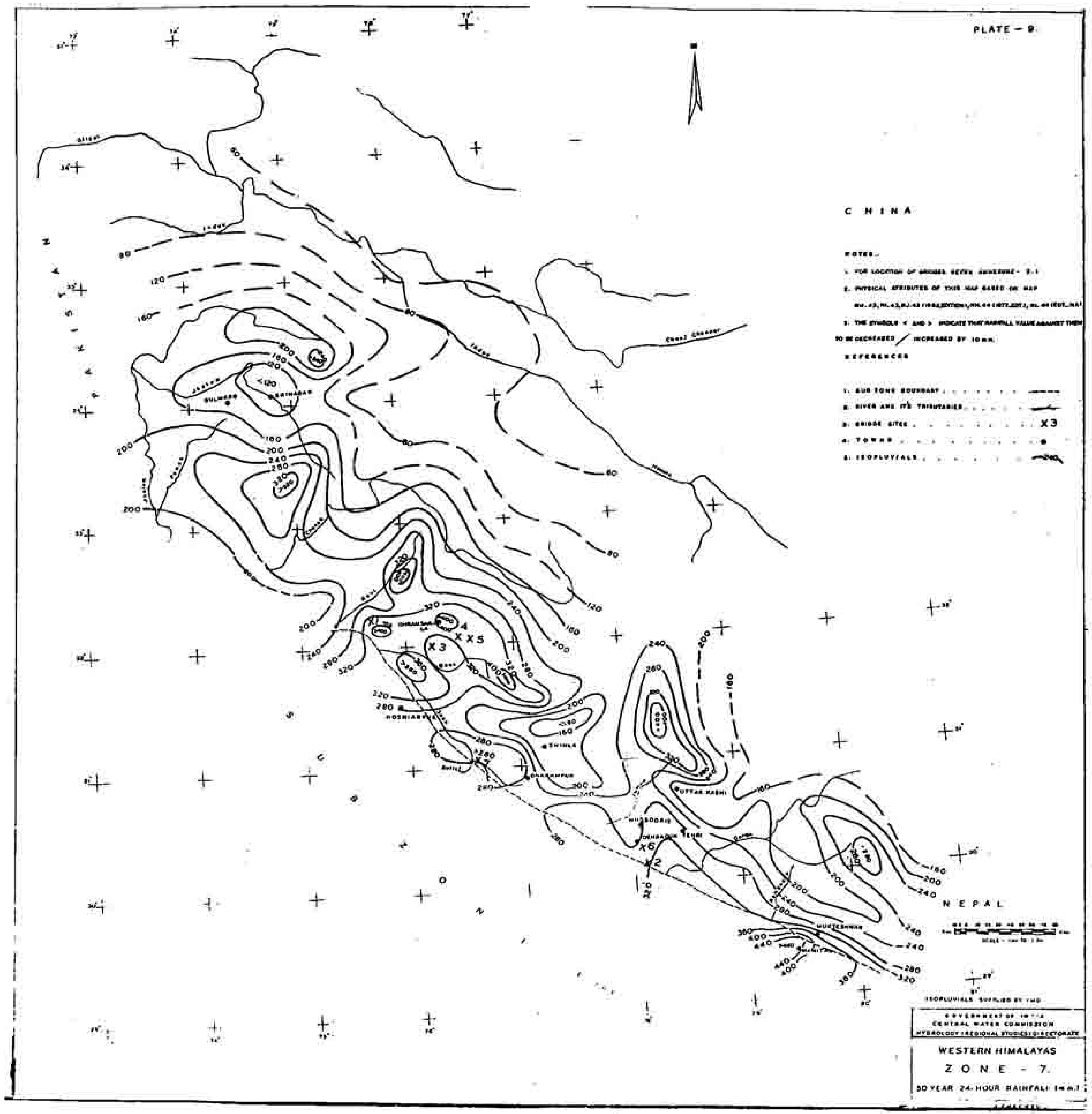
PLATE - 9.
CHINA
NOTES
REFERENCES
1. SUB ZONE BOUNDARY
2. RIVER AND ITS TRIBUTARIES
3. BRIDGE SITES
4. TOWNS
5. ISOPLUVIALS
PAKISTAN
NEPAL
SRINAGAR
HOSHIARPUR
SHIMLA
DHARAMPUR
UTTAR KASHI
MUSSOORIE
DEHRADUN
TEHRI
MUKTESHWAR
ISOPLUVIALS SUPPLIED BY IMD
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ZONE - 7.
50 YEAR 24-HOUR RAINFALL (mm)

