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REGIONAL FLOOD FREQUENCY APPROACH ESTIMATION OF FLOOD PEAKS FOR MAHI AND SABARMATI BASIN(SUB ZONE 3a)

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ABSTRACT

Knowledge of magnitude of flood related to its problem frequency of recurrence is necessary for rational and economical design of water-way and foundations of bridges and appurtenances. In this paper hydrometeorologically homogenous Mahi and Sabarmati Basin, Sub-zone 3(a) with semi-arid climate has been selected for study. Twelve bridge sites with catchment areas varying from 19 km^2 to 1094 km^2 with availability of annual flood peaks for the period from 1961 to 1985, have been considered for probability studies. Making use of this data and utilizing the regional frequency approach, a dimensionless curve giving the ratios of return period flood peaks to mean annual flood peak ($Q_{2.33}$) and a correlation between mean annual flood peak and relevant catchment characteristics have been developed using linear regression technique.

1.0 INTRODUCTION

The prime requirement while designing the water-way depth of foundations and training and protection works of bridges, is the magnitude of design discharge. With the increasing need of having flood peaks in relation to chosen frequency, the U.H. and flood frequency approaches are becoming relevant. Bridges and Floods Wing of RDSO has been constantly engaged in developing rational approaches to fulfil this need. Initially a set of charts and graphs were prepared correlation 50-year 1 hr. rainfall, slope and catchment area, introducing frequency concept. With the availability of more data for limited number of sites (i.e) 60 for the whole country using unit hydrograph technique, a report was brought out by CWC. This report furnishes a set of equations and Isopluvial values for estimating flood peaks of 50 year recurrence interval. Later, based on collection of hydrometeorological data, comprising run-off and rainfall for 5-6 years, by Indian Railways at selected representative sites in 26 homogenous sub-zones, into which the country was divided, flood estimation reports were brought out in collaboration with CWC and IMD. So far 16 put of 26 sub-zones have been covered. Such reports are based on synthetic unit hydrograph approach and are applicable for catchment areas lying between 25 - 5000 km^2. One of the sub-zones for which flood estimation report has been finalised is sub zone 3(a).

The present paper is an attempt to provide an alternative approach for the same sub-zone to estimate design discharge for any ungauged catchment lying within the sub-zones. This approach is based on availability of more stream flow data (25 years) in small and medium catchments and applying regional flood frequency technique as described by Dalrymple(2)

