GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

Flood Plan Coordination Organisation

FAP-25

FLOOD MODELLING AND MANAGEMENT

Flood Hydrology Study

Annex 1

June, 1992

Krüger Consult
in association with
BCEOM

Governments of
Denmark, France,
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FLOOD HYDROLOGY STUDY

MAIN REPORT

Volume 1	**Main Report**	
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LIST OF ABBREVIATIONS

BWDB	Bangladesh Water Development Board
CAT	Coordination Advisory Team.
DANIDA	Danish International Development Assistance
EPWAPDA	East Pakistan Water Development and Power Authority
FAP	Flood Action Plan
FAPMCC	FAP Modelling Coordination Committee
FEC	French Engineering Consortium
FHS	Flood Hydrology Study
FPCO	Flood Plan Coordination Organisation (under MIWD&FC)
FMM	Flood Management Model
GEV	General Extreme Value
GM	General Model
GOB	Government of Bangladesh
GPS	Global Positioning System
HYMOS	Software Package for Hydrometeorological Data Base Management and Processing System
IECO	International Engineering Company, Inc.
MIWD&FC	Ministry of Irrigation Water Development & Flood Control.
MIKE 11	Software Package for One Dimensional River Modelling
MPO	Master Plan Organisation (under MIWD&FC), now WARPO
NAM	Rainfall Runoff Model (Danish Abbreviation)
NCRM	North Central Regional Model
NWP	National Water Plan (under MPO)
RMC	Resident Model Coordinator
SWH	Surface Water Hydrology Directorate (under BWDB)
SWMC	Surface Water Modelling Centre (under MPO)
UK	United Kingdom
UNDP	United Nations Development Programme
WARPO	Water Resources Planning Organisation

APPENDIX 1

Methodology of the Flood Hydrology Study

1. INTRODUCTION

The present appendix contains the detailed methodology described in the report of the second CAT mission and adopted in the Flood Hydrology Study. Some revisions have taken place during subsequent CAT missions. A summary of this appendix can be found in Chapter 2 of the Main Report.

2. COLLECTION, VALIDATION AND COMPLETION

Major FAP projects will be designed and implemented in Bangladesh on the basis of statistics of the Brahmaputra and the Ganges river flows. Improving these statistics and consequently retrieving these data to do so, as far back into the past as possible, should therefore be pursued to the maximum.

One would expect a lot more information to be available on Brahmaputra and Ganges flows, possibly going back as far as the early part of this century, but this may only concern stations located in India. It is known that old records exist for the following stations in India:

- Farakka on the Ganges River, about 20 km upstream of the border between India and Bangladesh;
- Pandu on the Brahmaputra River, about 250 km upstream of the border.

Some of these data are available in Dhaka within the Indo-Bangladesh Joint Rivers Commission. It is said that data have been exchanged for the near-border stations, for periods for which both India and Bangladesh possess data. This may imply that data on Brahmaputra flows before the sixties are not available within the Joint Rivers Commission in Bangladesh. It is imperative that the FHS make all possible efforts to obtain these earlier flow data on river flows.

A serious attempt should be made to bring to the surface the results of earlier work on river flows in the Ganges and Brahmaputra.One would expect old reports, dating back to the time before 1947, to be somewhere available, either in Bangladesh or in the UK. in London, reports and other documents concerning surveys in all parts of the former British Empire are kept at the Oriental and Indian Office of the British Library.

Correlation of the data from India with those recorded in Bangladesh will be of great help to check the quality of the data recorded at Hardinge Bridge on the Ganges and at Bahadurabad on the Brahmaputra, to correct these data as far
considered appropriate and to extend the series for the two stations in Bangladesh back into history. These updated series will then provide a sound basis for any statistical analysis or simulations with the GM, as required.

A full fledged data screening and validation study cannot be part of the FHS, since these are very time consuming efforts and require many field visits to check on measurement procedures, gauge histories, etc. Such work should actually be done by MPO, but can also

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well be part of the FAP 24 project. Hence, the FHS should carry out only data screening for about 15 key-stations used for the validation of the GM, as far as this can be done in office and without too many time consuming field visits.

Obvious errors can easily be removed by plotting observed hydrographs. Efforts should be put in establishing annual relation curves between water levels observed at pairs of gauging stations, as a basis for detecting errors and obtaining an impression on the reliability of observed water levels at various stations.

Much attention should also be devoted to the establishment of reliable annual rating curves for a few key- stations, in particular for the boundary stations of the GM.

2. JOINT PROBABILITIES OF MAIN STREAM FLOWS AND RAINFALL INSIDE BANGLADESH

The question of correlations between main stream flows and rainfall in Bangladesh will often arise. It is, therefore, proposed to search for joint probabilities between rainfall over (part of) Bangladesh and flow in the Ganges river, between rainfall and flow in the Brahmaputra river, and between flows in both the rivers. The question comes down to determine for example the rainfall distribution for various values of the river flow, etc. A first simple approach can be to plot all observed values of both variables against each other, to determine the regression line and related correlation coefficient, and to determine the probability distribution of the residues of the dependant variable for various class intervals of the other variable (a normal distribution to be assumed for a first quick analysis).

It is meaningless to determine such joint probabilities for daily values of flows and rainfall over Bangladesh. Most likely, hardly any correlation will be found. Instead, it is suggested to correlate first seasonal values of river flow (flood volumes) and rainfall. Given encouraging results, i.e. rather high correlation coefficients, one could continue with sub-seasonal flood volumes and rainfall.

A correlation between annual maximum water levels or flows with an average 10-day rainfall over (part of) Bangladesh preceding the peaks, or something similar, is unlikely to provide any useful results. If a good correlation does exist, then peak flows on both the Brahmaputra and Ganges rivers should usually coincide, which is not the case.

Although perhaps not of direct benefit for the FAP-studies, the results and graphs from this analysis will at least set the problem of joint probabilities in a proper perspective. Anyhow, the actual correlation structure of various causes of floodings is embedded in the actual data series for the last 25 years, and is therfore automatically well taken into account with simulation with the GM for this period, see Chapter 5.

3. REPRESENTATIVENESS OF RECENT YEARS FOR THE LONG TERM

Presently available flow data mainly pertain to the period 1965-1989. Most of the statistical analyses have necessarily to be confined to this period. This raises the question whether or not this recent period contains a sufficient range of flow and rainfall conditions to represent the same for a long period. The FHS should provide statistics of maximum levels and river flows, flood volumes (i.e. average flows) and rainfall (for a few rainfall stations in each region) on a seasonal and sub-seasonal basis, both for the long term and for the 1965-1989 period. Regional consultants can use these results to select specific years (for historical rainfall series) as representative for a specific return period. The activities to be undertaken will indicate the representativeness of such statistics for the long term, as outlined in the following.

3.1 Homogeneity Analysis of Flow and Rainfall Data

Given its long series of flow records (from 1910) the Hardinge Bridge station is appropriate for homogeneity analysis. It is also worth studying the rainfall records for one or two stations in each region in Bangladesh for the whole century. A simple analysis will do, for example:

- moving average analysis of annual flood season rainfall data back to the early part of this century (data back to 1964 are available in FAP-25 office for 22 stations);
- sum of residues of rainfall (same as above);
- same as above for Ganges flow data;
- trend analysis on rainfall data.

3.2 Frequency Analysis of Rainfall Data for Short and Long Periods

A frequency analysis of rainfall is to be made for 2 principal stations in each of the regions (in total 12 stations), where the following characteristics may be considered:

- seasonal and 3 sub-seasonal average values or totals (April - May, June - July and August - September);
- 2-days and 10-days sub-seasonal and seasonal extremes.

The analysis shall be carried out for the periods 1902 - 1989 and 1965 - 1989.

3.3 Remarks

The above analyses will produce:

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- a quantitative impression of the representativeness of the floods observed in the period 1965-1989 for the long term flood conditions;

- statistics of annual maximum water levels, discharges, seasonal and sub-seasonal flood volumes, and of seasonal and sub-seasonal rainfall data;

- a proper indication of return periods to be assigned to historical flood hydrographs and seasonal or sub-seasonal rainfall patterns.

It is noted that the FHS is not expected to perform a statistical analysis of rainfall data for all the stations in Bangladesh. It should therefore be considered that the rainfall analysis, as indicated in section 3.2 be carried out by the regional consultants in close cooperation with the FHS. Obviously a proper coordination of the adopted methodology and an intercomparison of obtained results is necessary.

4. UNIFIED METHODOLOGIES FOR STATISTICAL ANALYSES

The FHS is expected to provide methodologies for statistical analyses for:

- estimating extreme flows and water levels for given return periods;

- developing rainfall hyetographs of given depth-duration-return periods.

This requires the FHS to furnish descriptions of the theory, of the following statistical procedures:

- the maximum likelihood method for fitting of selected probability distributions (method of moments not to be adopted), and calculation of related confidence intervals;

- the maximum likelihood method for fitting of a suitable distribution function for extreme point rainfalls for a given duration and the derivation of rainfall depth-duration-frequency curves;

- statistical tests to determine the goodness-of-fit of theoretical distributions (chi-square).

FAP 25 is not expected to provide software for statistical analyses.

The FHS should provide a method for assessing standard errors for specific design floods. Standard errors as determined from the simulations for the period 1965-1989 together with standard errors of statistical estimates (quantiles) determine the standard error of the design conditions to be taken into account in determining the free board of embankments. Both type of standard errors can be taken as statistically independent variables.

5. DEDICATED VERSION OF THE GENERAL MODEL

The methodology of the FHS relies entirely on the possibility of making quite a number of simulation runs with the GM for a period of 25 years. This puts a high demand on computational speed. SWMC has therefore agreed to prepare a dedicated version of the GM for this purpose. It is referred to as FAP 25-GM.

6. BOUNDARY CONDITIONS FOR THE GM

The FHS requires the running of the GM for the period 1965-1989 for the present situation, for the ultimate embankment situation and possibly for various intermediate scenarios. This justifies a substantial effort in the setting up of a proper set of boundary conditions data for this period.

6.1 Flow Boundary Conditions

Daily river discharges at the upstream boundaries of the Ganges, Brahmaputra and Upper Meghna watershed are generally available. Missing data on the latter discharges can either be generated from rainfalls in the area (strong correlation) or be filled-in by using average values.

6.2 Rainfall Boundary Conditions

The contribution of rainfall over Bangladesh to the flow in its main river system is determined with the NAM model. The SWMC has used in total 26 stations to derive average daily areal rainfalls as inputs for 55 sub-catchments in the NAM model. FAP 25 will collect and process daily rainfall for these 26 stations and the station of Chittagong, which is outside but included for the sake of completeness.

6.3 Downstream Boundary Conditions

Downstream boundary conditions are to be provided for some 6 stations along the coast of Bangladesh. Water levels at a number of these stations, as far as located inland, are significantly affected by the upstream flows and are not adequate to provide downstream boundary conditions. Hence, it should be considered to extend the dedicated version of the General Model to the Bay of Bengal, provided sufficient data exist on daily levels in the Bay for the period 1965-1989 for stations such as Chittagong, Cox's Bazar and Heron Point.

The GM has to be run with average water levels instead of with tidal levels. To eliminate the effects of spring and neap tides, it is suggested to use moving average values (15 days).

6.4 Evaporation Data

Evaporation during the flood season is much less significant for the run-off to the main rivers than rainfall, giving anyhow only a marginal contribution to the flow in the main rivers. Hence, it appears adequate to use monthly average values for the period 1986-1989 as input to the NAM model. Any further work on this subject is not necessary.

7. VALIDATION OF THE GM AND ITS FLOW BOUNDARY CONDITIONS

The GM model has been calibrated and validated for the period 1986-1989 and is updated annually since then. Discharges measured in these years at various key stations as compared to those measured long ago at similar water levels, raise serious doubts as to either their accuracy or to the stability of the rivers on the long term. Either the measurements and the model are accurate and dynamic processes explain these differences, or the measurements are in serious error anmd the model has been adjusted to cope with these errors, or the river system has indeed significantly changed. The latter two reasons would seriously reduce the applicability of the GM for the simulation of possible future situation, involving a substantial embankment of the main river system in Bangladesh.

Hence, there is an urgent need to validate the GM for a much longer period. In view of the availability of data the period 1965 to 1989 has been selected for this purpose. Eventual significant differences between observed and simulated water levels for these years (nation-wide) may be due to :

- errors in the boundary conditions, in particular in the observed flows on the Ganges and Brahmaputra rivers;
- deficiencies in the calibration of the model;
- significant changes in the river system;
- errors, either systematically or at random, in the observed water levels.

Actions to be taken in the event of non-acceptable validation results can not be anticipated at this instant, and should be considered in close communication with the SWMC.

If the above analysis leads to the conclusion that significant changes have occurred in the river system during the last part of the century, one may well choose to add an extra freeboard to the design levels of the river embankments.

It is noted that the FAP-25 is not bound to produce a study of the long term morphological developments of the rivers in Bangladesh. At best some evidence for the existence or absence of such change will be produced. A more detailed analysis of such phenomena may be subject to further study under the FAP 24 (River Survey Programme).

FAP-25 should assess in consultation with the regional study consultants which output (levels and flows) is required at which locations. Upon completion of the boundary conditions the GM should then be run for the full period 1965-1989, or even further back into history depending upon the avalability of boundary conditions for the main rivers. Results of these computations should, after preliminary inspection and analysis, be supplied soonest to the regional studies.

The results of the simulations for the period 1965-1989 should be subjected to an error analysis. Computed flows and water levels should be analysed statistically, in terms of peak flows, seasonal and sub-seasonal flood volumes . This analysis is similar to the analysis mentioned in Chapter 3 for observed historical water levels and the reasons of eventual differences between the results of both analyses should be addressed.

Design events for projects within a region will probably not exceed 25 years, while the design return period for the embankments along the main rivers may well be in the order of 50 years. Therefore, the period 1965-1989 should provide a sound basis for such design, provided that this period is as far as rainfall concerns representative for a longer period of time.