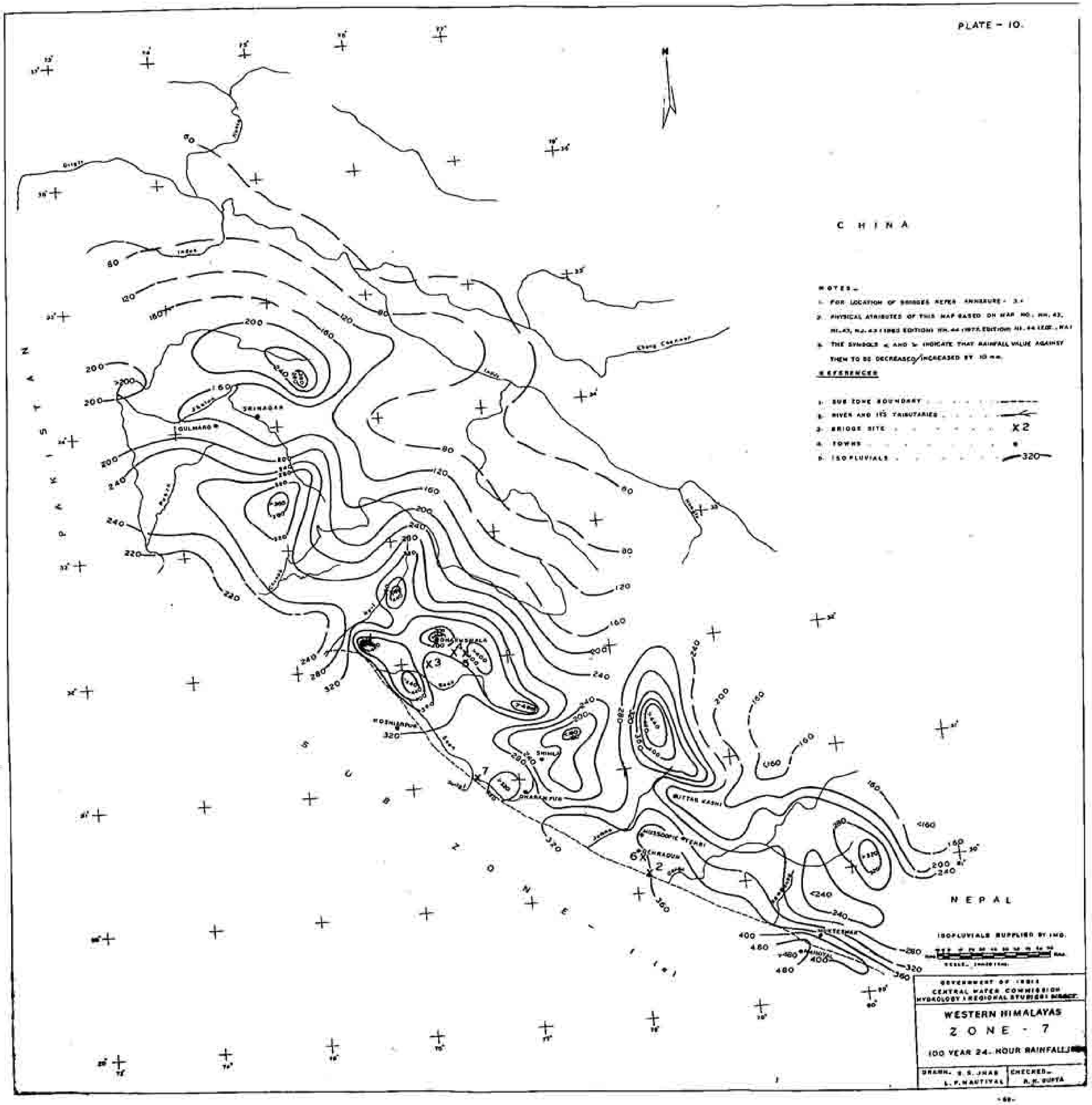


PLATE - 10.
CHINA
NOTES -
1. FOR LOCATION OF BRIDGES REFER ANNEXURE - 3.1
2. PHYSICAL ATTRIBUTES OF THIS MAP BASED ON MAP NO.
3. THE SYMBOLS AND INDICATE THAT RAINFALL VALUE AGAINST THEM TO BE DECREASED/INCREASED BY 10 mm.
REFERENCES
1. SUB ZONE BOUNDARY
2. RIVER AND ITS TRIBUTARIES
3. BRIDGE SITE
X2
4. TOWNS
5. ISOPLUVIALS
320
PAKISTAN
SUB ZONE - 7(i)