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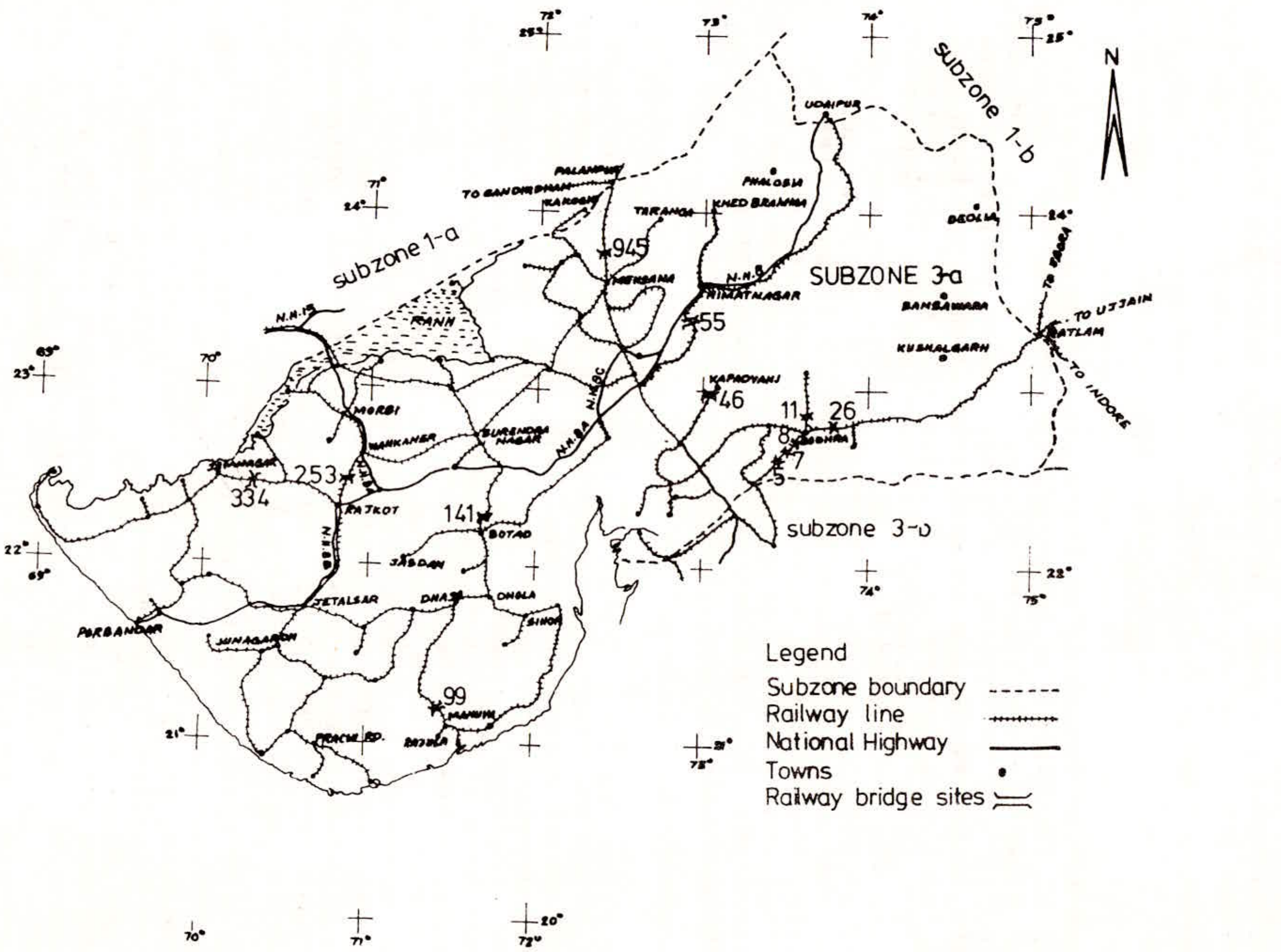
FIGURE-1



MAP SHOWING THE EXTENT OF SUBZONE 3(a), RAILWAY LINES AND NATIONAL HIGHWAY.

1.1 The sub-zone 3(a) covers an area of about 1,40,000 sq.km. and roughly lies between 69°to 75° east longitudes and 21° to 25° north latitudes. It covers parts of Southern Rajasthan, western Madhya Pradesh and Gujarat and comprises mostly of semi-arid zone. Fig. 1 shows the extent of the sub_zone, railway lines and location of representative bridge sites which have been included in the present study.

2. REGIONAL FREQUENCY APPROACH

2.1 This approach consists of two major components (a) development of basic dimensionless frequency curve representing the ratio of the flood of any return period to an index flood which is taken as mean annual flood ($Q2.33$) and (b) development of a curve by regression between mean annual floods ($Q2.33$) and relevant catchment characteristics to enable the mean annual flood to be predicted at any point of interest within the region (sub-zone 3a).

The flood peak of any desired return period of any catchment lying in the sub-zone can be conveniently estimated from these two components.

This approach is being successfully adopted in some of the advanced countries and general experience shows that this procedure leads to results with acceptable accuracy. This method, being based on actual stream flow data, is considered superior to rainfall based techniques.

3. DATA AVAILABILITY AND DATA GENERATED

3.1 Pursuant to Khosla Committee recommendations run-off and rainfall data was collected by Zonal railways under guidance of RDSO at a number of representative sites for derivation of Synthetic Unit hydrograph relations/rating curves and a flood estimation report was brought about.