8. METHODOLOGY FOR SELECTING BOUNDARY CONDITIONS FOR PROJECT DESIGN AT THE REGIONAL LEVEL

The methodology for the selection of boundary conditions for the design of projects within the regions necessarily should follow the same lines as outlines in this Chapter for the main river system, i.e. :

- baseline statistical analysis of rainfall and possibly other important design parameters, analysis of the representativeness of the period 1965-1989 for the century (as far as not achieved under the FHS) and selection of historical rainfall sequences to which a specific return period can be assigned;

- development of a dedicated version of the regional model, which allows larger timesteps to be used and makes running of this version practicable for long time period;

- preparation of boundary conditions required to run such a dedicated regional model for the period 1965-1989, or at the minimum for a selection of 10 years which contain both the 5 years with highest floods on the main rivers in the period and the 5 years with the highest rainfalls;

- running of the model for the present conditions and 10 to 25 historical flood seasons and statistical analysis of the results, aimed at assigning return period to selected historical seasonal or sub-seasonal period, which then can be used for preliminary design purposes;

- upon completion of the design, and perhaps also once at an intermediate stage, it will be necessary to test the performance of proposed protection schemes under all conditions as prevailed in the area in the period 1965-1989 (model runs for 25 years).

In the initial planning and design stage the main aim of using the regional models will be to assess the hydraulic efficiency of alternative flood protection schemes or components. For this purpose it will be quite sufficient to run the regional model only for some 3 historical flood seasons, say 1987, 1988 and another year. The need to follow a practical approach is evident.

It is felt that a highly theoretical joint probability analysis is both extremely difficult and quite impracticable. The actual correlation structure of various flood causing factors is embedded in the actual data series for the last 25 years, and is therefore automatically well taken into account. Moreover, the period 1965-1989 is likely to provide a sound basis for design for the regional studies since the return period of their design conditions is not expected to exceed 30 to 50 years.

9. ANALYSIS OF JOINT IMPACTS OF PROJECTS IN VARIOUS REGIONS

From time to time, FAP-25 is expected to run the GM with incorporation of various regional projects (development scenario or strategy), to determine joint impacts of all sort of projects and design conditions for such situations. This requires running the GM for the full period of 25 years. This exercise will be repeated a number of times during the course of the various FAP studies.

It is expected that such activities will mainly take place in stage 3 of the FHS, when the NW regional study has started its project preparation activities, the NC study has completed its preliminary activities, the SW study may have completed its Inception Report, the SE study has started with its feasibility studies and the NE study is well into it first year of planning.

Before that, consultants may wish to have a rough idea of the joint impacts, and the consequences thereof for their design, of a few roughly outlined development schemes. Provided the consultants together can given an outline of such schemes, it will be fairly simple, at short notice, to make runs with the GM for the full period of the last 25 years. This assumes that the validation of the GM for the period 1965-1989 does not confront the FHS with major problems. The FAP Modelling Coordination Committee (FAPMCC) may be the proper forum to initiate such activities.

Obviously, the role of the RMC is crucial in making arrangements for this sort of activities, where the regional studies should all participate actively in selecting a set of regional plans which should be incorported in such series of runs with the GM.

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APPENDIX 2

List of Available Data

Appendix 2 contains a list of hydrological data available with various agencies in addition to FAP 25. The information relates to rainfall, water level, discharge and evaporation.

Monthly rainfall data for 27 stations in Bangladesh from 1902 to 1959 and daily data from 1954 to 1989 are available with FAP 25 as being collected from Northwest Hydraulic Consultants. These are presented in pages A.2-2 to A.2-7.

Historical rainfall data for 22 stations in India out of which 18 stations in the Ganges, Brahmaputra and Meghna catchments and 4 stations for nearly areas for various periods from 1817-1950 are available and shown in page A.2-8. Rainfall data for the Indian stations have been collected from the Indian and Oriental office of the British Library in London and data of Nepalese stations have been received through Department of Irrigation, Hydrology and Meteorology, Nepal.

A list of evaporation data collected by FAP 25 is seen in page A.2-9.

A list of river gauges comprising both water level and discharge stations has been updated from information of BWDB, WARPO, SWMC and FAP Regional Studies. These are placed in pages A.2-10 to A.2-18. The list contains station codes, WARPO(MPO) planning area number and length of records..

Hydrological data collected by the FHS from various sources are available in its computer data base. A list of such data is presented in pages A.2-19 to A.2-22. The comprehensive list contains station code, length of record with source, data base format.

LIST OF RAINFALL DATA
AVAILABLE IN BANGLADESH
(ALSO AVAILABLE WITH FAP25)

STN. NO.	STATION NAME	DATE INSTALLED OR RE-INSTALLED	MONTHLY DATA PERIOD AVAIL.	DAILY DATA PERIOD ENTERED ON COMPUTER	MISSING DATA (Water Years)
R- 001	Atghoria	1961-11-19		1961 - 1990	
R- 002	Atia (Tangail)	1960-12-01	1902 - 1948	1954 - 1989	59/60 60/61
R- 003	Atrai	1962-02-18		1962 - 1990	
R- 004	Bera	1961-12-03		1962 - 1990	82/83 83/84 84/85
R- 005	Bhaluka	1962-07-13		1962 - 1990	86/87
R- 006	Bogra	1961-02-01	1902 - 1961	1954 - 1989	
R- 007	Chatmohar	1963-07-15		1963 - 1990	84/85
R- 008	Chaugram	1961-05-21	1921 - 1954	1954 - 1979	59/60 60/61
R- 009	Dhaka	1960-07-08	1902 - 1961	1954 - 1990	59/60 60/61
R- 010	Daulatpur	1961-11-14		1961 - 1990	
R- 011	Dhunot	1962-01-06		1962 - 1990	81/82
R- 012	Faridpur (Banwarinagar)	1961-11-23		1961 - 1990	
R- 013	Gopalpur	1961-09-01		1961 - 1990	88/89
R- 014	Gurudaspur	1961-12-21		1961 - 1990	
R- 015	Ishurdi	1961-02-01	1910 - 1942	1954 - 1990	59/60 60/61
R- 016	Joari	1962-01-09	1921 - 1953	1954 - 1990	59/60 60/61 61/62
R- 017	Joydebpur	1961-03-11	1902 - 1923	1954 - 1990	59/60 60/61
R- 018	Kalihati	1962-02-26		1962 - 1990	
R- 019	Kushtia	1961-01-01	1902 - 1953	1954 - 1989	59/60 60/61
R- 020	Manikganj	1961-01-24	1902 - 1953	1954 - 1990	59/60 60/61
R- 021	Mirzapur	1961-08-31		1961 - 1990	68/69 76/77 77/78 79/80 80/81
R- 022	Nandigram	1962-01-08		1962 - 1990	
R- 023	Natore	1961-10-26	1902 - 1947	1954 - 1990	59/60 60/61 71/72
R- 024	Nawkhila	1961-01-01	1902 - 1961	1954 - 1990	59/60 60/61 86/87
R- 025	Pabna	1961-02-08	1902 - 1961	1954 - 1990	59/60 60/61
R- 026	Pangsa	1961-02-01	1909 - 1954	1954 - 1979	59/60 60/61
R- 027	Phulbaria	1962-06-02		1962 - 1990	
R- 028	Pingna	1961-02-25	1905 - 1956	1954 - 1979	59/60 60/61
R- 029	Raiganj	1962-02-20		1962 - 1990	
R- 030	Rajbari	1960-11-27	1902 - 1937	1954 - 1989	59/60 60/61
R- 031	Savar	1961-11-23		1961 - 1990	88/89
R- 032	Sarishabari	1961-02-24	1906 - 1939	1954 - 1990	59/60 60/61 83/84 87/88
R- 033	Sherpur (Bogra)	1961-03-15	1902 - 1945	1954 - 1990	59/60 60/61
R- 034	Serajganj	1961-03-01	1902 - 1961	1954 - 1990	59/60 60/61
R- 035	Shahzadpur	1961-02-15	1912 - 1961	1954 - 1990	59/60 60/61
R- 036	Singra	1962-01-25		1962 - 1989	
R- 037	Sreepur	1962-01-07		1962 - 1990	83/84
R- 038	Sujanagar	1963-12-24		1963 - 1990	
R- 039	Taras	1963-10-13		1964 - 1990	
R- 040	Ullapara	1961-02-14	1940 - 1942	1954 - 1990	59/60 60/61
R- 041	Bheramara	1960-10-01		1961 - 1990	
R- 061	Bajitpur	1961-09-11		1961 - 1990	
R- 062	Dewanganj	1961-03-09	1902 - 1953	1954 - 1990	59/60 60/61
R- 063	Durgapur	1961-02-26	1902 - 1954	1954 - 1990	59/60 60/61
R- 064	Gaffargaon	1961-09-22		1961 - 1990	
R- 065	Gouripur	1961-09-16		1961 - 1990	86/87
R- 066	Islampur	1961-09-01		1961 - 1979	
R- 067	Jamalpur	1961-02-25	1902 - 1950	1954 - 1990	59/60 60/61

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STN. NO.	STATION NAME	DATE INSTALLED OR RE-INSTALLED	MONTHLY DATA PERIOD AVAIL.	DAILY DATA PERIOD ENTERED ON COMPUTER	MISSING DATA (Water Years)
R- 068	Jaria-Jhanjail	1961-09-10		1961 - 1990	
R- 069	Kaliganj	1961-12-26		1961 - 1978	
R- 070	Kapasia	1961-03-04	1908 - 1941	1954 - 1979	59/60 60/61
R- 071	Kishoreganj	1961-01-22	1902 - 1951	1954 - 1990	59/60 60/61
R- 072	Muktagacha	1961-09-21		1961 - 1990	87/88
R- 073	Mymensingh	1960-12-18	1902 - 1959	1954 - 1990	59/60 60/61
R- 074	Nalitabari (Taraganj)	1961-02-28	1902 - 1946	1961 - 1990	76/77-79/80 81/82-83/84
R- 075	Nandail	1962-06-11		1962 - 1990	87/88
R- 076	Narsingdi	1961-03-06	1908 - 1945	1954 - 1989	59/60 60/61
R- 077	Phulpur	1962-06-11		1962 - 1990	80/81 81/82 82/83 83/84
R- 078	Sherpur (Town)	1961-04-14	1902 - 1947	1954 - 1990	59/60 60/61
R- 079	Shibpur	1961-11-16		1961 - 1990	83/84
R- 101	Bhairab Bazar	1961-09-11		1961 - 1990	
R- 102	Bholaganj	1961-09-09		1961 - 1990	75/76 76/77
R- 103	Brahmanbaria	1961-02-05	1902 - 1961	1954 - 1990	59/60 60/61
R- 104	Chandbagh	1961-03-04	1926 - 1961	1954 - 1990	59/60 60/61
R- 105	Chandpur Bagan	1960-11-01	1912 - 1961	1954 - 1990	59/60 60/61 78/79
R- 106	?				
R- 107	Chhatak	1961-09-08		1961 - 1990	
R- 108	Dakshinbagh (Samanbagh)	1961-08-06	1902 - 1961	1961 - 1990	
R- 109	Gobindaganj	1961-09-06		1961 - 1990	59/60 60/61
R- 110	Habiganj	1961-02-13	1902 - 1954	1954 - 1990	59/60 60/61
R- 111	Itakhola (Baikunthapur)	1961-06-14	1922 - 1961	1961 - 1990	
R- 112	Itna	1962-03-29		1962 - 1990	
R- 113	Khaliajuri	1962-03-31		1962 - 1990	
R- 114	Kamalganj	1961-03-06	1928 - 1946	1954 - 1990	59/60 60/61
R- 115	Kendua	1962-06-26		1962 - 1990	86/87 87/88
R- 116	Lallakhal	1961-04-05	1902 - 1961	1954 - 1990	59/60 60/61
R- 117	Langla	1961-02-01	1902 - 1961	1954 - 1990	59/60 60/61
R- 118	Latu	1961-10-26		1961 - 1990	
R- 119	Manumukh	1961-02-18	1926 - 1949	1954 - 1990	59/60 60/61 75/76
R- 120	Markuli	1961-09-11		1961 - 1990	
R- 121	Mohanganj	1962-04-04		1962 - 1990	
R- 122	Moulvibazar	1961-02-20	1902 - 1946	1954 - 1990	59/60 60/61 81/82
R- 123	Netrokona	1961-01-29	1902 - 1954	1954 - 1990	59/60 60/61 82/83 84/85
R- 124	Pagla	1961-09-11		1961 - 1982	
R- 125	Sheola	1962-09-27		1962 - 1989	
R- 126	Srimangal	1961-01-31	1947 - 1961	1954 - 1990	59/60 60/61 76/77
R- 127	Sunamganj	1961-01-31	1902 - 1950	1954 - 1990	59/60 60/61
R- 128	Sylhet	1961-01-31	1902 - 1961	1954 - 1989	
R- 129	Tajpur	1961-10-25		1961 - 1990	
R- 130	Zakiganj	1962-03-01		1962 - 1990	
R- 131	Sarail	1961-02-15	1940 - 1956	1954 - 1990	59/60 60/61 71/72
R- 132	Nasirnagar	1961-10-26	1902 - 1949	1954 - 1990	59/60 60/61
R- 151	Adamdighi	1961-06-02	1926 - 1956	1954 - 1979	59/60 60/61 68/69 76/77
R- 152	Badalgachi	1961-07-29	1926 - 1953	1954 - 1989	59/60 60/61
R- 153	Badarganj	1962-05-28		1962 - 1989	82/83
R- 154	Bagdogra (Nilphamari)	1961-06-01	1902 - 1948	1954 - 1988	58/59 59/60 60/61 74/75 88/89
R- 155	Baliadangi	1962-10-15		1962 - 1979	
R- 156	Bhawaniganj (Gaibandha)	1961-06-02	1902 - 1950	1954 - 1988	59/60 60/61 86/87 88/89
R- 157	Bhitargarh	1962-07-15		1962 - 1989	
R- 158	Bholahat	1961-11-30		1961 - 1990	
R- 159	Bhurungamari	1963-05-20		1963 - 1990	71/72 75/76