NEPAL
SRINAGAR
GULMARG
DHARAMSHALA
HOSHIARPUR
SHIMLA
UTTAR KASHI
MUSSOORIE
DEHRADUN
ISOPLUVIALS SUPPLIED BY IMD.
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
WESTERN HIMALAYAS
ZONE - 7
100 YEAR 24 - HOUR RAINFALL
DRAWN - S. S. JHAS
L. P. NAUTIYAL
CHECKED -
R. K. GUPTA

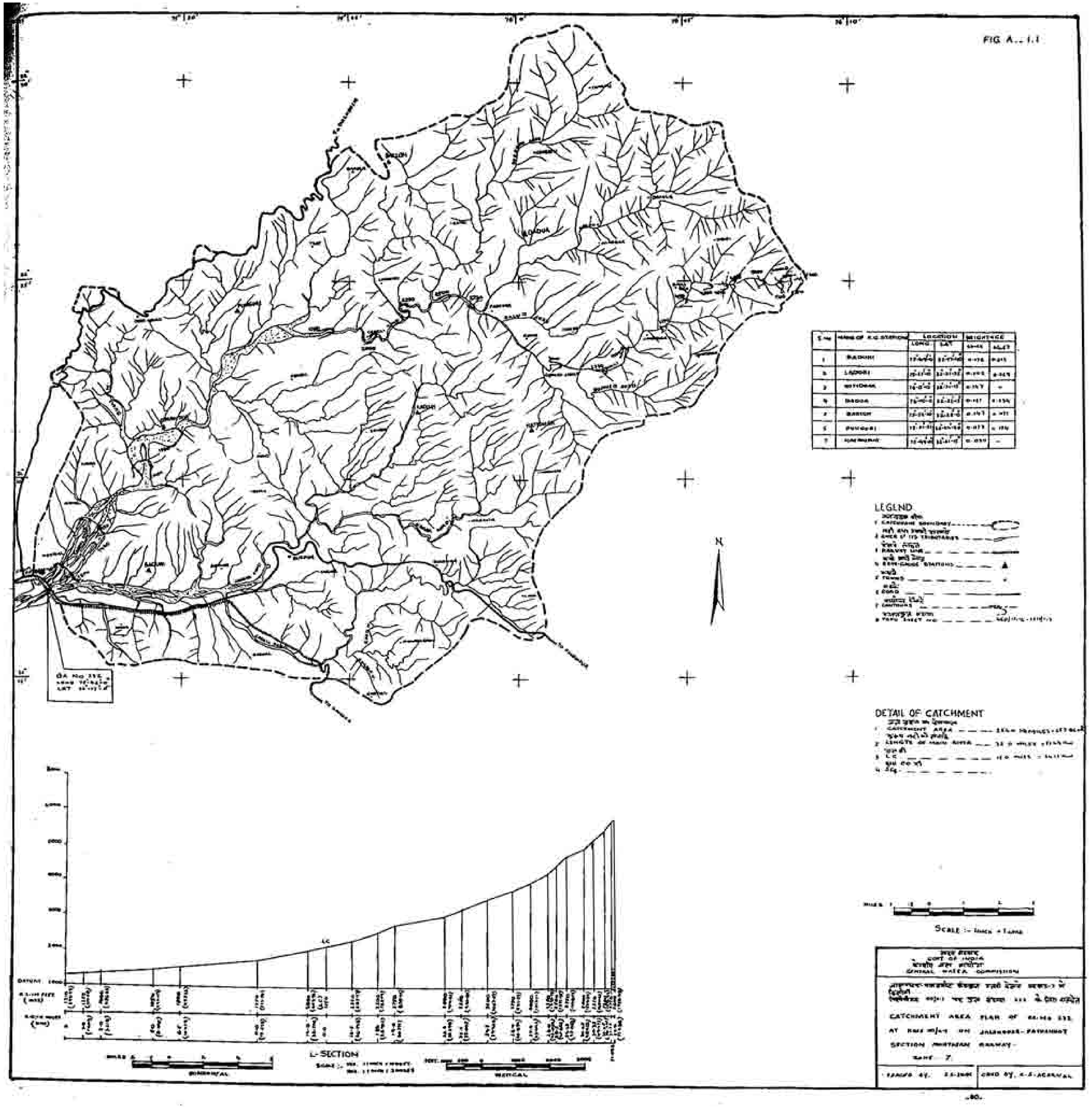
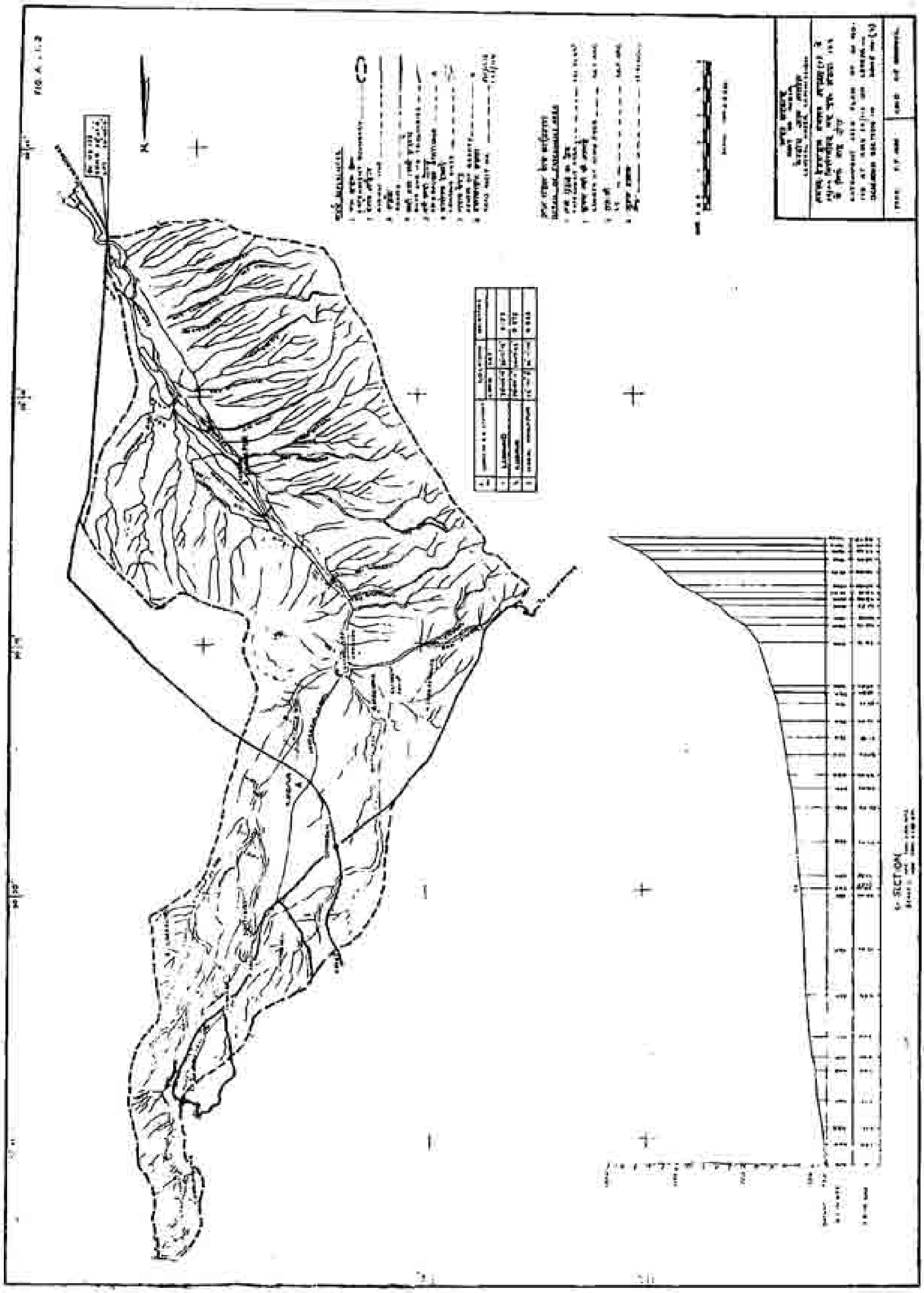
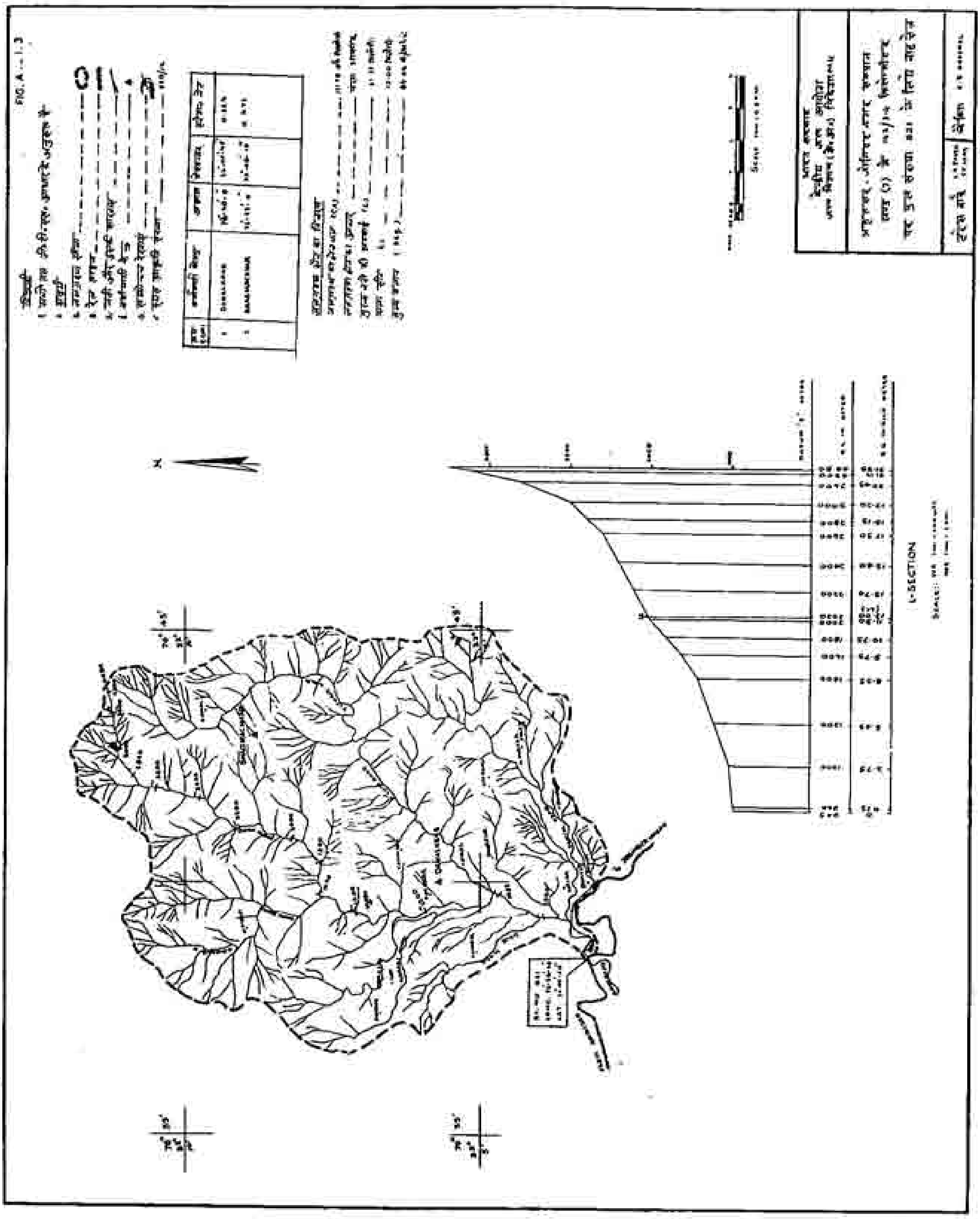