After that the representative sites were converted into crest gauge and annual peak stage values were compiled, and based on available rating curves, annual flood peak values were computed for each bridge.

3.2 Data in respect of year, for which observed peak stage could not be observed due to some unavoidable reason was generated by simple interpolation from the nearest suitable bridge site for which annual peak records for long period were available in order to form a continuous series with a common base period.

3.3 Bridge numbers along with year-wise flood peaks both observed and generated, are shown in Table-1.

4.0 PROCEDURE ADOPTED FOR ANALYSIS

4.1 The available annual flood peak values (Q) were tabulated in descending order, assigning their merit order. T-values (Return Period) were computed for each Q-value by using Gringorten's formula, TABLE - 1

(Sub-Zone-3a)

ANNUAL FLOOD PEAKS .

S. No.	Br.No.	Section	C.A. (Km²)	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
1.	5	Vadodara-Godhra	230	500	700	197	88	302	37	185	52	224	31	84	83	310	440	64	600	380	1000	31	275	25	56	150	110	52
2.	7	-do-	19	116	170	17	3	22	61	115	30	32	18	6	2	84	225	86	136	103	28	72	59	16	1	59	12	16
3.	8	-do-	30	68	168	37	26	64	60	105	63	32	30	28	27	27	37	240	64	260	58	3	72	50	5	58	28	2
4.	11	Godhra-Lunavada	98	386	648	88	39	135	122	247	70	92	88	35	3	236	5	148	250	128	180	34	75	300	2	66	500	40
5.	26	Godhra-Ratlam	1094	4115	6923	942	420	1447	68	770	385	700	620	160	380	950	440	160	146	700	1100	195	260	280	180	320	900	175
6.	46	Nadiad-Kapadvauj	580	1400	213	581	814	1128	570	420	75	195	245	82	67	720	100	390	718	900	280	132	53	220	44	300	640	38
7.	55	Ahmedabad-Khed Brahma	253	520	740	259	364	29	406	26	120	304	18	187	340	175	5	210	195	62	130	100	36	130	130	24	170	4
8.	99	Dhasa-Mahuwa	145	536	818	148	207	287	60	53	240	150	400	170	135	350	440	335	600	570	130	400	595	70	390	490	260	19
9.	141	Surendranagar-Botad.	73	272	415	75	105	146	118	106	97	88	280	170	98	146	39	98	33	135	175	175	48	88	4	198	220	12
10.	253 (Old) 192 (New)	Wankaner-Rajkot	48	160	185	93	148	275	225	3	268	58	380	2	285	165	77	270	175	152	44	435	120	330	2	140	1	1
11.	334 (Old) 28 (New)	Jamnagar-Rajkot	18	190	2	48	35	26	54	2	29	22	32	14	3	56	3	150	103	87	43	375	78	36	12	43	24	4
12.	945	Palanpur-Sabarmati	253	765	924	237	332	461	115	16	180	68	330	125	311	275	3	600	220	140	540	1	72	95	52	15	140	2

Note: Underlined data indicates generated data.

$$T = \frac{N + 0.12}{M - 0.44}$$

where N is the number of years for which the data is used and M is the merit order of Q.

4.2 Q-values were plotted against their corresponding T on Gumbels probability paper by eye judgement to fit the plotted points ignoring the effect of Outliers for each station. Such plotted values along with best-fit line drawn in respect of one bridge is shown in Fig. 2 and Table II.

4.3 Homogeneity of the region from where this data was collected, has already been established by the members of Planning and Co-ordination Committee considering their flood producing characteristics, while dividing the country into 26 hydrometeo-logically homogenous sub-zones.

4.3.1 However statistical homogeneity of the available data has also been tested based on the method developed by Langbein and practised by U.S. Geological Survey. The main steps are described below:

(a) The ratio of 10 year flood to mean annual flood ($Q_{2.33}$) is determined from the frequency curve at each station. These ratios for all the sites are averaged to obtain the mean 10 year ratio for the subzone as a whole.