STN. NO.		STATION NAME	DATE INSTALLED OR RE-INSTALLED	MONTHLY DATA PERIOD AVAIL.	DAILY DATA PERIOD ENTERED ON COMPUTER	MISSING DATA (Water Years)
R-	160	Birganj	1961-05-15	1902 - 1952	1954 - 1982	59/60 60/61
R-	161	Boda	1969-07-16		1962 - 1990	71/72 82/83
R-	162	Bullibandh	1963-04-30		1963 - 1979	71/72
R-	163	Chilmari	1962-12-20		1962 - 1990	
R-	164	Ghoraghat	1963-05-26		1963 - 1988	82/83 88/89
R-	165	Chhotadhap	1961-05-29	1901 - 1946	1954 - 1979	59/60 60/61
R-	166	Debiganj	1961-05-01	1947 - 1956	1954 - 1990	59/60 60/61
R-	167	Dimla	1963-03-20		1963 - 1990	84/85
R-	168	Dinajpur	1960-11-01	1902 - 1960	1954 - 1990	59/60 60/61
R-	169	Dubchanchia	1961-06-05	1927 - 1955	1954 - 1990	59/60 60/61
R-	170	Durgapur	1962-10-01		1962 - 1979	
R-	171	Gobindaganj	1961-06-06	1902 - 1947	1961 - 1990	
R-	172	Godagari	1962-11-01		1962 - 1990	
R-	173	Gomastapur	1961-06-17	1947 - 1954	1954 - 1979	59/60 60/61 75/76
R-	174	Hatibandha	1962-06-14		1962 - 1990	75/76 82/83
R-	175	Hilli (Hakimpur)	1963-01-01		1963 - 1989	
R-	176	Mohasthan	1967-07-06		1967 - 1979	68/69
R-	177	Kaliganj	1961-01-01		1961 - 1990	88/89
R-	178	Kaunia	1962-03-22		1962 - 1990	
R-	179	Khansama	1963-05-15		1963 - 1990	82/83
R-	180	Kantanagar	1962-09-09		1962 - 1990	71/72
R-	181	Khetlal	1961-06-11	1914 - 1950	1954 - 1990	59/60 60/61
R-	182	Kurigram	1961-05-21	1902 - 1951	1954 - 1990	59/60 60/61
R-	183	Lalmonirhat	1962-04-18		1962 - 1990	88/89
R-	184	Lalpur	1961-07-14	1902 - 1946	1954 - 1990	59/60 60/61
R-	185	Manda	1961-10-22	1902 - 1947	1954 - 1990	59/60 60/61
R-	186	Mithapukur	1962-12-23		1962 - 1988	68/69 88/89
R-	187	Mohaderpur	1961-11-16	1902 - 1946	1954 - 1990	59/60 60/61
R-	188	Mahipur	1962-10-29		1962 - 1990	
R-	189	Mohanpur	1962-08-19		1962 - 1982	
R-	190	Nachol	1962-10-13		1962 - 1990	
R-	191	Naogaon	1961-07-23	1902 - 1955	1954 - 1990	59/60 60/61
R-	192	Nazirpur (Patnitala)	1961-06-25	1926 - 1949	1954 - 1989	59/60 60/61
R-	193	Nekmard	1962-11-02		1962 - 1990	71/72 82/83
R-	194	Nithpur	1961-02-21	1902 - 1952	1954 - 1990	59/60 60/61 72/73
R-	195	Chapai Nawabagnj	1961-04-07	1947 - 1951	1961 - 1990	
R-	196	Nawabganj	1961-06-01	1902 - 1948	1954 - 1990	59/60 60/61 82/83 84/85 88/89
R-	197	Panchagarh	1962-07-14		1962 - 1990	
R-	198	Panchbibi	1961-05-22	1902 - 1945	1954 - 1979	59/60 60/61 71/72
R-	199	Parbatipur	1961-05-17	1902 - 1948	1954 - 1979	59/60 60/61
R-	200	Patgram	1963-02-08		1963 - 1989	71/72 84/85 86/87
R-	201	Phulbari	1962-01-18		1962 - 1989	
R-	202	Pirgacha	1962-05-27		1962 - 1990	82/83
R-	203	Pirganj	1961-05-08	1902 - 1954	1954 - 1989	59/60 60/61 87/88
R-	204	Puthia	1962-01-19		1962 - 1990	
R-	205	Rajshahi	1961-05-01	1902 - 1961	1954 - 1990	59/60 60/61
R-	206	Rangpur	1961-03-01	1902 - 1961	1954 - 1989	59/60 60/61
R-	207	Ranisankail	1962-10-27		1962 - 1976	68/69
R-	208	Rohanpur	1961-12-10		1961 - 1990	
R-	209	Ruhea	1961-03-01		1961 - 1989	82/83
R-	210	Saidpur	1961-06-01	1902 - 1958	1954 - 1988	59/60 60/61 88/89
R-	211	Sapahar	1962-11-01	1930 - 1950	1954 - 1990	59/60 60/61 61/62
R-	212	Sardah	1961-11-19		1961 - 1990	

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STN. NO.	STATION NAME	DATE INSTALLED OR RE-INSTALLED	MONTHLY DATA PERIOD AVAIL.	DAILY DATA PERIOD ENTERED ON COMPUTER	MISSING DATA (Water Years)
R- 213	Setabganj	1961-06-01	1902 - 1946	1954 - 1989	59/60 60/61 79/80 82/83
R- 214	Amla	1961-01-01		1961 - 1989	
R- 215	Shibganj (Rajshahi)	1961-08-28	1947 - 1948	1954 - 1990	59/60 60/61 80/81 81/82
R- 216	Shibganj (Dinajpur)	1962-07-17		1962 - 1990	
R- 217	Sikarpur (Pragpur)	1962-05-26		1962 - 1990	
R- 218	Sundarganj	1961-09-06	1902 - 1947	1954 - 1989	59/60 60/61 81/82 82/83
R- 219	Tanore	1961-11-12	1903 - 1950	1954 - 1990	59/60 60/61
R- 220	Tentulia	1962-07-18		1962 - 1990	
R- 221	Thakurgaon	1961-06-01	1902 - 1953	1954 - 1990	59/60 60/61
R- 222	Ulipur	1961-05-21	1902 - 1950	1954 - 1989	59/60 60/61 71/72
R- 223	Hogalbaria	1962-12-11		1962 - 1990	65/66
R- 224	Chuadanga	1961-01-27	1902 - 1954	1954 - 1990	59/60 60/61
R- 225	Meherpur	1961-01-01	1902 - 1956	1954 - 1990	59/60 60/61 78/79 88/89
R- 251	Badartuni	1962-07-05		1962 - 1979	
R- 252	Bakerganj	1961-09-23		1961 - 1989	
R- 253	Bamna	1961-09-24		1961 - 1990	
R- 254	Banaripara	1962-06-20		1962 - 1990	
R- 255	Bauphal	1960-11-01	1902 - 1955	1954 - 1990	59/60 60/61
R- 256	Barguna	1960-10-01	1908 - 1951	1954 - 1990	59/60 60/61
R- 257	Barhanuddin	1962-01-22		1962 - 1990	
R- 258	Barisal	1961-01-08	1902 - 1961	1954 - 1990	
R- 259	Bhandaria	1961-09-23		1961 - 1990	
R- 260	Bhola	1960-10-01	1902 - 1948	1954 - 1990	59/60 60/61
R- 261	Daulatkhan	1960-10-01	1902 - 1947	1954 - 1990	59/60 60/61
R- 262	Golachipa	1961-09-10		1961 - 1990	71/72 81/82
R- 263	Gournadi	1960-11-01	1902 - 1953	1954 - 1990	59/60 60/61
R- 264	Jhalakati	1961-09-17		1961 - 1990	
R- 265	Mathbaria	1962-06-23		1962 - 1990	
R- 266	Patuakhali	1960-11-01	1902 - 1957	1954 - 1990	59/60 60/61
R- 267	Pirojpur	1960-11-01	1902 - 1961	1954 - 1988	59/60 60/61
R- 268	Charfesson	1967-06-18		1968 - 1979	
R- 269	Khepupara	1967-05-18		1968 - 1990	
R- 270	Anjurhat (Mayerchar)	1967-06-15		1968 - 1979	
R- 271	Nazirpur	1967-05-09		1968 - 1990	75/76
R- 272	Patharghata	1967-05-10		1968 - 1990	
R- 273	Rangabali	1967-06-06		1968 - 1979	
R- 301	Amtali	1961-09-18		1961 - 1990	
R- 302	Anwara	1962-08-27		1962 - 1990	
R- 303	Bandarban	1960-09-01	1902 - 1959	1954 - 1990	59/60 60/61
R- 304	Barkal	1964-09	1902 - 1959	1954 - 1985	59/60-63/64 76/77 82/83 83/84
R- 305	Chandarkhil	1961-09-14		1961 - 1979	75/76 76/77
R- 306	Chittagong	1961-02-03	1902 - 1961	1954 - 1990	
R- 307	Cox's Bazar	1961-01	1902 - 1961	1954 - 1990	59/60 60/61 88/89
R- 308	Dighinala	1964-09	1920 - 1959	1954 - 1983	59/60-63/64 79/80
R- 309	Dolu	1961-09-01		1961 - 1979	
R- 310	Dulahazara	1962-09-08		1962 - 1990	88/89
R- 311	Fatikchari	1961-05-20		1961 - 1990	
R- 312a	Gosapara	1961-09-16		1961 - 1968	
R- 312b	Guimara	1970-04-28		1970 - 1976	
R- 313	Hathazari	1961-08-29		1961 - 1990	
R- 314	Hiakhu	1961-09-19		1961 - 1979	68/69
R- 315	Kaptai (Chowdhury Chara)	1960-07-01	1926 - 1959	1954 - 1990	59/60 60/61
R- 316	Kutubdia	1961-12-18	1902 - 1953	1954 - 1990	59/60 60/61

STN. NO.	STATION NAME	DATE INSTALLED OR RE-INSTALLED	MONTHLY DATA PERIOD AVAIL.	DAILY DATA PERIOD ENTERED ON COMPUTER	MISSING DATA (Water Years)
R- 317	Lama	1961-01-26	1916 - 1961	1954 - 1990	59/60 60/61 88/89
R- 318	Mahalchari	1964-09	1916 - 1959	1954 - 1990	59/60-63/64 83/84
R- 319	Manikchari	1960-11-01	1920 - 1960	1954 - 1990	59/60 60/61 75/76 80/81 85/86-87/88
R- 320	Mirsarai	1961-01-01	1902 - 1947	1954 - 1990	59/60 60/61 86/87
R- 321	Mirzahat	1961-09-12		1961 - 1976	
R- 322	Nakhyongchari	1962-09-22	1928 - 1959	1954 - 1990	59/60-61/62 76/77 88/89
R- 323	Narayanhat	1961-09-16		1961 - 1990	
R- 324	Nazirhat	1961-08-25		1961 - 1990	
R- 325	Patia	1961-10-27		1961 - 1990	
R- 326	Rajbaritilla	1961-09-16		1961 - 1976	
R- 327	Ramgarh	1961-02-04	1916 - 1957	1954 - 1990	59/60 60/61 86/87
R- 328	Rangamati	1961-02-17	1902 - 1961	1954 - 1990	59/60 60/61
R- 329	Rangapani	1961-09-28		1961 - 1976	
R- 330	Rangunia	1961-05-12	1934 - 1949	1954 - 1990	59/60 60/61
R- 331	Sandwip (Harispur)	1961-04-20	1902 - 1956	1961 - 1990	86/87 88/89
R- 332	Satkania	1961-03-01	1902 - 1944	1954 - 1990	59/60 60/61 87/88
R- 333	Sikderhat	1961-09-20		1961 - 1979	71/72
R- 334	Sitakunda	1962-09-09		1962 - 1990	88/89
R- 335	Tenturi	1961-09-17		1961 - 1979	75/76
R- 351	Bancharampur	1961-03-02	1939 - 1948	1954 - 1990	59/60 60/61
R- 352	Barura	1962-04-30		1962 - 1990	
R- 353	Basurhat	1962-10-14		1962 - 1990	
R- 354	Chandpur	1961-02-20	1902 - 1952	1954 - 1990	59/60 60/61 75/76
R- 355	Chhagalnaya	1960-	1902 - 1960	1954 - 1990	59/60 60/61
R- 356	Comilla	1961-02-01	1902 - 1959	1954 - 1990	59/60 60/61
R- 357	Daudkandi	1961-06-27	1902 - 1942	1954 - 1990	59/60 60/61
R- 358	Feni	1960-11-01	1902 - 1951	1954 - 1990	59/60 60/61
R- 359	Gunabati	1961-08-20		1961 - 1990	76/77 83/84
R- 360	Hajiganj	1962-02-24		1962 - 1990	
R- 361	Hatiya	1962-01-18	1902 - 1953	1954 - 1989	59/60 60/61 61/62
R- 362	Kasba	1961-03-04	1902 - 1945	1954 - 1989	59/60 60/61
R- 363	Laksam	1961-01-01	1902 - 1945	1954 - 1990	59/60 60/61
R- 364	Lakshmipur	1961-08-18	1902 - 1948	1954 - 1990	59/60 60/61
R- 365	Munshiganj	1960-11-25	1902 - 1961	1954 - 1990	59/60 60/61
R- 366	Muradnagar	1961-08-26		1961 - 1990	
R- 367	Nabinagar	1961-04-18	1939 - 1952	1954 - 1990	59/60 60/61 68/69 76/77-80/81
R- 368	Narayanganj	1960-	1902 - 1960	1954 - 1977	59/60 60/61 71/72 72/73
R- 369	Noakhali	1961-02-01	1902 - 1961	1954 - 1990	59/60 60/61
R- 370	Parshuram	1961-09-01		1961 - 1990	
R- 371	Raipur (Comilla)	1960-12-01	1939 - 1950	1954 - 1979	59/60 60/61
R- 372	Raipur (Noakhali)	1961-08-24		1961 - 1989	
R- 373	Ramchandrapur	1961-03-01	1902 - 1951	1954 - 1976	59/60 60/61 68/69
R- 374	Ramganj	1960-12-01	1902 - 1948	1954 - 1979	59/60 60/61 75/76
R- 375	Ramgati	1962-12-18		1962 - 1990	65/66
R- 376	Senbag	1960-	1941 - 1956	1954 - 1990	59/60 60/61 82/83 87/88
R- 377	Sonaimuri	1962-09-30		1962 - 1990	
R- 401	Baliakandi	1961-03-01	1909 - 1959	1954 - 1979	59/60 60/61
R- 402	Bhagyakul	1961-11-05		1961 - 1990	88/89
R- 403	Bhanga	1961-04-06	1909 - 1956	1954 - 1990	59/60 60/61
R- 404	Bhusna (Boalmari)	1961-01-01	1909 - 1951	1954 - 1990	59/60 60/61 81/82
R- 405	?				
R- 406	Faridpur	1961-01-04	1902 - 1961	1954 - 1990	59/60 60/61