FIG A...1.1
LEGEND
1 CATCHMENT BOUNDARY
RAIN-GAUGE STATIONS
TOWNS
ROAD
CONTOURS
DETAIL OF CATCHMENT
CATCHMENT AREA
LENGTH OF MAIN RIVER
L.C
N
L-SECTION
HORIZONTAL
VERTICAL
DATUM
SCALE
GOVT OF INDIA
CENTRAL WATER COMMISSION
CATCHMENT AREA PLAN OF
SECTION





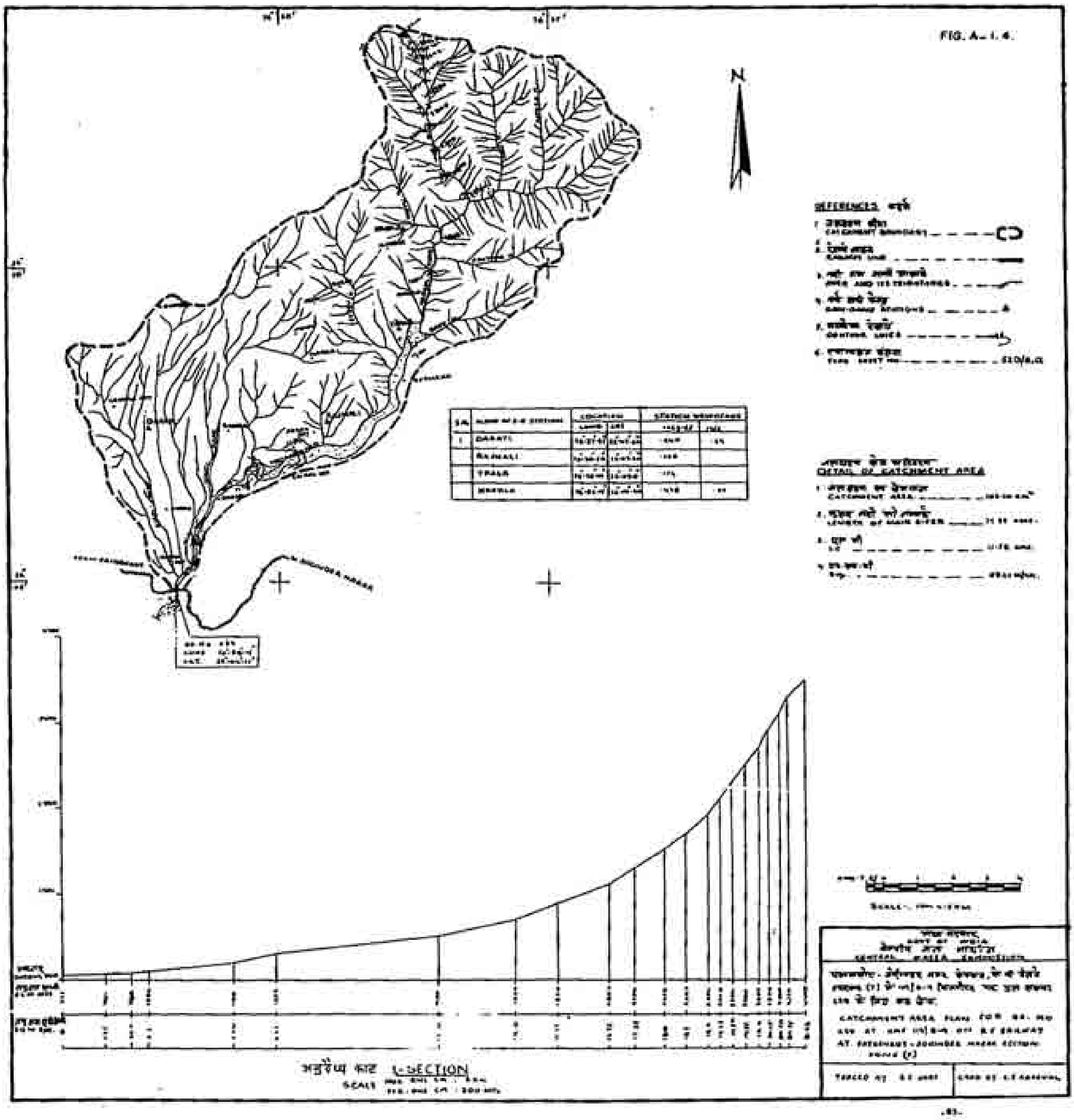


FIG. A-I.4.
N
REFERENCES
DETAIL OF CATCHMENT AREA
L-SECTION

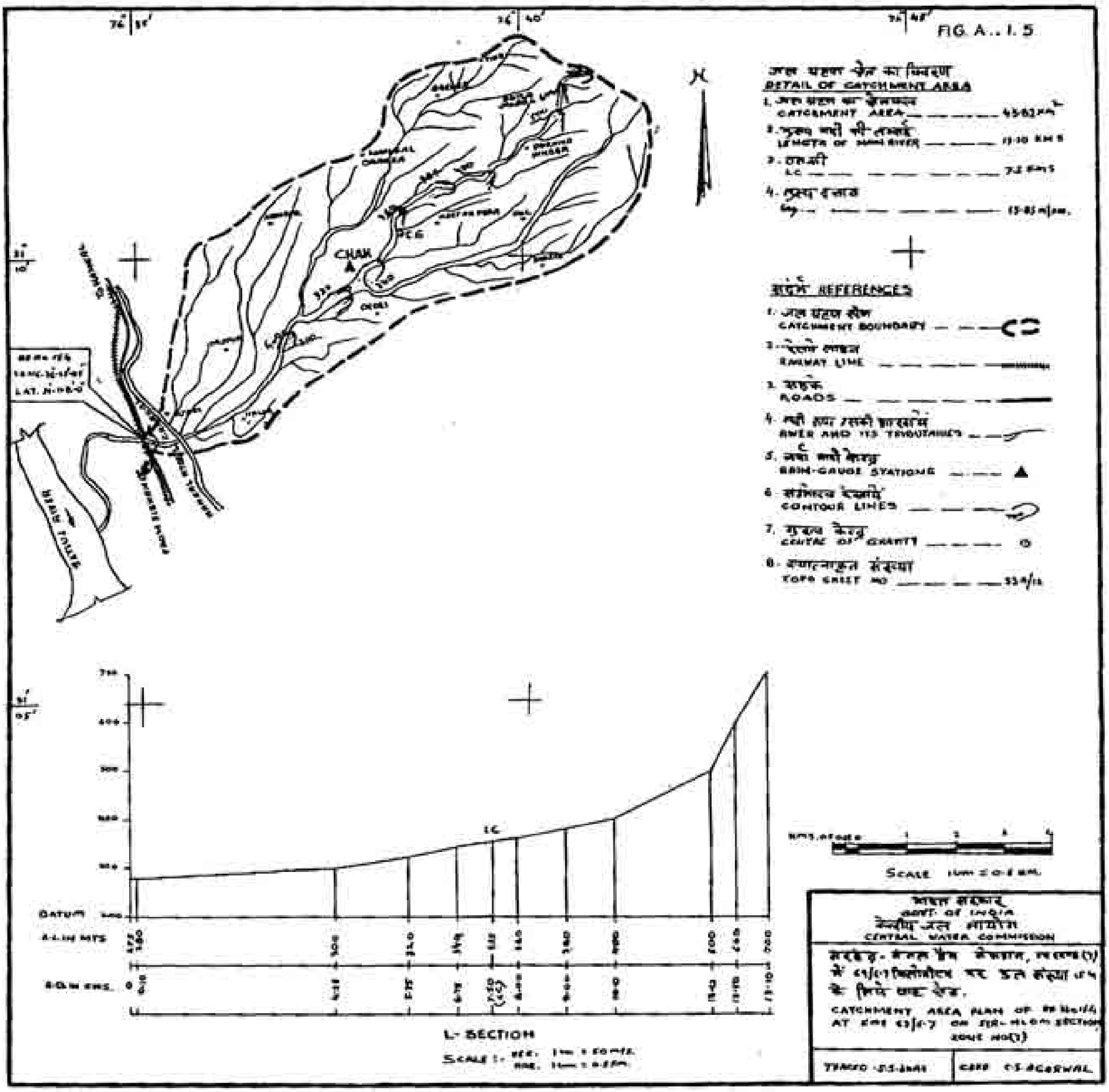
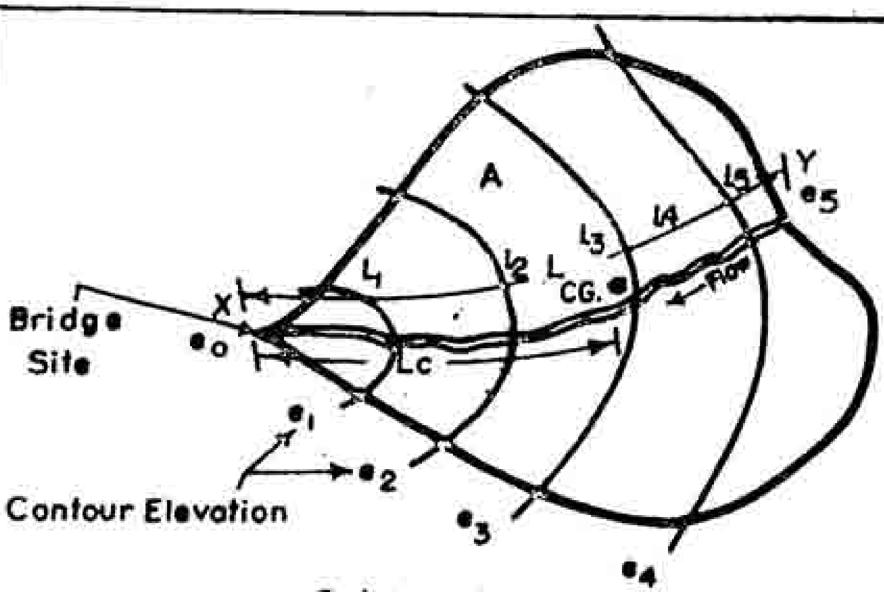
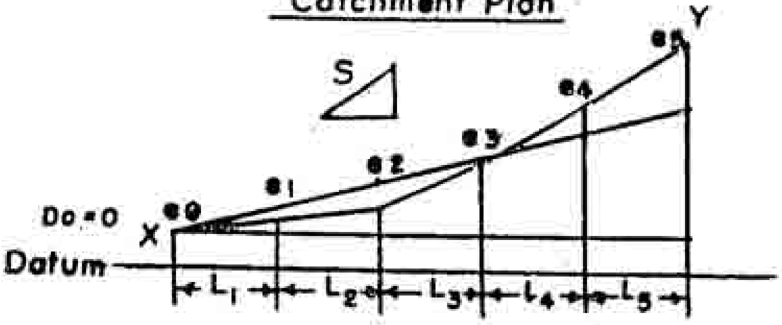