(b) The return period corresponding to the product of mean annual flood and average ratio is determined from the frequency curve of each station (Table III) and plotted against the period of record on standard test graph (Fig.3). As all the points for all the stations be within the test curve shown on graph, the data is considered homogeneous.

4.4 The ratio's of floods of 50, 20, 10 and 5 year recurrence interval to mean annual flood ($Q_{2.33}$) are shown in table IV along with their median values. A regional dimensionless freq-uency curve is drawn taking these median values of the ratios against the return period (Fig.4).

4.5 The mean annual flood peak values computed for each site are correlated with their corresponding catchment areas and 50 year 24 hr. rainfall values and also with catchment areas alone by regression analysis. The later one was found suitable and is given by the regression equation:

$Q_{2.33} = 8.02\,(A)^{0.63}$ where

$Q_{2.33}$ = mean annual flood peak in m^3/sec.

A = Catchment area in km^2

The coefficient of correlation (γ) was found to be 0.934 which is quite significant. Data used for such correlation is given in table V.

5.0 APPLICATION OF THE METHOD

5.1 For estimation of design discharge in respect of any bridge

TABLE II

PROFORMA FOR FLOOD FREQUENCY STUDIES

Section: Nadiad-Kapodvanj

Subzone 3(a) Rly W/57 Br.No. 46 CA 500 Km^2

S.No.	Year	Stage	Observed peak flood in cumecs.	Peak flood rearranged in descending order	Merit order M	Recurrence interval T in year $T = \frac{N+0.12}{M-0.44}$
1	1961		1400	1400	1	44.85
2	1962		213	1128	2	16.10
3	1963		581	900	3	9.81
4	1964		814	814	4	7.06
5	1965		1128	720	5	5.51
6	1966		570	718	6	4.52
7	1967		420	640	7	3.83
8	1968		75	581	8	3.32
9	1969		195	570	9	2.93
10	1970		245	420	10	2.62
11	1971		82	390	11	2.38
12	1972		67	300	12	2.17
13	1973		720	280	13	2.00
14	1974		100	245	14	1.85
15	1975		390	220	15	1.72
16	1976		718	213	16	1.61
17	1977		900	195	17	1.52
18	1978		280	132	18	1.43
19	1979		132	100	19	1.35
20	1980		53	82	20	1.28
21	1981		220	75	21	1.22
22	1982		44	67	22	1.16
23	1983		300	53	23	1.11
24	1984		640	44	24	1.06
25	1985		38	38	25	1.02

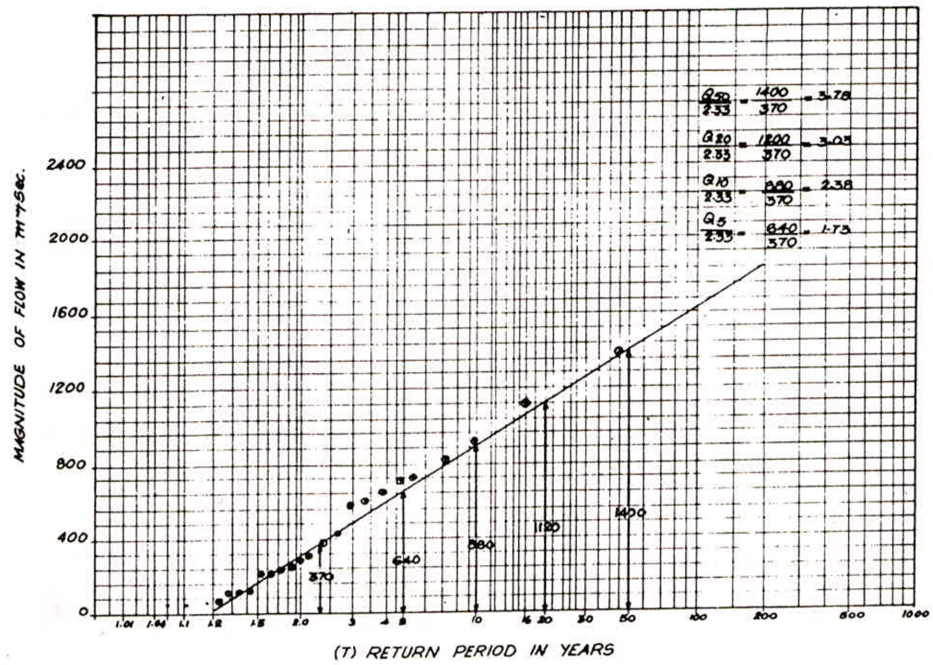
lying in sub-zone 3(a), the method based on above approach can be adopted as indicated below:

i) Find out catchment area either from actual survey or topo sheets.

ii) Compute the value of mean annual flood peak (Q 2.33) by using the regression equation given in para 4.5.

iii) Multiply this value of mean annual flood peak (Q2.33) as obtained in step (ii) above by the regional frequency ratio for the desired return period by referring to Fig. 4.

FIGURE-2 BRIDGE NO. 46. (NADIAD-KAPADVANJ). WESTERN RAILWAY



SUB-ZONE 3 (a)

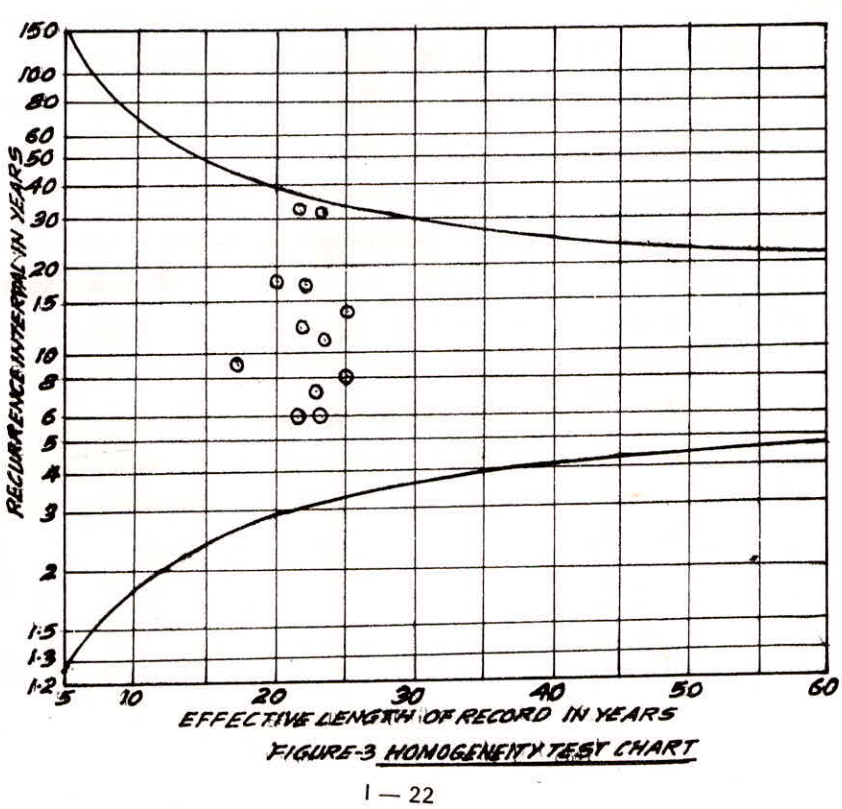


FIGURE-3 HOMOGENEITY TEST CHART

Table III

Data for homogeneity test, base period 1961-1985

s.no.	Br.no.	CA km^2	Mean annual flood ($Q_{2.33}$) m^3/sec.	10 year flood (Q_{10}) m^3/sec.	Ratio of Q_{10} and $Q_{2.33}$ = r	Product of r x $Q_{2.33}$ = Q	T for Q of col. 7	Period of record adjusted (years)	Remarks
1	2	3	4	5	6	7	8	9	10
1	26	1094	950	3150	3.32	2504	7	23	
2	46	580	570	880	2.38	976	12	23	
3	55	253	185	410	2.22	488	18	22	
4	945	253	250	630	2.52	659	13	22	
5	5	230	180	550	3.06	475	9	17	
6	99	145	320	600	1.87	844	35	22	
7	11	98	110	385	3.50	290	6	22	
8	141	73	115	252	2.19	303	18	20	
9	253old (192New)	48	160	305	1.91	422	33	24	
10	8	30	60	137	2.28	158	14	25	