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STN. NO.		STATION NAME	DATE INSTALLED OR RE-INSTALLED	MONTHLY DATA PERIOD AVAIL.	DAILY DATA PERIOD ENTERED ON COMPUTER	MISSING DATA (Water Years)
R-	407	Fatehpur	1961-01-01	1938 - 1961	1954 - 1990	59/60 60/61
R-	408	Fatulla (Lalpur)	1961-02-25		1961 - 1982	80/81
R-	409	Haridaspur	1961-01-05	1909 - 1954	1954 - 1990	59/60 60/61
R-	410	Madaripur	1961-03-05	1902 - 1952	1954 - 1990	59/60 60/61
R-	411	Madhukhali	1961-10-14		1961 - 1990	
R-	412	Nawabganj	1961-03-13	1908 - 1947	1954 - 1990	59/60 60/61 76/77 86/87
R-	413	Palong	1961-03-07	1909 - 1948	1954 - 1990	59/60 60/61
R-	414	Shibchar	1961-12-01		1962 - 1990	
R-	451	Abhoynagar	1962-09-04		1962 - 1990	
R-	452	Alamdanga	1962-09-18		1962 - 1990	
R-	453	Benapole	1962-05-20		1962 - 1990	85/86
R-	454	Chaugacha	1962-04-30		1962 - 1990	
R-	455	Dattanagar	1961-02-01		1961 - 1990	
R-	456	Jessore	1961-01-25	1902 - 1961	1954 - 1990	
R-	457	Jhenaidah	1961-03-13	1902 - 1948	1954 - 1989	59/60 60/61
R-	458	Kaliganj (Jessore)	1962-04-25		1962 - 1990	
R-	459	Keshabpur	1962-06-20		1962 - 1990	87/88
R-	460	Magura	1960-12-01	1902 - 1960	1954 - 1990	59/60 60/61 85/86
R-	461	Narail	1960-11-01	1902 - 1948	1954 - 1989	59/60 60/61
R-	462	Salikha	1962-07-25		1962 - 1990	88/89
R-	463	Sailkupa	1962-06-30		1962 - 1990	
R-	501	Bagerhat	1961-02-23	1902 - 1948	1954 - 1990	59/60 60/61 86/87
R-	502	Benerpota	1961-01-01		1961 - 1990	
R-	503	Chalna	1962-06-13		1962 - 1990	78/79 80/81 88/89
R-	504	Dumuria	1961-05-19	1902 - 1961	1954 - 1990	59/60 60/61
R-	505	Islamkati	1961-05-01	1927 - 1961	1954 - 1990	59/60 60/61
R-	506	Kaikhali	1962-06-28		1962 - 1990	81/82 82/83
R-	507	Kalaroa	1961-02-28	1902 - 1955	1954 - 1990	59/60 60/61
R-	508	Kaliganj (Khulna)	1961-05-18	1902 - 1961	1954 - 1990	59/60 60/61
R-	509	Kapilmuni	1962-05-29		1962 - 1989	
R-	510	Khulna	1961-02-01	1902 - 1961	1954 - 1989	59/60 60/61
R-	511	Mollahat	1961-05-18	1902 - 1947	1954 - 1989	59/60 60/61 87/88
R-	512	Morrelganj	1961-06-01	1902 - 1961	1954 - 1987	59/60 60/61 87/88 88/89
R-	513	Nakipur	1961-03-09	1902 - 1939	1954 - 1979	59/60 60/61
R-	514	Nalianala	1962-08-26		1962 - 1979	
R-	515	Paikgacha	1961-05-13	1902 - 1945	1954 - 1989	59/60 60/61 87/88
R-	516	Rampal	1961-06-01	1902 - 1946	1954 - 1990	59/60 60/61 87/88
R-	517	Rupsa - East	1962-07-01		1962 - 1981	
R-	518	Satkhira	1961-02-07	1902 - 1961	1954 - 1990	59/60 60/61

Source : North West Hydraulic Consultants Limited

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LIST OF INDIAN RAINFALL DATA
AVAILABLE WITH FAP25

LIST OF INDIAN RAINFALL DATA AVAILABLE WITH FAP25

BRAHMAPUTRA BASIN		
STATION NAME	**AVAILABLE PERIOD**	**MISSING YEARS**
GOALPARA	1891-1950	1937,38
GAUHATI	1891-1950	1937,38,43
DIBRUGARH	1891-1950	1937,38
DARJEELING	1891-1950	1937,38
JORHAT	1891-1950	1937,38,43
SILCHAR	1891-1950	1937,38

GANGES BASIN		
STATION NAME	**AVAILABLE PERIOD**	**MISSING YEARS**
RAJMAHAL	1891-1950	1937,38
MONGHYR	1891-1950	1924,37,38
PATNA	1891-1950	1937,38,41
ALLAHABAD	1891-1950	1937,38
BENARES	1891-1950	1937,38
BAREILLY	1891-1950	1937,38
AGRA	1891-1950	1937,38
KANPUR	1891-1950	1937,38
DELHI	1891-1950	1937,38
JAIPUR	1891-1950	1937,38
BHOPAL	1891-1950	1937,38
KOTAH	1891-1950	1937,38,50

STATIONS OUTSIDE CATCHMENT		
STATION NAME	AVAILABLE PERIOD	MISSING YEARS
BOMBAY	1817-1950	1877-1890,1937-1938
NAGPUR	1826-1950	1833-1854,1877-1890,1937-1938
JABALPUR	1845-1950	1877-1890,1937-1938
CALCUTTA	1829-1947	1877-1890,1937-1938

LIST OF EVAPORATION DATA
AVAILABLE WITH FAP25

STATIONS	CODES	AVAILABLE PERIOD	MISSING YEARS
AMLA	E 01	1983 TO 1989	88
BARISAL	E 02	1983 TO 1989	NO
BOGRA	E 05	1983 TO 1989	NO
BRAHMANBARIA	E 06	1983 TO 1989	NO
DINAJPUR	E 11	1983 TO 1989	84/88
JAMALPUR	E 16	1983 TO 1989	88
JESSORE	E 17	1983 TO 1989	88
NETROKONA	E 26	1983 TO 1989	84/88
PABNA	E 28	1983 TO 1989	88
RASJAHI	E 29	1983 TO 1989	NO
RANGPUR	E 32	1983 TO 1989	84/88
BAGHERAT	E 34	1983 TO 1989	85/88
SYLHET	E 38	1983 TO 1989	NO

LIST OF WATER LEVEL DATA AVAILABLE IN BANGLADESH

STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
1 BAGERHAT	31(A)	TD	1959/1989	65/67,78,82,86/88
3 BRAHMANBARIA	31(A)	TD	1959/1981	64/67,75,77
3A B.BARIA RB	31(A)	TD	1959/1989	64/76,88
4 KALIKAPUR	55	TD	1962/1979	65/67
4A ARIAL KHAN	57	TD	1976/1989	77/78,81/82,85/88
5 MADARIPUR	57	TD	1957/1989	59/61,65/67,76,88
6 OFFTAKE SURMA	24(A)	NT	1960/1976	
7 PUBAIL	18	TD	1945/1989	64/67,78/79,81/82
7.5 DEMRA	18	TD	1962/1989	64/67,85,88
8 BASURI	18	NT	1976/1989	80
9 KAORAID	18	TD	1964/1989	67,71
9.5 TRIMOHINI	18	NT	1968/1989	82/84
10 SIMULBARI	5(A)	NT	1945/1989	62/63,71
11 KHANPUR	6	NT	1948/1989	62/63,71
11A SARIAKANDI	6	NT	1974/1989	76
12 MADHUPUR	15(A)	NT	1957/1989	
13 KAUL- JANI	15(A)	NT	1959/1989	83
14 MIRZAPUR	15(A)	NT	1945/1989	64/76,79,85
14.5 NAYERHAT	16(A)	TD	1968/1989	71,85/86,88
15 CHARGHAT	12	NT	1964/1979	
16 NANDANGACHI	12	NT	1964/1984	
16.1 MOLONCHI	12	NT	1965/1989	71
17 ATGHORIA	13	NT	1964/1979	
17.1 BARAL RLY. BR.	13	NT	1964/1989	
18 BARISAL	52	TD	1938/1989	65/67,87
18.1 BAKERGANJ	54	TD	1968/1989	86/87
20 AMTALI	55	TD	1957/1989	65/67,75/76
21 ARPARA	43	TD	1958/1989	65/67,88
22 NAVARON	46	NT	1965/1981	71
22.5 SANKERPUR	46	NT	1981/1984	
23 KALAROA	46	TD	1968/1989	
24 BENARPOTA	46	TD	1968/1989	
25 CHAPRA	49(A)	TD	1968/1987	
26 PROTAPNAGAR	49(A)	TD	1968/1987	
27 KESHABPUR	47	TD	1956/1987	59/67,83
28 DUMURIA	47	TD	1968/1989	
29 SUTERKHALI	49(A)	TD	1968/1989	88
30 AFRAGHAT	45	TD	1956/1989	65/67
31 GILATALA	48(A)	TD	1960/1981	65/67
32 KATHULI	42	NT	1960/1989	62/64,71/73
33 GOBINDAGANJ	27	NT	1958/1981	62/63,71
34 NAKUAGAON	21(A)	NT	1957/1989	61/62
35 NALITABARI	21(A)	NT	1957/1989	61/62
35.5 SACHAPUR	21(A)	NT	1964/1989	

Notes : NT means non tidal stations
TD means tidal stations

STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
36 JARIA JANJAIL	21(A)	NT	1959/1989	61/62
36.1 MOHANGANJ	21(A)	NT	1964/1989	
37 JHALAKATI	52	TD	1952/1989	65/67,86/88
38 BAMNA	54	TD	1959/1989	65/67,87/88
39 PATHARGHATA	55	TD	1957/1989	65/67
40 RAMU	39	NT	1965/1989	84
41 COX'S BAZAR	41	TD	1968/1989	76/77,79/82
42 DHAKA M. BARAK	16(A)	TD	1909/1989	62/67,76,88
43 HARIHARPUR	16(A)	TD	1945/1989	48/52,62/67,78,82
44 DUHULI	4	NT	1960/1979	62
44.1 NIZBARI	4	NT	1964/1989	
45 NOONKHAWA	2	NT	1957/1989	59/61,63,82
45.5 CHILMARI	3	NT	1956/1989	59/61,63/64,81/82
45.6 PERARCHAR	3	NT	1979/1984	80/82
46 KAMARJANI	5(A)	NT	1957/1988	59/61,63,71,82,87
46.7L KHOLABARICHAR	19	NT	1964/1989	
46.7R KRISTOMANICHAR	19	NT	1964/1984	
46.9L BAHADURABAD TR.	15(A)	NT	1949/1989	
46.9R PHULCHARI TR.	5(A)	NT	1964/1989	79/81
47 BAHADURABAD	15(B)	NT	1962/1983	63
47.3L JAGNAICHAR	15(A)	NT	1965/1984	
47.3R PATILBARICHAR	5(A)	NT	1964/1984	66/74,81
48 JAGANNATHGANJ	15(B)	NT	1962/1989	63,81/82
49 SERAJGANJ	14	NT	1945/1989	59/61,63,71
49A KAZIPUR	6	NT	1967/1989	71
50 PORABARI	14	NT	1940/1989	59/61,63,80
50.3 MATHURA	14	NT	1964/1989	71
50.6 ARICHA	17(A)	NT	1964/1989	
51 RAMDIA	44(A)	NT	1965/1989	71
51A CHANDANA R. BR.	44(A)	NT	1966/1977	71/73
52 GHOSEPUR	44(A)	NT	1965/1989	71,85/87
53 BATKUCHI	21(B)	NT	1957/1988	64,71,87
54 KALIGANJ	43	NT	1951/1964	
55 KHATURMAGURA	45	TD	1957/1989	65/67
55.1 RATANDANGA	48(A)	TD	1968/1989	78,80,82,87/88
56 GOBRAHAT	48(A)	TD	1957/1984	65/67
56.1 NARAIL	48(A)	TD	1968/1989	87/88
57 BURABURI	10	NT	1959/1981	71
58 HAZIGANJ	32	TD	1957/1989	65/67,79,81
59 RAIPUR	32	TD	1948/1977	51/55,65/67
60 HAZIMARA	32	TD	1958/1977	59,65/67
61 BORAGARI	4	NT	1960/1989	71,82
62 BADARGANJ	5(A)	NT	1959/1989	71,82
62.1 BARATI	4	NT	1964/1989	83