FIG. A.. I. 5
DETAIL OF CATCHMENT AREA
CATCHMENT AREA
LENGTH OF MAIN RIVER
LC
REFERENCES
CATCHMENT BOUNDARY
RAILWAY LINE
ROADS
RIVER AND ITS TRIBUTARIES
RAIN-GAUGE STATIONS
CONTOUR LINES
CENTRE OF GRAVITY
TOPO SHEET NO
CHAK
DATUM
L-SECTION
SCALE
GOVT. OF INDIA
CENTRAL WATER COMMISSION
CATCHMENT AREA PLAN

FIG.-1.



Catchment Plan



L - Section

S = Statistical stream slope (m/km.)

L = Length of longest stream course (km.)

Lc = Length of longest stream course from a point opposite the centre of gravity of the catchment to the Bridge site (km.)

A = Catchment Area (km.^{2})

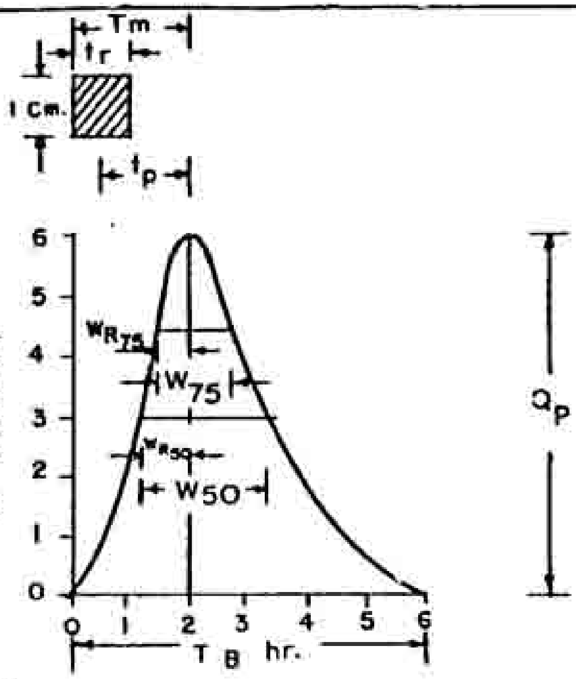
$$S = \left\{ \frac{L}{\frac{L_1}{\sqrt{S_1}} + \frac{L_2}{\sqrt{S_2}} + \cdots} \right\}^2$$

Where –

L_1, L_2 . . . Segment Lengths (km.)

S_1, S_2 . . . Segment Slopes (mt./km.)

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (REGIONAL STUDIES) DTE.	
PHYSIOGRAPHIC PARAMETERS	
DRAWN – L. P. NAUTIYAL	CHECKED – VINOD KAUL



U.G = Unit Graph

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

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

Q_P = Peak Discharge of Unit Hydrograph (Cumecs.)

t_p = Time from the Centre of Effective Rainfall duration to the U.G Peak (hr.)

W_{50} = Width of the U.G measured at the 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.)

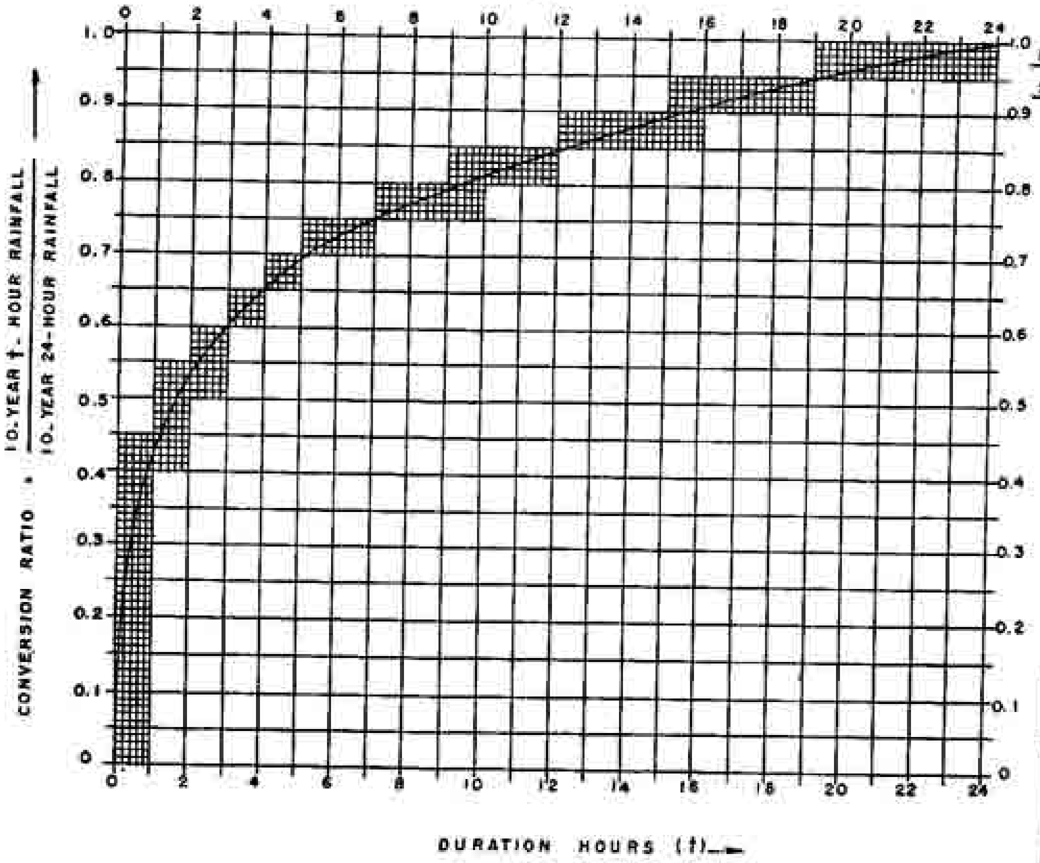
T_B = Base width of Unit Hydrograph (hr.)

A = Catchment Area (Sq.km.)

q_p = Q_P / A = Cumec per sq.km.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (R.S.) DIRECTORATE	
UNIT GRAPH PARAMETERS	
DRAWN BY– NAUTIYAL	CHECKED BY– A.K. GHOSH

FIG. - 3.



RATIOS FOR 24-HOUR POINT RAINFALL TO SHORT DURATION RAINFALL.

DURATION (HOURS)	RATIOS
1	0.425
2	0.550
3	0.600
4	0.650
5	0.695
6	0.725
7	0.750
8	0.770
9	0.790
10	0.810
11	0.830
12	0.845
13	0.860
14	0.880
15	0.895
16	0.910
17	0.920
18	0.935
19	0.950
20	0.960
21	0.970
22	0.980
23	0.990
24	1.000

CURVE SUPPLIED BY IMD.