11	7	19	47	145	3.09	124	8	25	
12	234old (28New)	18	50	165	3.30	132	6	23	

Mean r = 2.64

TABLE IV

RATIOS BETWEEN RETURN PERIOD FLOOD PEAKS TO MEAN ANNUAL FLOOD PEAKS

S.No.	Br.No.	CA Km^2	Mean annual flood 2.33 yrs.	RATIO OF ANNUAL LOAD OVER MEAN ANNUAL FLOOD			
				5/2.33	10/2.33	20/2.33	50/2.33
1.	26	1094	950	2.0	3.32	4.58	6.16
2.	46	580	370	1.73	2.38	3.03	3.78
3.	55	253	185	1.68	2.22	2.76	3.41
4.	945	253	250	1.80	2.52	3.24	4.08
5.	5	230	180	2.17	3.06	4.11	5.22
6.	99	145	320	1.47	1.88	2.28	2.75
7.	11	98	110	2.36	3.50	4.64	6.00
8.	141	73	115	1.65	2.19	2.71	3.39
9.	253 Old (192 New)	48	160	1.50	1.91	2.31	2.81
10.	8	30	60	1.67	2.28	2.87	3.58
11.	7	19	47	2.13	3.09	3.94	5.0
12.	(234 Old (28 New)	18	50	2.2	3.3	4.4	5.8
Median values				1.90	2.45	3.14	3.93

TABLE V

DATA USED FOR CORRELATION BETWEEN Q2.33 AND CATCHMENT CHARACTERISTICS

Sr.No.	Br.No.	CA(Km^2)	50 years 24 hr. point rainfall value (C_m)	Q2.33 (m^3/sec.)
1	26	1094	35.0	950
2	46	580	34.0	370
3	55	253	32.0	185
4	945	253	27.0	250
5	5	230	39.0	180
6	99	144	32.0	320
7	11	98	33.0	110
8	141	73	23.0	115
9	253 Old (192 New)	48	32.0	160
10	8	30	36.0	60
11	7	19	38.0	47
12	334 (New 28)	18	32.0	50