Notes : NT means non tidal stations
TD means tidal stations

STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
63 CHAK RAHIMPUR	5(A)	NT	1945/1989	64/76,82
64 SHIBGANJ	5(B)	NT	1945/1989	71,86
65 BOGRA	6	NT	1947/1989	85/86
66 ULLAPARA	14	NT	1960/1989	
67 KAMALGANJ	25	NT	1964/1989	
68 TILLI	17(A)	NT	1949/1989	58,62/63
68.5 JAGIR	17(A)	NT	1964/1989	71
69 SAVAR	17(A)	TD	1945/1989	62/67,79/82,85
70 KALATIA	17(A)	TD	1968/1989	76,79,82
71 KALAGACHIA	30	TD	1945/1987	50/51,62/69,78/82
71A RAKABI BAZAR	30	TD	1968/1989	76,78/79,81/82
72 KHALIAJURI	29	TD	1945/1989	49,64/68,77,81/82
72B SUKDEBPUR	23	NT	1983/1989	
73 ITNA	29	TD	1945/1989	49,58,64/68,82
74 DILALPUR	29	TD	1945/1989	49,64/67,81/82
75 PATGRAM	2	NT	1960/1989	61,63,81/82
76 TALUKSIMULBARI	2	NT	1960/1989	61,63/64,71
77 KURIGRAM	2	NT	1946/1989	58,61,63
78 KANTANAGAR	10	NT	1945/1989	59/61,71
79 MATLAB BAZAR	32	TD	1959/1989	65/67,78,81/82,84
81 PATESWARI	1	NT	1962/1989	71
82 JOTEBAZAR	9	NT	1976/1989	79/81,87
83 BAGMARA	9	NT	1977/1989	
83.1 NALDANGA R BR.	13	NT	1964/1989	
84 RAMGARH	36	NT	1970/1989	81,87
84.1 KALIACHARI	36	NT	1974/1988	81/82
85 SOVAPUR	36	TD	1968/1983	79/82
86 DHOOMGHAT	36	TD	1956/1989	59/67
87 CHARSONAPUR	36	TD	1968/1989	78/81
88 RAMPURBOALIA	9	NT	1923/1989	38/56
89 SARDAH	12	NT	1929/1989	39/41,46,
90 HARDINGE BRIDGE	42	NT	1910/1989	71
91 TALBARIA	58	NT	1944/1989	59/61,64/67
91.1 SENGRAM	44(A)	NT	1962/1989	71,78,82
91.2 MANENDRAPUR	44(A)	NT	1964/1989	71,73,82/84
91.7R URAKANDA	44(A)	NT	1964/1981	73
91.9L BARURIA TR.	44(A)	NT	1964/1989	
91.9R GOALANDA TR.	44(A)	NT	1964/1982	
92 GOALANDA GHAT	44(B)	TD	1946/1982	49/55,78
92.3L KADAMTALA	17(A)	NT	1964/1978	
93 KUSHUM HATI	17(B)	TD	1945/1984	50/52,65/67,78/82
93.4L JASHILDA	30	TD	1968/1989	78/80,82
93.4R CHARJANAJAT	57	TD	1968/1977	
93.5L MAWA	30	TD	1968/1989	87/88

Notes : NT means non tidal stations
TD means tidal stations

02

STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
93.5R BATESWAR	57	TD	1968/1977	76
93.6L WARI	30	TD	1968/1977	
94 TARPASHA	30	TD	1928/1989	65/67,76/79,81/82
95 SURESWAR	57	TD	1954/1989	59/61,65/67,76/83
96 ISLAMPUR	5(B)	NT	1946/1989	61,64/76,82,85
96A JAFARGANJ	5(B)	NT	1964/1989	71,85/86
97 GAIBANDHA	5(B)	NT	1946/1989	64,71,85
98 GHIOR	17(B)	NT	1952/1979	56
99 GORAI RLY. BR.	44(B)	NT	1946/1989	71
100 JANIPUR	44(B)	NT	1959/1982	62/64
101 KAMARKHALI	44(B)	NT	1965/1987	71,81
101.5 KAMARKHALI TR.	44(B)	NT	1957/1982	
102 BHATIAPARA	44(B)	TD	1951/1989	62/67
103 BARADIA	44(C)	TD	1941/1981	61/67
104 MANIKDAH	57	TD	1947/1978	62/67
105 ATHAROBANKA	57	TD	1929/1989	62/67
106 PATGATI	57	TD	1953/1985	62/67,84
107 PIROZPUR	53	TD	1983/1988	62/67,80,87
107.2 RAYENDA	49	TD	1967/1989	82
108 CHARDUANI	55	TD	1959/1985	62/67,82,84
109 BIBIR BAZAR	34	NT	1923/1989	77,81
110 COMILLA	31(A)	NT	1940/1989	
111 SHOLONAL	31(A)	NT	1927/1983	
112 GOBINDAPUR	31(A)	NT	1923/1965	63
113 KANGSANAGAR	31(A)	NT	1953/1989	62,77
114 JIBANPUR(GUMTI)	31(A)	NT	1954/1989	57/58,62
114A JIBANPUR(BURI)	31	NT	1959/1985	62,77/78
115 DAUDKANDI	31(B)	TD	1956/1989	61,65/67,78/80
116 MANIKCHARI	36	NT	1959/1983	
117 NARAYANHAT	37(A)	NT	1959/1989	
118 MIRZAHAT	37(A)	NT	1959/1978	71
119 FATIKCHARI		NT	1954/1964	
119A SOUTH SUNDARPUR	37(A)	NT	1965/1981	
119.1 PANCH PUKURIA	37(A)	NT	1965/1989	
120 TELPARI	37(A)	TD	1949/1989	65/67
121 ENAYET HAT	37(B)	TD	1959/1989	65/67,82
121A MADNAGHAT	37(B)	TD	1968/1983	
122 SANDWIP	60	TD	1968/1989	83/85
123 GANGASAGAR R.B.	31(B)	NT	1956/1989	71
124 THANDACHARI	37(B)	NT	1955/1989	
125 RANGUNIA	37(B)	TD	1958/1989	61,65/67
126 PABNA	14	NT	1930/1958	39/43
128 SHAKRA	49(A)	TD	1968/1989	82,85
129 BASANTAPUR	49(A)	TD	1952/1989	59/67,78,81/82

Notes : NT means non tidal stations
TD means tidal stations

STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
130 KAIKHALI	49(A)	TD	1968/1989	82
131 SAKTIARKHOLA	23	NT	1964/1989	71
132 MANMATHPUR	8	NT	1964/1989	71,76,82
132.5 JAIPURHAT	9	NT	1964/1989	71
133 NAOGAON	8	NT	1965/1989	
133A TAJNAGAR	8	NT	1979/1985	82/83
134 JOKERCHAR	15(B)	NT	1958/1989	
134A BAUSHI R.B.	15(B)	NT	1965/1989	71
134B OFFTAKE JHENAI	15(B)	NT	1966/1989	71,80
135 JURI	25	NT	1957/1977	
135A CONTINALA	26	NT	1965/1989	
136 KAUKHALI	54	TD	1958/1984	63/67,80/82
136.1 UMEDPUR	53	TD	1975/1978	76
137 MANIKGANJ	17(B)	NT	1958/1968	62/63
137A TARAGHAT	17(B)	NT	1964/1989	71
138 SOFIABAD	25	NT	1958/1989	62/64
139 BARDESHWARI	7	NT	1961/1989	64/71,81/82,87/88
140 PANCHAGARH	7	NT	1948/1989	71
141 DEBIGANJ	7	NT	1948/1989	56/58,63/86
142 KHANSHAMA	7	NT	1945/1988	71
142.1 BHUSHIR BANDAR	7	NT	1964/1989	71,87
143 SHAMJIGHAT	7	NT	1949/1989	64/71
144 CHAKHARIHARPUR	9	NT	1960/1989	64/71,84/85
145 MOHADEBPUR	9	NT	1959/1989	64/71
146 RASULPUR	13	NT	1953/1985	57
147 ATRAI RLY. BR.	13	NT	1959/1989	
147.5 SINGRA	13	NT	1974/1989	
148 CHANKCHAR	13	NT	1959/1989	71,78/79,81/85
149 ASTOMANISHA	13	NT	1958/1989	71,84/86
149.1 GUMANI R. B.	13	NT	1964/1989	77/78,82/85
150 DOHAKALADANGA	14	NT	1958/1989	71,78,82
151 BAGHABARI	14	NT	1945/1989	
152 KODALA	39	TD	1968/1978	
152A CHANDRAGHONA	39	TD	1968/1978	
153 CHITTAGONG	41	TD	1968/1988	83/84
154 PATENGA	41	TD	1968/1978	
155 MAHIMAGANJ	5(B)	NT	1964/1988	
156A KUNDAL	8	NT	1964/1989	71
157 BALLAH	25	NT	1957/1989	63,71,81
158 CHUNARGHAT	25	NT	1957/1989	63,71,78/80
158.1 SHAISTAGANJ	25	NT	1964/1989	
159 HABIGANJ	28	NT	1948/1989	63
160 ANDULBARIA	45	NT	1965/1978	76
161 TAHERPUR	45	NT	1965/1989	

Notes : NT means non tidal stations
TD means tidal stations

STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
162 JHIKARGACHA	46	TD	1965/1987	
163 TALAMAGURA	45(B)	TD	1968/1989	78,85
164 CHANDKHALI	49(B)	TD	1968/1989	
165 KOBADAK F. O.	49(B)	TD	1968/1989	
167 IBRAHIMDI	44(C)	NT	1965/1984	77/78,80
168 FARIDPUR	57	TD	1968/1989	87/88
169 MUZURDIA	44(C)	NT	1965/1989	71
170 BHANGA	57	TD	1968/1989	85
171 GARAGANJ	58	NT	1958/1989	62/64
172 AMALSHID	25	NT	1951/1989	64/78,81
173 SHEOLA	25	NT	1949/1989	
173A SADAKHAL	26	NT	1962/1977	65
174 FENCHUGANJ	26	NT	1948/1989	
175 MANUMUKH	26	NT	1958/1963	
175.5 SHERPUR	27	NT	1982/1989	
176 LEMSHIKHALI	41	TD	1969/1985	79/80
177 LAKPUR	18	TD	1968/1989	78/81,85,88
178 GHORASAL	18	TD	1968/1985	78/79,81/84
179 DEMRA	18	TD	1952/1989	59/63,70,83
180 NARAYANGANJ	30	TD	1947/1982	59/67,70,78/79
181 GUNABATI R. B.	34	TD	1965/1989	66,74,78/82
182 COMPANIGANJ	35	TD	1968/1989	70,84
183 KAITPARA	55	TD	1968/1989	70
184 PATUAKHALI	55	TD	1968/1984	
185 GALACHIPA	55	TD	1968/1986	77,85
186 JUGINI	15(B)	NT	1945/1989	47,59/63,79/80,82
187 TAKERHAT	51	TD	1968/1984	
188 RAJOIR	57	TD	1968/1978	
189 AMGRAM	57	TD	1968/1978	
190 MUSTAFAPUR	50	TD	1968/1989	78/87
191 CHARMUGURIA	57	TD	1968/1984	78/82
192 MOTIGANJ	25	NT	1958/1989	
193 KABIRAJPUR	57	TD	1968/1989	52/58,61,65/67,85
194 FATEHPUR	51	TD	1927/1978	45/51,58,61,65/67
195 JALILPAR	51	TD	1959/1979	65/67
196 SATPAR	51	TD	1959/1978	65/67
197 TENTULIA	51	TD	1932/1979	61,65/67
198 HARIDASPUR	51	TD	1958/1989	61,65/67,87
200 SHAPLAPUR	41	TD	1968/1989	75/82
201 MANU RLY. BR.	26	NT	1958/1989	
202 MOULVIBAZAR	26	NT	1949/1989	85
203 LAMA	39	NT	1962/1989	81
204 CHIRINGA	40	TD	1955/1989	58/61,65/68,75
205 KAZIPUR	42	NT	1960/1989	62/64

Notes : NT means non tidal stations
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STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
205A INSAFNAGAR	42	NT	1978/1989	80/82,84,87/88
206 HATBOALIA	42	NT	1946/1989	62/64
207 CHUADANGA	42	NT	1946/1989	62/64,71
208 DARSANA	42	NT	1958/1989	62/64
209 MOKRAMPUR	11	NT	1978/1979	
209A TENTULIA		NT	1978/1989	81/82
210 MOHANPUR	11	NT	1958/1981	59/63
211 GODAGARI	11	NT	1945/1980	59/63
211.5 CHAPAI N. GANJ	11	NT	1979/1989	
212 PARSURAM	36	NT	1957/1989	59
213 HARIPUR	36	TD	1968/1989	78,81/82
214 BELGORIA	12	NT	1951/1976	58,61
214A BADYA BELGORIA	13	NT	1965/1977	71
214a TELKUPI	13	NT	1964/1977	71
215 JHENAIDAH	58	NT	1949/1989	64,71
216 MAGURA	58	NT	1951/1989	64,78
216a MAGURA	44(C)	NT	1965/1985	
217 KALACHANDPUR	44(C)	TD	1957/1989	64/67
217A LOHAGARA	44(C)	TD	1968/1989	88
218 BARDIA	48(B)	TD	1953/1983	64/67
219 GAZIRHAT	48(B)	TD	1957/1989	64/67,84
220 KHEPUPARA	55	TD	1958/1986	65/67,81
221 NAODONA	33	TD	1959/1976	
222 NOAKHALI	35	TD	1958/1989	65/67
223 GOALKANDA	19	NT	1945/1989	83/85
224 OFFTAKE BANGSI		NT	1959/1963	
225 JAMALPUR	19	NT	1945/1989	82/85
226 SIRKHALI	19	NT	1959/1984	
227 O.T.OLD B.PUTRA	18	NT	1959/1989	71
228 MYMENSINGH	19	NT	1944/1985	48/56,59/60,71
228.5 NILUKHIRCHAR	20	NT	1959/1988	62/65,71
229 TOKE	20	TD	1948/1989	64/69,81/82
230 MOTHKHOLA	20	TD	1959/1984	64/67,81/82
230.1 B. BAZAR R.B.	30	TD	1964/1989	
232 PHULBARI	7	NT	1964/1989	71
233 RATNER BHANGA	24(A)	NT	1959/1989	62/63,66/74,81
234 COMPANIGANJ	24(A)	NT	1964/1989	71
235A PRANNAGAR	10	NT	1964/1989	65,71,87
236 PHULHAT	10	NT	1949/1989	59/63
237 NITHPUR	11	NT	1964/1989	86
238 ROHANPUR	11	NT	1950/1989	58/63,84/85
239 LAKSMIPUR	33	TD	1958/1989	62/67,71
240 BHAWANIGANJ	35	TD	1958/1989	62/67
241 KHULNA	48(B)	TD	1937/1989	39/40,58/61,63/67