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

WESTERN HIMALAYAS

ZONE — 7

DURATION VS. CONVERSION RATIO

DRAWN – S. N. MALHOTRA | CHECKED – K. K. AICH.

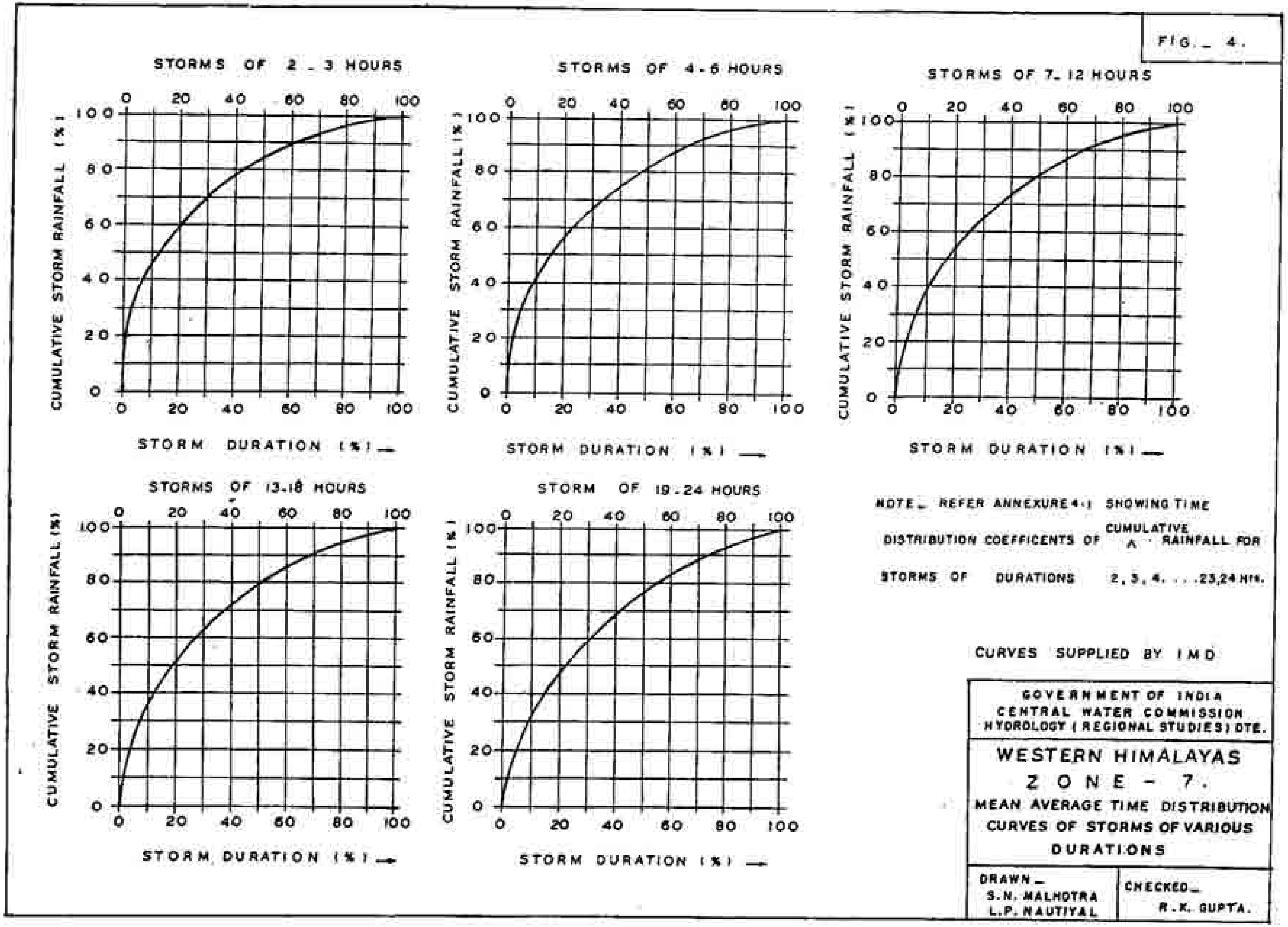
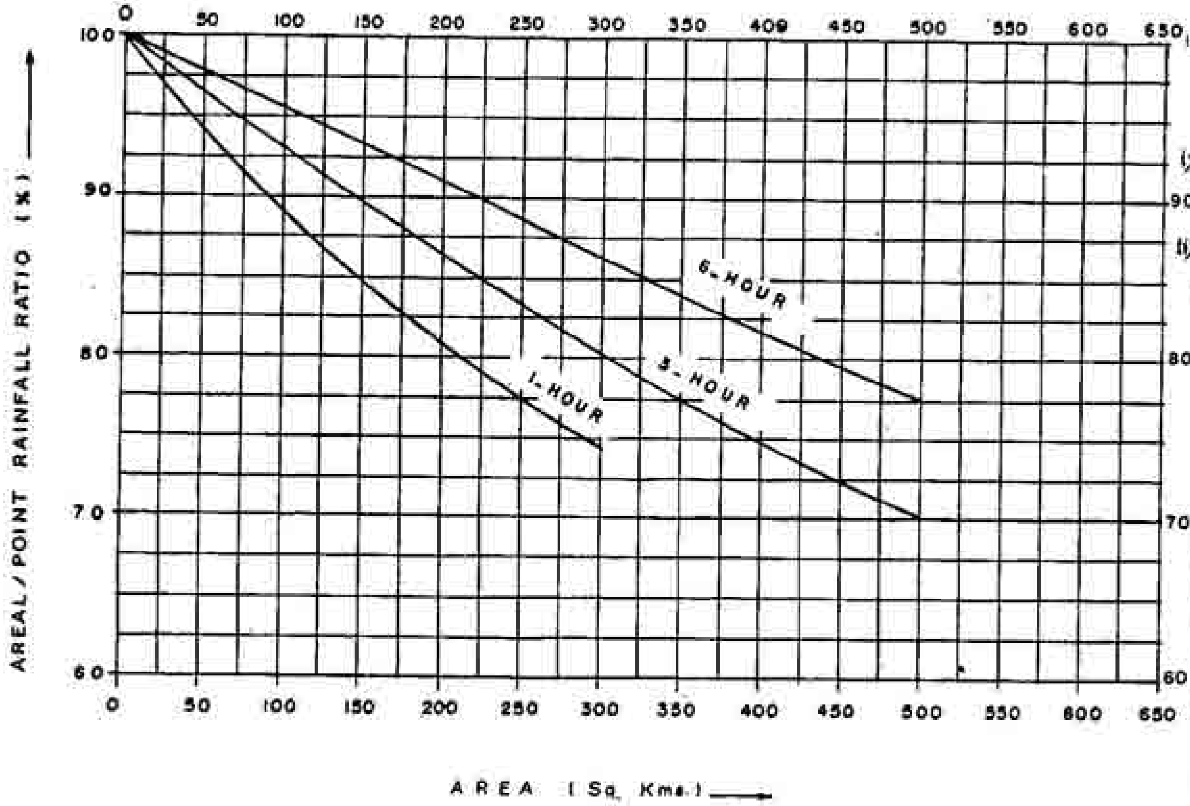


FIG. _ 4.
STORMS OF 2 _ 3 HOURS
STORMS OF 4 - 6 HOURS
STORMS OF 7 _ 12 HOURS
STORMS OF 13-18 HOURS
STORM OF 19 - 24 HOURS
CUMULATIVE STORM RAINFALL (%)
STORM DURATION (%) →
0 20 40 60 80 100
NOTE _ REFER ANNEXURE 4.1 SHOWING TIME DISTRIBUTION COEFFICENTS OF CUMULATIVE RAINFALL FOR STORMS OF DURATIONS 2, 3, 4, . . . 23, 24 Hrs.
CURVES SUPPLIED BY I M D
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.
WESTERN HIMALAYAS
Z O N E - 7.
MEAN AVERAGE TIME DISTRIBUTION CURVES OF STORMS OF VARIOUS DURATIONS
DRAWN _ S. N. MALHOTRA L. P. NAUTIYAL
CHECKED _ R. K. GUPTA.