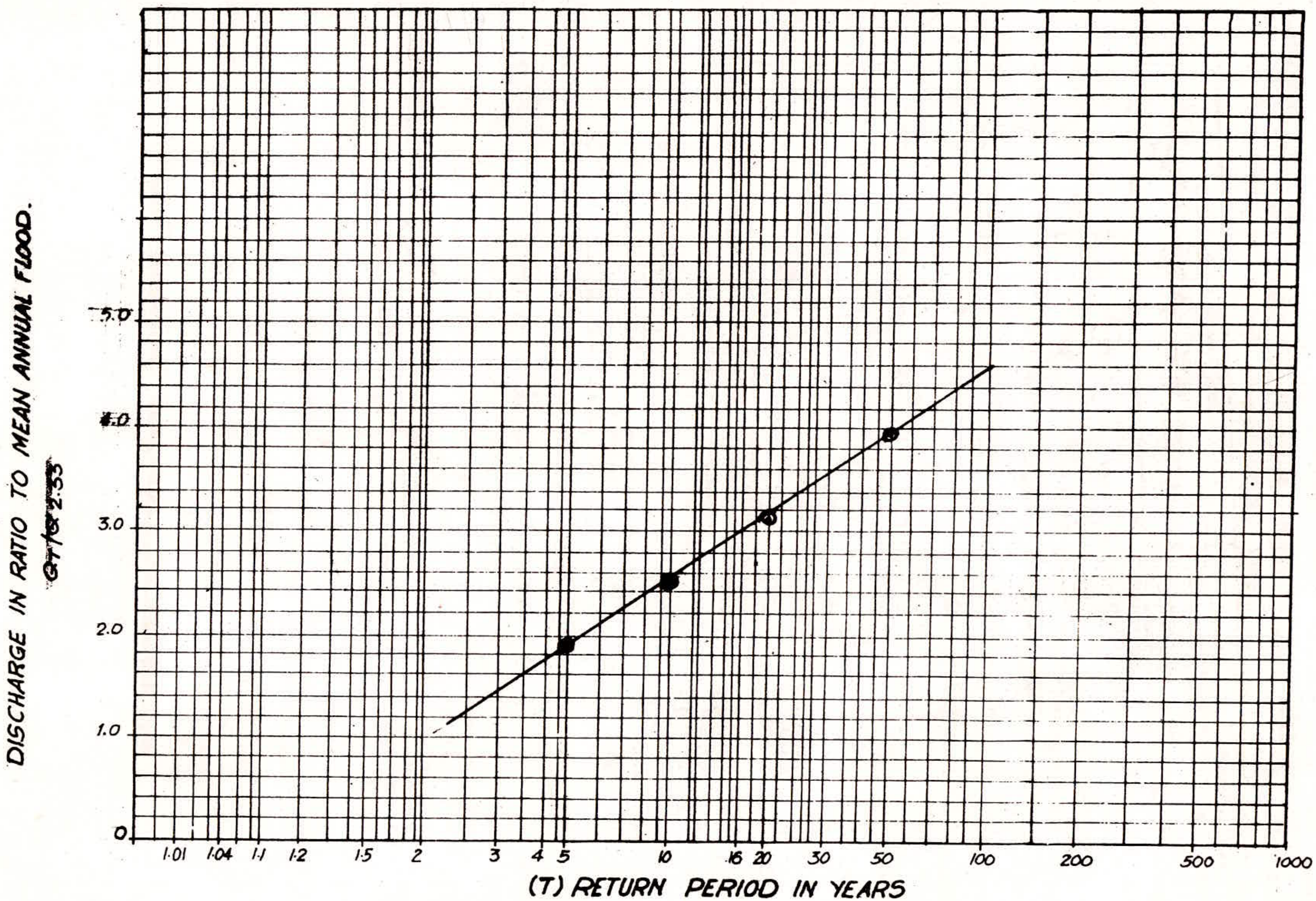


FIG. 4. RELATION BETWEEN RECURRENCE INTERVAL IN YEARS AND DISCHARGE IN RATIO TO MEAN ANNUAL PEAK FLOW ($Q_{2.33}$)

6.0 ADVANTAGES AND LIMITATIONS OF THE METHOD:

6.1 Advantages

i) The empirical formula in vogue e.g. Dicken's, Ryves and Inglis do not incorporate the concept of return period and risk factor. Choosing the value of coefficient 'C' depends mainly on subjective judgement of the individual.

ii) This method indicated in this paper is based on statistical approach utilizing observed stream-flow data and thus is a sound alternative for estimating magnitude of design discharge for a bridge in an ungauged catchment lying in sub zone 3(a).

iii) Computation load involved in the present method is considerably less compared to the regional synthetic U.H. approach. Individual judgement will not vitiate the results. The degree of reproducibility is very high.

6.2 Limitations

i) Results obtained by application of this method,however, have some drawbacks due to inadequate number of samples and length of data, generation of missing data, extension and extrapolation of stage-discharge curves and approximation due to regionalisation.

However, these results can be improved when size of samples became more.

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