Notes : NT means non tidal stations
TD means tidal stations

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STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
242 JALMA	49(B)	TD	1962/1981	63/67
243 CHALNA	49(B)	TD	1937/1989	43,47,63/67,78,82
244 MONGLA	49(C)	TD	1961/1989	63/67
245 RUMA	39	NT	1965/1989	79/83
246 GALIMKATA	39	NT	1965/1983	
247 BANDARBAN	39	NT	1965/1989	
248 DOHAZARI	40	TD	1969/1989	
249 ICHAKHALI	40	TD	1968/1978	
250 BANIGRAM	40	TD	1968/1985	83
251 SARIGHAT	24(A)	NT	1951/1989	71
252 GOWAINGHAT	24(A)	NT	1950/1989	
252.1 SALUTIKAR	24(A)	NT	1964/1989	71
253 SARUPKATI	50	TD	1959/1989	65/67,87
254 SATKHIRA	49(C)	TD	1968/1982	78
255 SHOVANALI	49(C)	TD	1968/1980	78
256 HABRAGANJ	49(C)	TD	1968/1980	78
257 MALIPUR	36	TD	1958/1989	65/67,78
258 PAIKGACHA	49(C)	TD	1961/1989	65/67,78/79
259 NALIANALA	49(C)	TD	1961/1989	65/67,72,78
260 PEARPUR	9	NT	1959/1978	60,71
261 NOWHATA	9	NT	1959/1989	71
262 BIJOYPUR	21(B)	NT	1958/1989	62/63,71,83
263 DURGAPUR	21(B)	NT	1965/1989	
263.1 KAMALKANDA	23	NT	1964/1989	69,71
264 MADHABPUR	31(B)	NT	1958/1963	
265 JALDHUP	26	NT	1957/1989	
266 KANAIGHAT	24(B)	NT	1952/1989	62/63,71,81
267 SYLHET	24(B)	NT	1937/1989	42/43,62/63,71
268 CHATAK	24(B)	NT	1949/1989	62/63,71
269 SUNAMGANJ	24(B)	NT	1949/1989	62/63
270 MARKULI	27	TD	1949/1989	62/67,77,82/83
271 AJMIRIGANJ	29	TD	1951/1989	62/67,77,82
272 MADNA	29	TD	1957/1989	62/67,77,82
272.1 AUSTAGRAM	29	TD	1968/1989	82
273 BHAIRAB BAZAR	31(B)	TD	1959/1989	62/67
274 NARSINDI	30(B)	TD	1959/1989	62/67
275 BADYER BAZAR	30(B)	TD	1959/1989	62/67,78,85
275.5 MEGHNA F. GHAT	30(B)	TD	1968/1989	78/79
276 SATNAL	30(B)	TD	1949/1989	61/68,78
277 CHANDPUR	32	TD	1947/1989	61/68,78/79
277.3 NILKAMAL	56	TD	1968/1989	78,85
277.5 CHARKURULIA	32	TD	1968/1977	
278 DAULAT KHAN	55	TD	1959/1989	62/67,80/82
279 TAJMUDDIN	55	TD	1959/1989	62/67,80/82

Notes : NT means non tidal stations
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STATIONS CODE & NAME (NUMERICAL ORDER)	PL.AREA (MPO)	NT/ TD	PERIOD AVAILABLE	MISSING YEARS
280 SUTANG RLY. BR.	29	NT	1964/1989	71
282 BHITARGARH	7	NT	1959/1989	71,81/82
283 MOLANI	7	NT	1959/1989	64,71,81
284 RANIGANJ	10	NT	1959/1989	62/63,71,82
285 THAKURGAON	10	NT	1964/1989	71
286 KAHARPARA	10	NT	1958/1981	62/76
287 KODALKATIGAON	10	NT	1960/1989	62/63,76,81
288 OFFTAKE MEGHNA	56	TD	1968/1982	
289 DHULIA	55	TD	1968/1985	78
290 DASMUNIA	55	TD	1968/1985	78
291 UTTARKHABARI	3	NT	1959/1962	
291.5 DOANI	3	NT	1979/1989	
291.5 DALIA	3	NT	1961/1989	63,69,71,73/77
292 GADDIMARI	3	NT	1951/1962	
293 KALIGANJ	3	NT	1948/1989	63,71
294 KAUNIA	3	NT	1945/1989	71
294.5 HARIPUR	3	NT	1978/1980	
295 AJABPUR	29	TD	1959/1989	64/67,71,77/78,82
296 AKHAURA	31(B)	TD	1959/1989	63/67,71,75/77,82
297 GOKARNA GHAT	31(B)	TD	1960/1989	64/67,77/78,81/82
298 HABINAGAR	31(B)	TD	1959/1989	61,64/67,77/78
299 TONGI	16(B)	TD	1960/1989	64/67,81
300 GOURNADI	50	TD	1957/1989	65/67,80,82
301 KALIAKAIR	16(B)	NT	1949/1989	81,83
302 MIRPUR	16(B)	TD	1952/1989	67,71
303 BRUNGAIL	17(B)	NT	1965/1975	71
304 GAZILKALI	17(B)	NT	1965/1976	71
305 CHATIRGHAT	7	NT	1961/1977	64/76
305.5 GHORAMARA GHAT	7	NT	1969/1978	71
306 GABTALI	6	NT	1965/1976	
307 KARNAPARA	17(B)	TD	1968/1975	71
308 KHAJANCHIGAON	27	NT	1964/1977	
309 LALCHANDPUR	4	NT	1964/1976	71
310 NETROKONA	22	NT	1977/1987	82,86
311 ATPARA	22	NT	1987/1989	
312 TALORA	8	NT	1965/1988	71
313 NONGURA R. B.	14	NT	1965/1989	
314 GHOSE GAON	21(B)	NT	1965/1989	71
315 CHHATAK	24(B)	NT	1966/1976	
316 TEKNAF	40	TD	1968/1988	83/85
321 HATYA	60	TD	1968/1989	78,82
324 DHUNAT	6	NT	1964/1989	66,71
325 SONAMUKI	8	NT	1973/1989	75
327 BOALMARI		NT	1983/1989	

Notes : NT means non tidal stations
TD means tidal stations

LIST OF WATER LEVEL AND DISCHARGE
DATA AVAILABLE WITH FAP25

FAP-25 WATER LEVEL DATA STATUS

STATION	YRS	64	65	66	67	68	69	70	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
5 Madaripur	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
7.5 Demra	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	A	A	A	*
9 Kaoraid	23	A	A	A	M	A	A	A	A	A	A	A	A	A	A	A	*	*	*	*	*	*	*	*	*	M
36 Jaria Janjail	24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
39 Patherghata	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
45 Nunkhawa	24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*
45.5 Chilmari	17	M	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	M	M	*	*	*	M	M	M	M
46.7L Kholabarichar	25	A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
46.9L Bahadurabad	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
46.9R Fulchari	21	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	M	*	*	*	*	*	*	*	M
49 Serajganj	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
49A Kazipur	22	M	M	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
50 Porabari	25	A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	A	*	*
50.3 Mathura	24	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
66 Ullapara	23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	M
90 Hardinge Bridge	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
91.1 Sengram	23	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*
91.2 Mahendrapur	22	M	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*
91.9L Baruria	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
91.9R Goalunda Tr	21	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	A	A	M	M	M	*	*
93.5L Mawa	21	M	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	M	*	*
93.5R Bhagyakul	12	M	M	M	M	*	*	*	*	*	*	*	M	*	M	M	M	*	M	*	*	*	M	M	M	M
99 Gorai Rly Bridge	23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	*	*	*	*
101 Kamarkhali	23	M	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*
101.5 Kamarkhali	21	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	M	*	*	*	M
107.2 Rayenda	20	M	M	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	M
137A Taraghat	22	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	M	M

Note : * = Data Available in Computer Database; A = Hardcopy Available; M = Missing

FAP-25 WATER LEVEL DATA STATUS

STATION	YRS	64	65	66	67	68	69	70	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
145 Mohadevpur	24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M
147 Atrai	23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M
173 Sheola	24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
174 Fenchuganj	23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	M
185 Golachipa	23	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*
225 Jamalpur	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	A	A	A	A
228.5 Nilukhirchar	22	M	M	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
229 Toke	18	M	M	M	M	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	*	*	A	A	M	M
230.1 Bharab RB	24	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
243 Chalna	12	M	M	M	M	*	*	*	*	*	*	*	*	*	M	M	*	*	M	*	M	M	M	M	M	M
244 Mongla	24	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
266 Kanaighat	24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*
267 Sylhet	23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	*	*	*	*
268 Chatak	22	A	A	A	M	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	*	*	*	*	M	M
273 Bhairab Bazar	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
275 Badyer Bazar	19	M	M	M	M	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	M	*	*
275.5 Meghna F. Ghat	13	M	M	M	M	*	*	*	*	*	*	*	*	M	M	M	*	M	M	M	M	M	*	*	*	*
277 Chandpur	24	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
278 Daulatkhan	21	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	M	*	*	*	*	*	*	*
290 Dasmonia	22	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	*	*	*	*	*	*	*
291.5L Doani	3	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	*	*	M	*
294 Kaunia	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
302 Mirpur	8	M	M	M	M	M	M	M	M	M	M	M	M	M	*	M	M	*	*	*	*	*	*	*	M	M

Note : * = Data Available in Computer Database; A = Hardcopy Available; M = Missing

FAP-25 DISCHARGE DATA STATUS

STATION	YRS	64	65	66	67	68	69	70	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
9 Kaoraid	13	M	*	*	*	*	*	*	M	*	*	*	*	*	*	M	*	M	M	M	M	M	M	M	M	M
14.5 Nayarhat	9	M	M	M	M	M	M	M	M	M	M	M	M	M	M	A	A	A	A	A	A	A	A	A	M	M
36 Jaria Janjail	21	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*
46.9L Bahadurabad	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
66 Ullapara	23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	*	M
90 Hardinge Bridge	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
91.9L Baruria	22	M	M	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*
93.5L Mawa	22	M	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	*	*	M
99 Gorai Rly Bridge	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
101 Kamarkhali	3	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	A	A	A	M	M	M	M
101.5 Kamarkhali	18	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	M	M	M	M	M
134 Jokerchar	18	M	M	M	M	A	A	A	A	A	A	A	A	A	A	A	A	M	M	A	A	A	A	A	A	M
134A Baushi Bridge	10	M	M	M	M	M	M	A	A	A	A	A	A	A	A	A	A	M	M	M	M	M	M	M	M	M
137A Taraghat	18	M	M	M	M	*	*	*	*	*	*	*	*	M	*	*	*	*	M	*	*	*	A	A	A	M
145 Mohadevpur	17	M	M	M	M	M	M	M	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
162 Jhikargacha	17	M	*	*	*	*	M	*	M	*	*	*	*	*	A	A	A	A	A	*	*	M	M	M	M	M
173 Sheola	22	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
179 Demra	18	M	*	*	*	*	M	M	M	M	M	*	*	*	M	*	*	*	*	*	*	*	*	A	*	A
228.5 Nilukhirchar	23	*	*	*	*	*	*	*	M	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
230.1 Bharab RB	19	M	M	M	M	M	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	*	*
266 Kanaighat	19	M	M	M	M	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
273 Bhairab Bazar	21	*	*	*	*	*	*	*	*	*	*	*	*	M	M	M	M	*	*	*	*	*	*	*	*	*
294 Kaunia	23	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M

Note : * = Data Available in Computer Database; A = Hardcopy Available; M = Missing

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82

LIST OF OBSERVED DISCHARGE DATA
AVAILABLE WITH FAP25

FAP-25 OBSERVED DISCHARGE DATA STATUS

STATION	YRS	65	66	67	68	69	70	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
36 Jaria Janjail	14	M	M	M	M	*	*	M	*	*	M	M	M	M	M	M	*	*	*	*	*	*	*	*	*	*
46.9L Bahadurabad	22	M	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	M
90 Hardinge Bridge	21	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M	M	*	*	*	*	*	*	*	M
91.9L Baruria	20	M	*	*	*	*	*	*	*	*	*	*	M	M	*	M	*	*	*	*	*	*	*	*	*	M
93.5L Mawa	22	M	*	*	*	*	*	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	M
145 Mohadevpur	16	M	M	M	M	M	M	M	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	*	*	M
173 Sheola	15	M	M	M	M	*	*	M	*	*	*	M	M	M	M	*	M	*	*	*	*	*	*	*	*	*
266 Kanaighat	14	M	M	M	M	*	*	M	*	*	M	M	M	M	M	*	M	*	*	*	*	*	*	*	*	*
273 Bhairab Bazar	21	M	M	*	*	*	*	*	*	*	M	*	*	*	*	*	*	*	*	*	*	*	*	*	*	M
294 Kaunia	19	M	*	*	*	*	*	*	*	*	*	*	*	*	M	*	M	M	*	M	*	*	*	*	*	M

Note : * = Data Available in Computer Database; M = Missing

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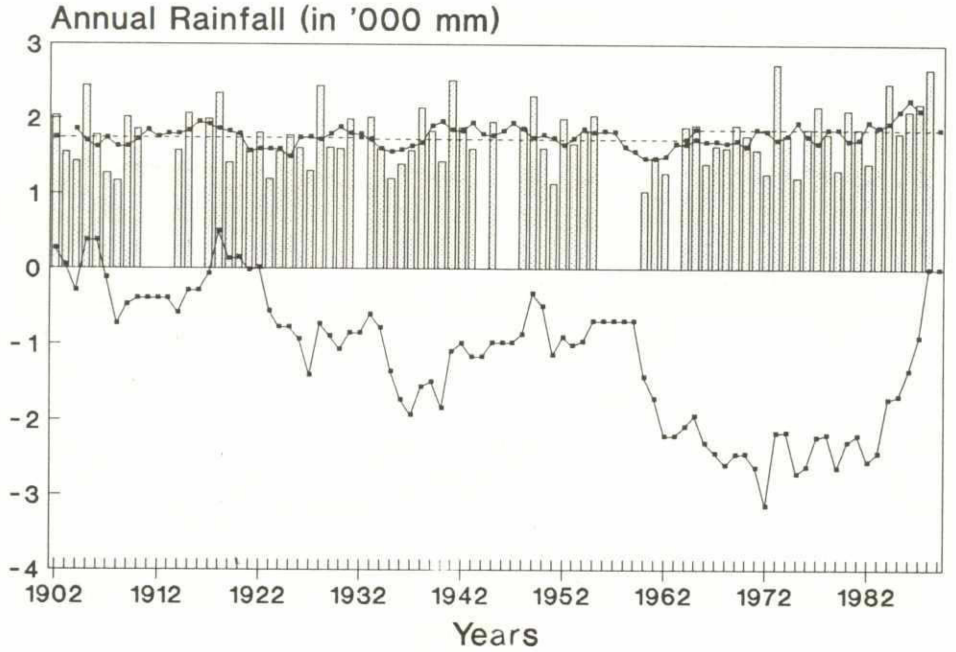
APPENDIX 3