FIG._ 5 (a)



NOTE_

i) REFER ANNEXURE _4.2 FOR AREAL TO POINT RAINFALL RATIOS FOR DURATION FROM 1_24 Hrs.

ii) REFER FIG_5(b) FOR AREAL TO POINT RAINFALL RATIOS FOR DURATION 12_HOURS AND 24-HOURS.

CURVE SUPPLIED BY IMD.

GOVERNMENT OF INDIA
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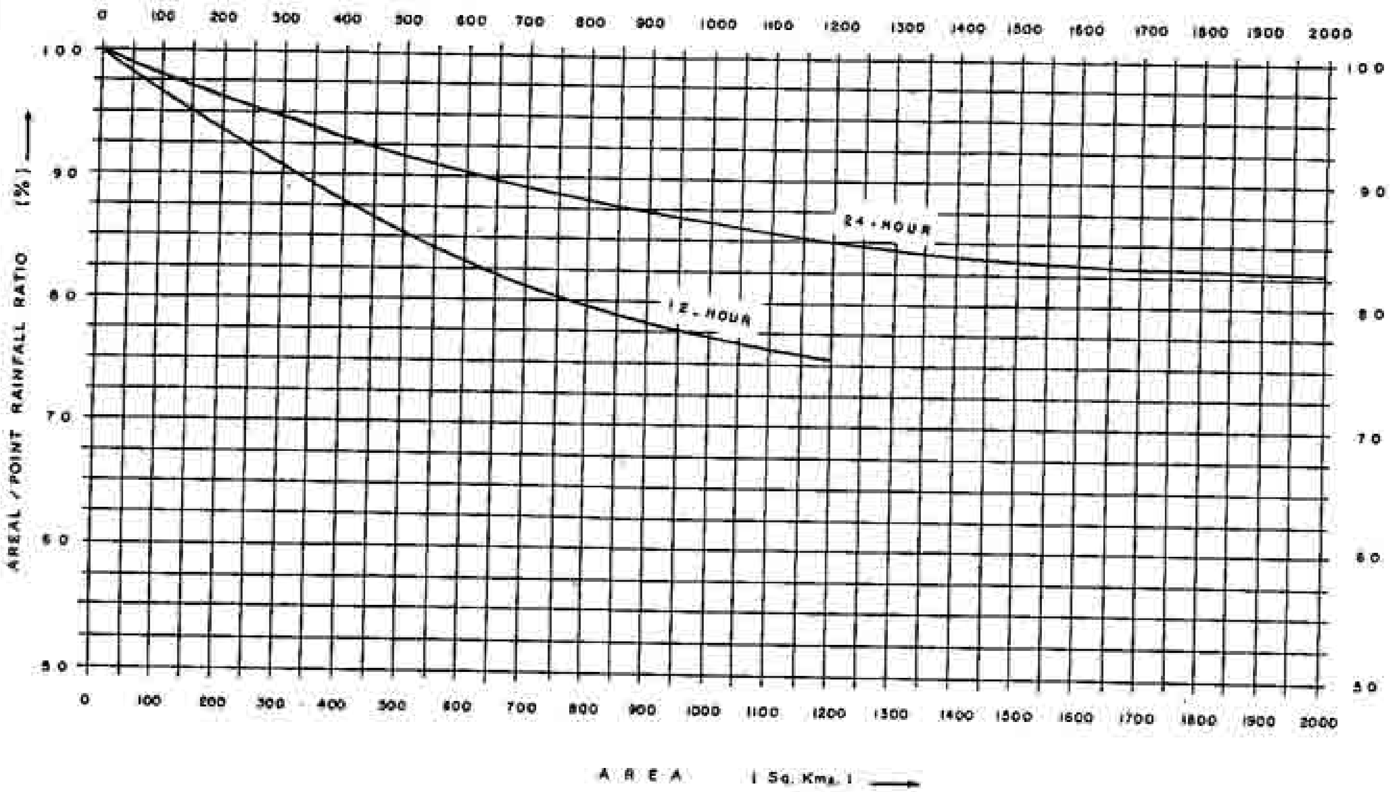
HYDROLOGY (REGIONAL STUDIES) DTE.

WESTERN HIMALAYAS
ZONE - 7.
AREAL TO POINT RAINFALL RATIO(%)
FOR 1.Hrs, 3.Hrs. & 6_Hrs.

DRAWN_	CHECKD_
S.N. MALHOTRA L.P. NAUTIYAL	R. K. GUPTA

FIG. 5(b)



NOTE –

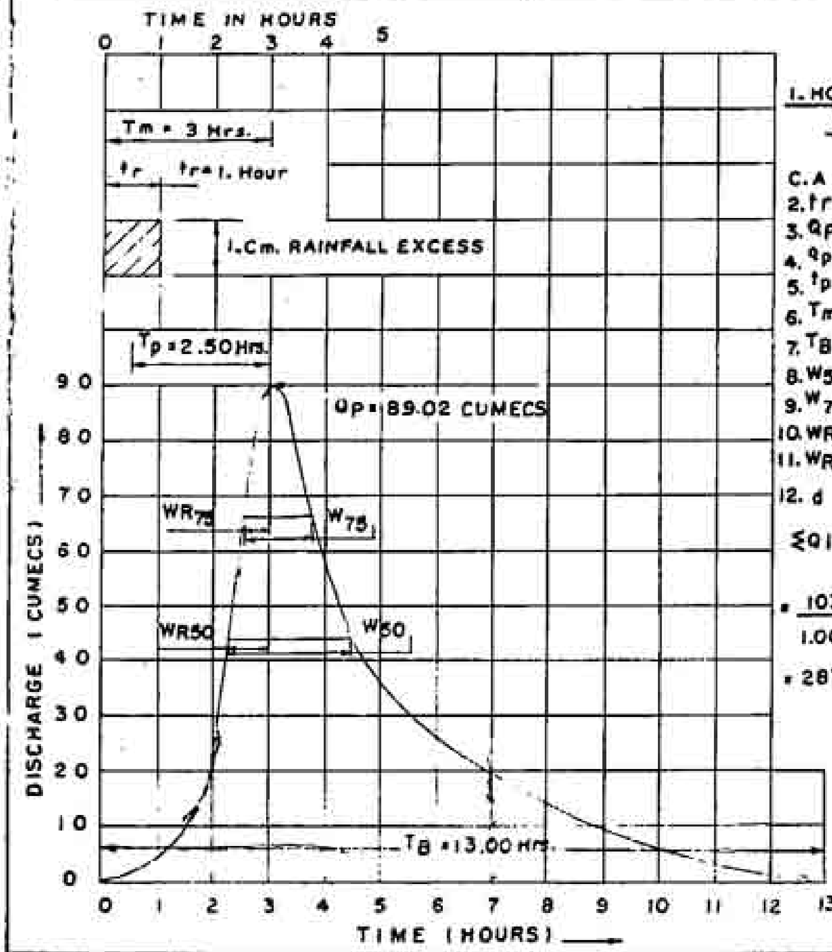
i) REFER ANNEXURE – 4-2 FOR AREAL TO POINT RAINFALL RATIOS FOR DURATION FROM 1 TO 24 HOURS AND FOR CATCHMENT AREAS UP TO 2000 KM².

ii) REFER FIG. – 5(a) FOR AREAL TO POINT RAINFALL RATIOS FOR DURATION 1-HOUR, 3-HOURS AND 6-HOURS.