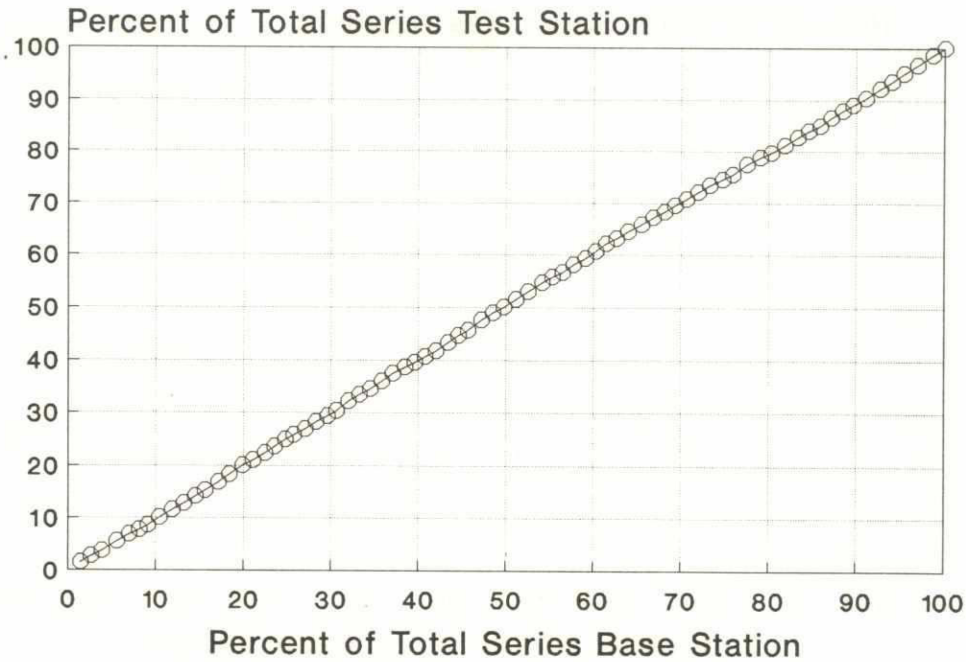
ReviewRainfall Data

Appendix 3 contains graphical representation of rainfall data analyses carried out by Flood Hydrology Study for 27 stations in Bangladesh, 17 stations in India and one station in Nepal. The upper graphs show the time series plot, 5 year moving average, 2-interval mean and residual mass curves for the available record and the lower one presents double mass analysis of each station against mean of the representative stations of the catchment considered for the study. Analyses of Bangladeshi stations are given in pages A.3-2 to A.3-28. Similar plots of Indian stations are available at page A.3-29 to A.3-45. The single Nepalese station (Kathmandu) is shown in page A.3-46.

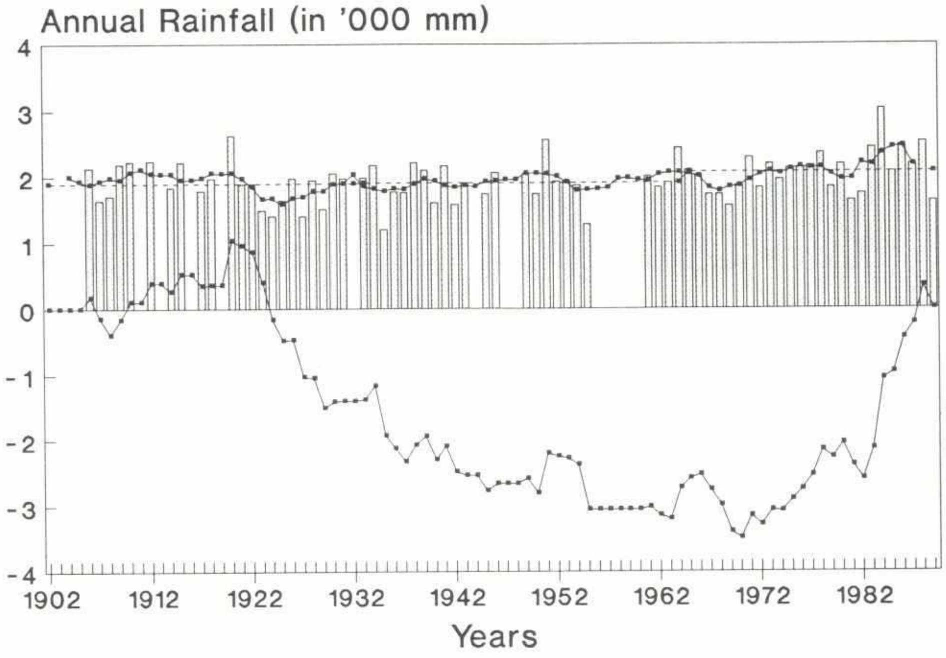
STATIONS IN BANGLADESH

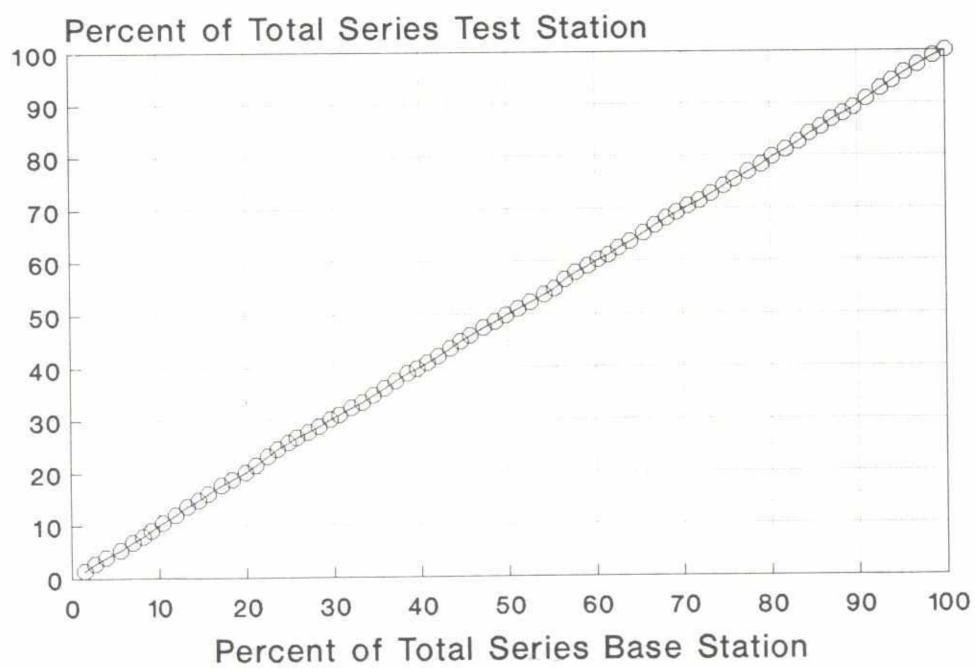
BOGRA


Annual Rainfall (in '000 mm)
3
2
1
0
-1
-2
-3
-4
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years

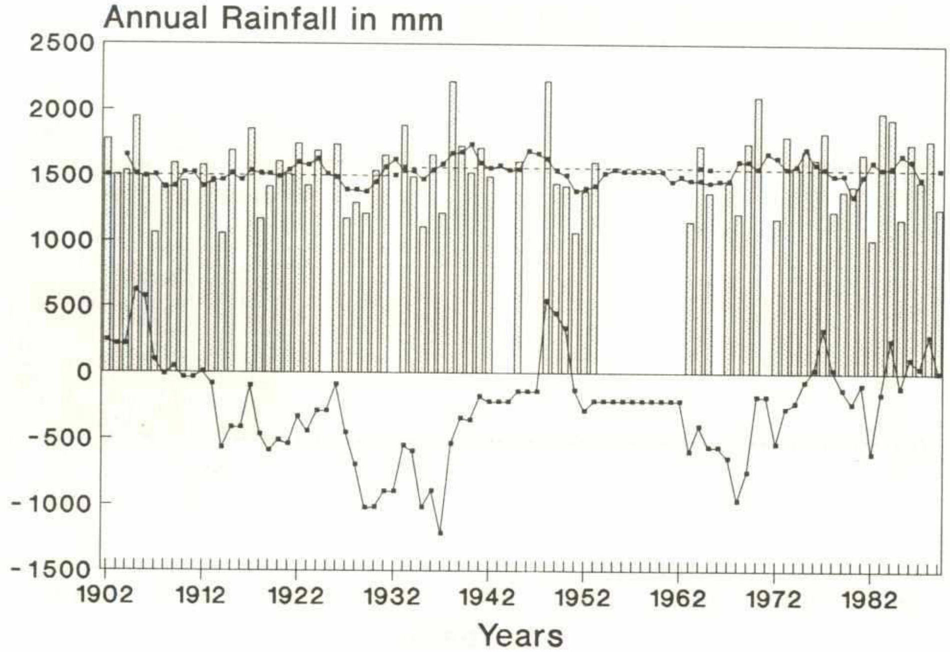

Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

DHAKA

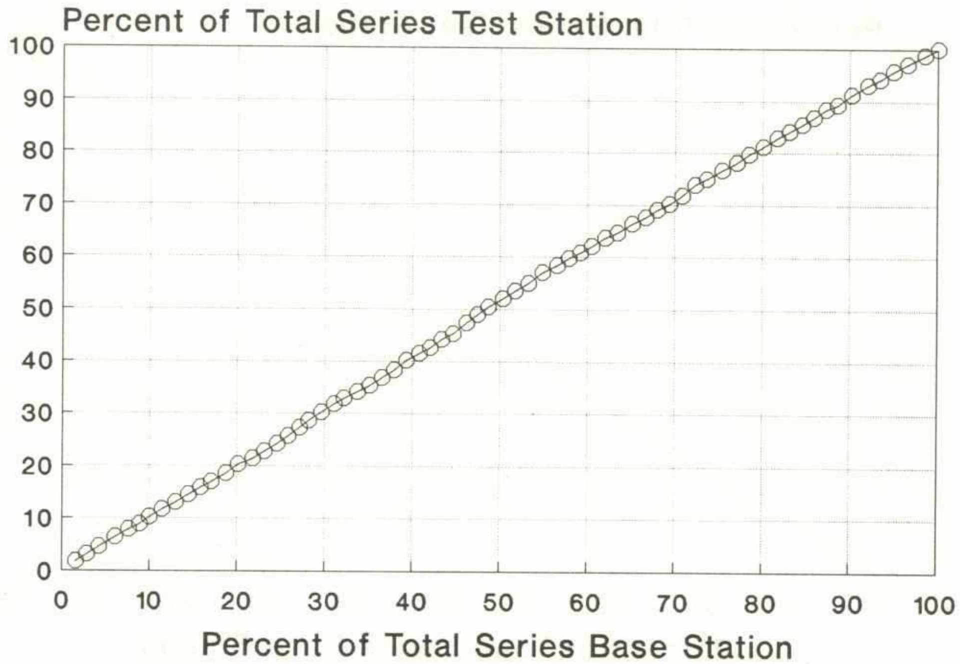

Annual Rainfall (in '000 mm)
4
3
2
1
0
-1
-2
-3
-4
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

PABNA

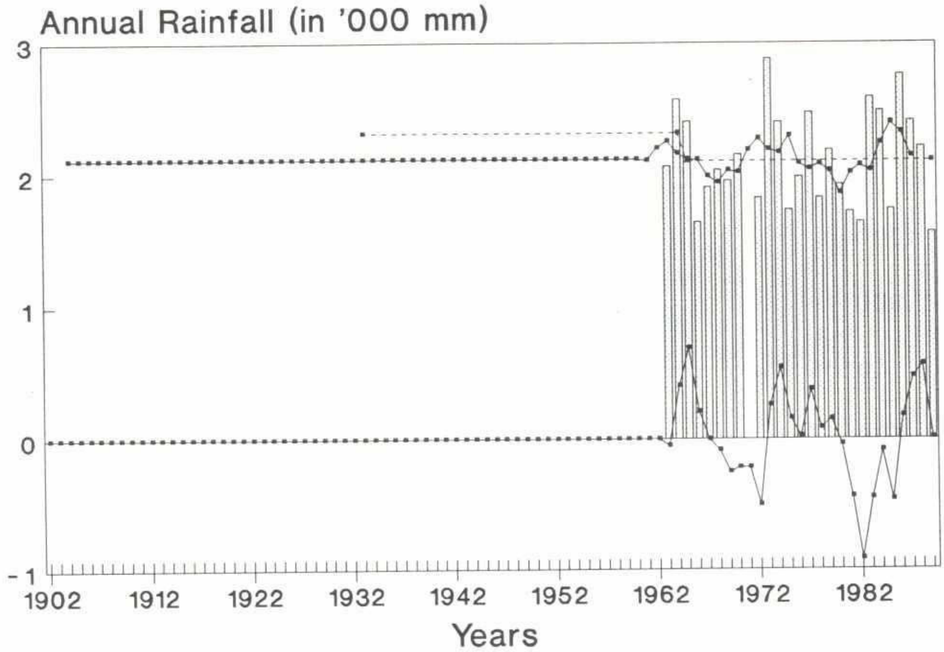


Annual Rainfall in mm
2500
2000
1500
1000
500
0
-500
-1000
-1500
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years