CURVES SUPPLIED BY I M D.

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGICAL (REGIONAL STUDIES) DTE.	
WESTERN HIMALAYAS ZONE – 7. AREAL TO POINT RAINFALL RATIO(%) FOR 12-HOURS AND 24-HOURS.	
DRAWN – S. N. MALHOTRA L. P. NAUTIYAL	CHECKED – R. K. GUPTA

FIG. A - 2.



1. HOUR SYNTHETIC U.G ORDINATES

C.A AREA 103.60 Km^2
2. t_r = 1.00 Hrs.
3. Q_p = 89.02 Cum.
4. q_p = 0.86 Cum/Km^2
5. t_p = 2.50 Hrs.
6. T_m = 3.00 Hrs.
7. T_B = 13.00 Hrs.
8. W_{50} = 2.26 Hrs.
9. W_{75} = 1.14 Hrs.
10. WR_{50} = 0.77 Hrs.
11. WR_{75} = 0.47 Hrs.
12. d = 1.00 Cm.

$$\Sigma Q_1 = \frac{A \times d}{t_r \times 0.36} = \frac{103.60 \times 1.00}{1.00 \times 0.36} = 287.78 \text{ CUMECS}$$

1. HOUR SYNTHETIC U.G PARAMETERS

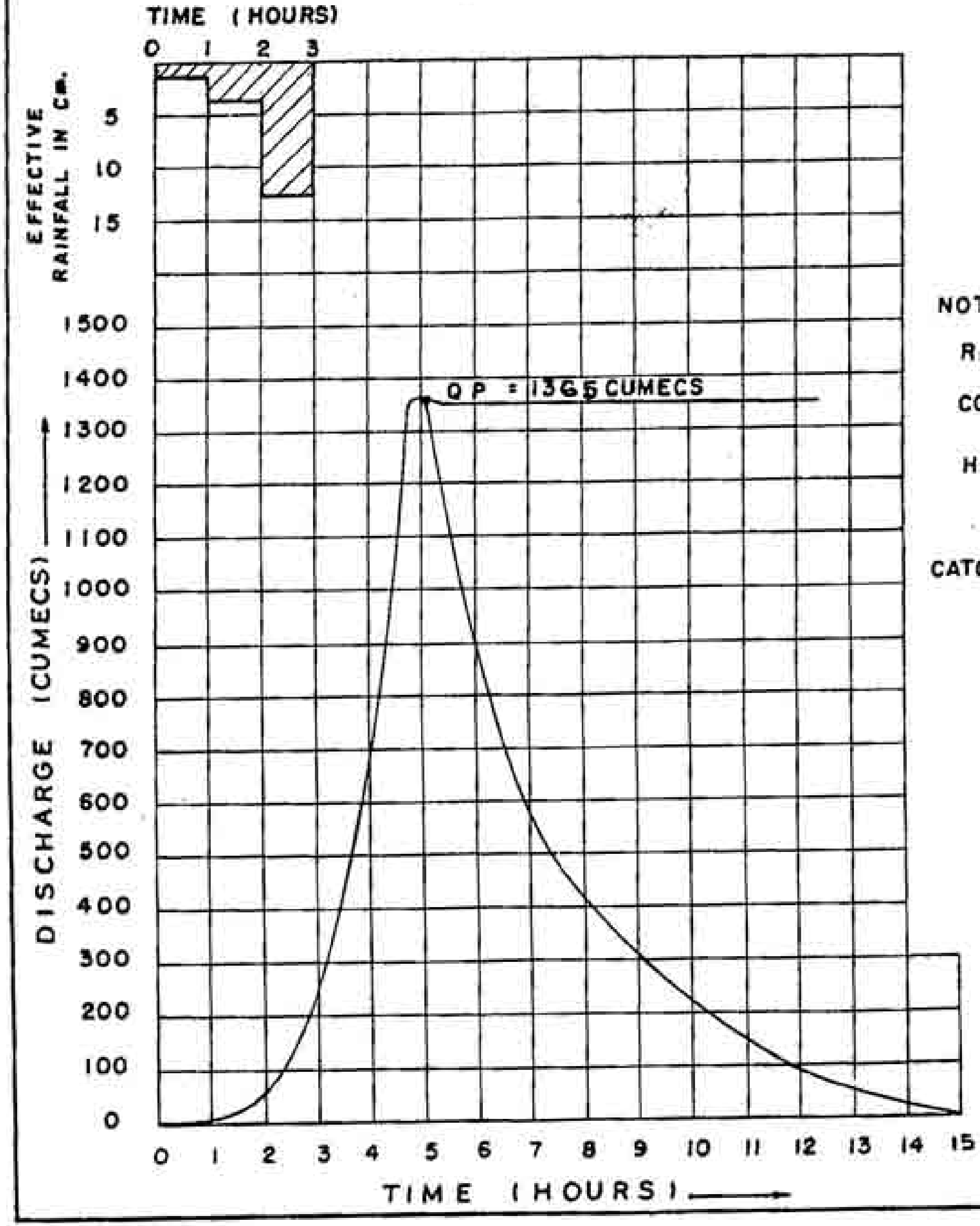
0	0.00
1	4.00
2	23.26
3	89.02
4	56.50
5	35.00
6	26.00
7	19.00
8	14.00
9	10.00
10	6.00
11	3.50
12	1.50
13	0.00
TOTAL	287.78 CUMECS.

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

WESTERN HIMALAYAS
ZONE - 7.
SYNTHETIC UNIT HYDROGRAPH
OF BRIDGE NO.. 629.

DRAWN -	CHECKED -
L. K. PANT	K. K. AICH.

FIG. - A.3.



NOTE –

REFER ANNEXURE - 5.3 FOR COMPUTATION OF DESIGN FLOOD HYDROGRAPH.

CATCHMENT AREA = 103.60 Km²

GOVERNMENT OF INDIA CENTRAL WATER COMMISSION HYDROLOGY (R.S) DIRECT.	
WESTERN HIMALAYAS ZONE – 7. DESIGN FLOOD HYDROGRAPH OF BRIDGE NO. – 629.	
DRAWN – L.P. NAUTIYAL	CHECKED – VINOD KAUL.

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4.	Shri A.K.D.Chowdhary	C.D.A.(B&F)
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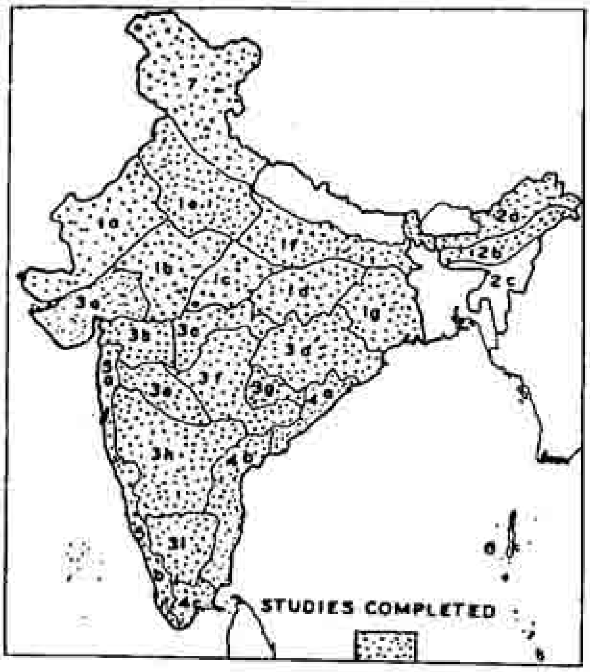

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