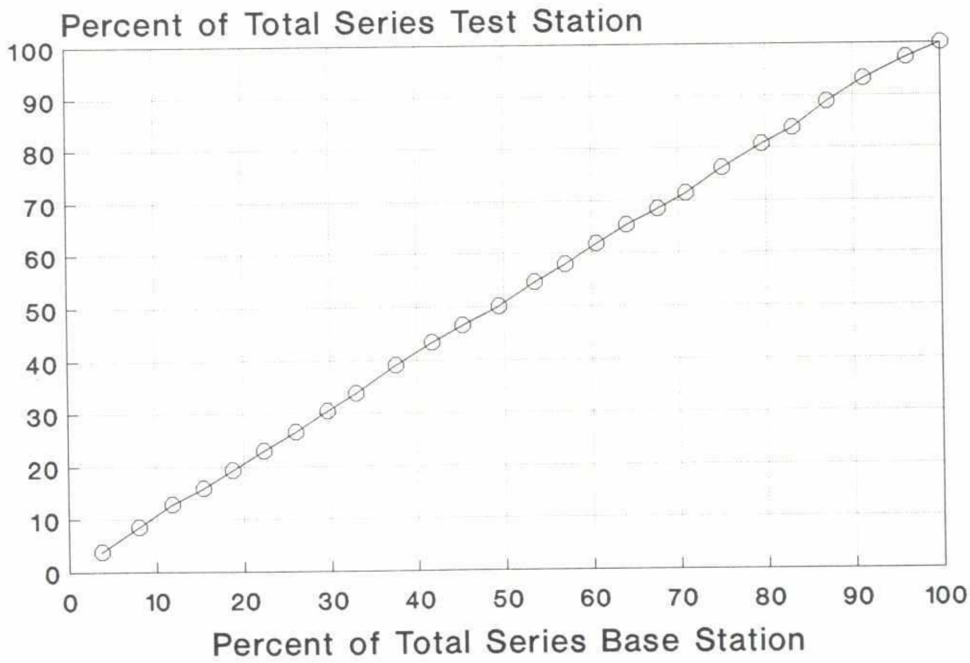


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

PHULBARI

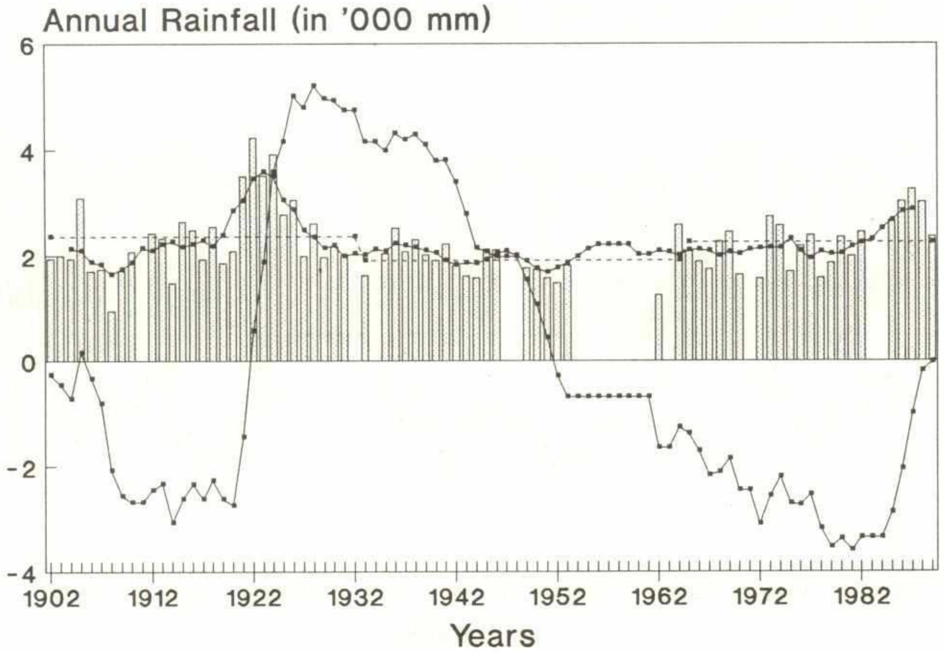


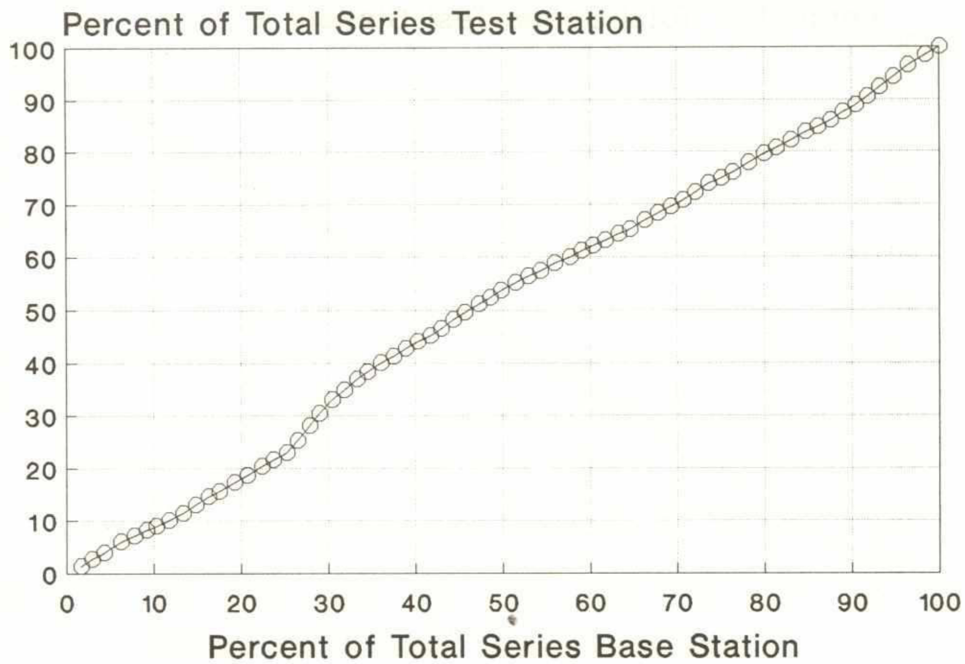
Annual Rainfall (in '000 mm)
3
2
1
0
- 1
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years



Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

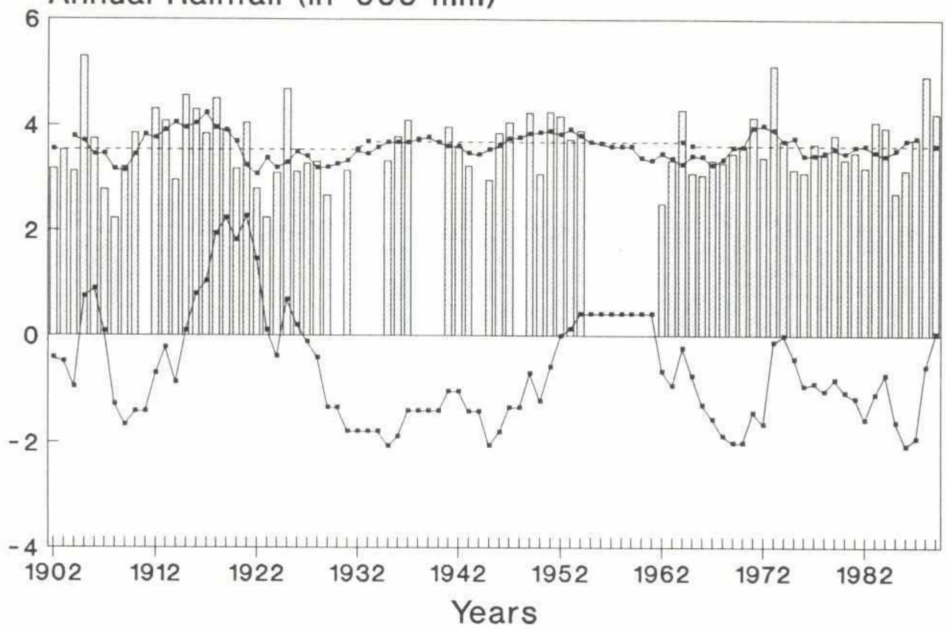
DEWANGANJ

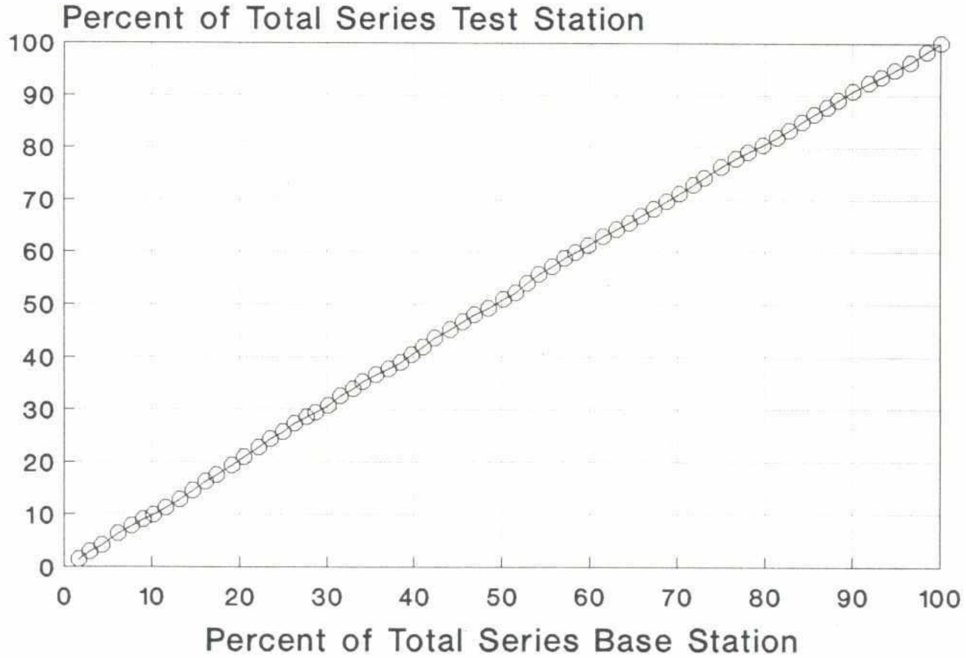

Annual Rainfall (in '000 mm)
6
4
2
0
-2
-4
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

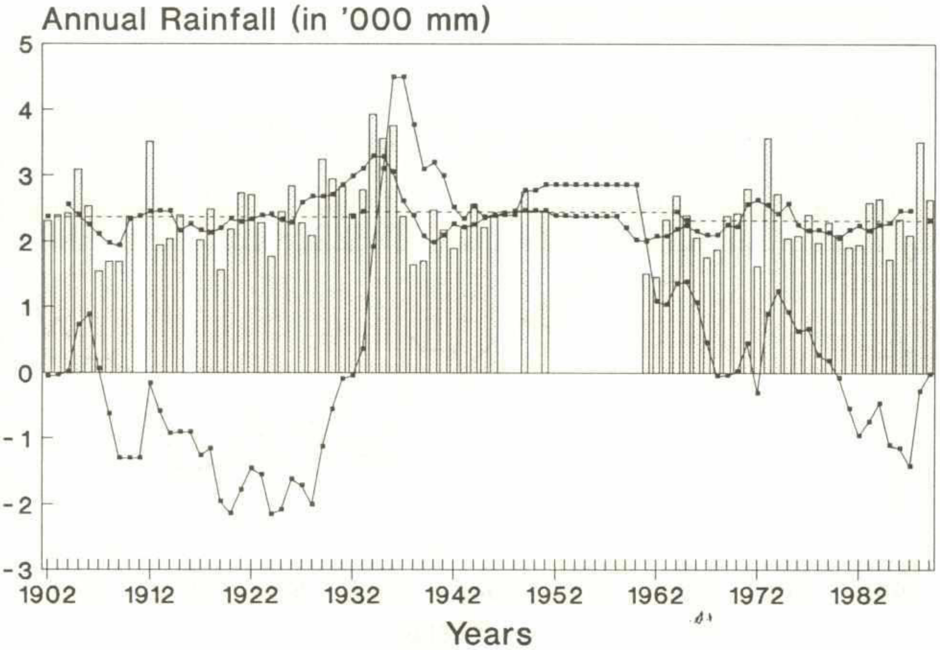
82

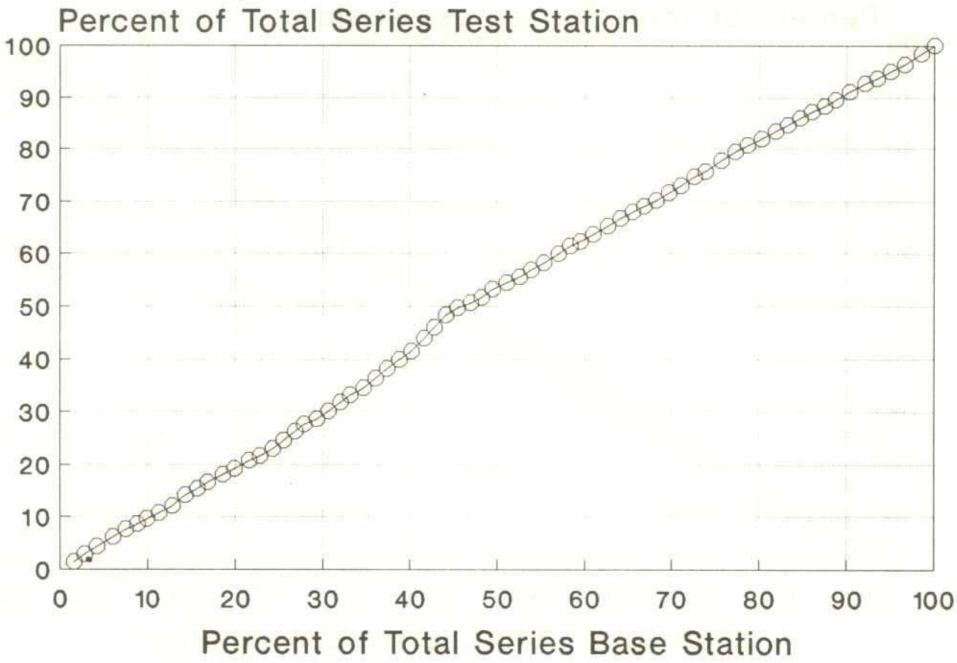
DURGAPUR


Annual Rainfall (in '000 mm)
6
4
2
0
-2
-4
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

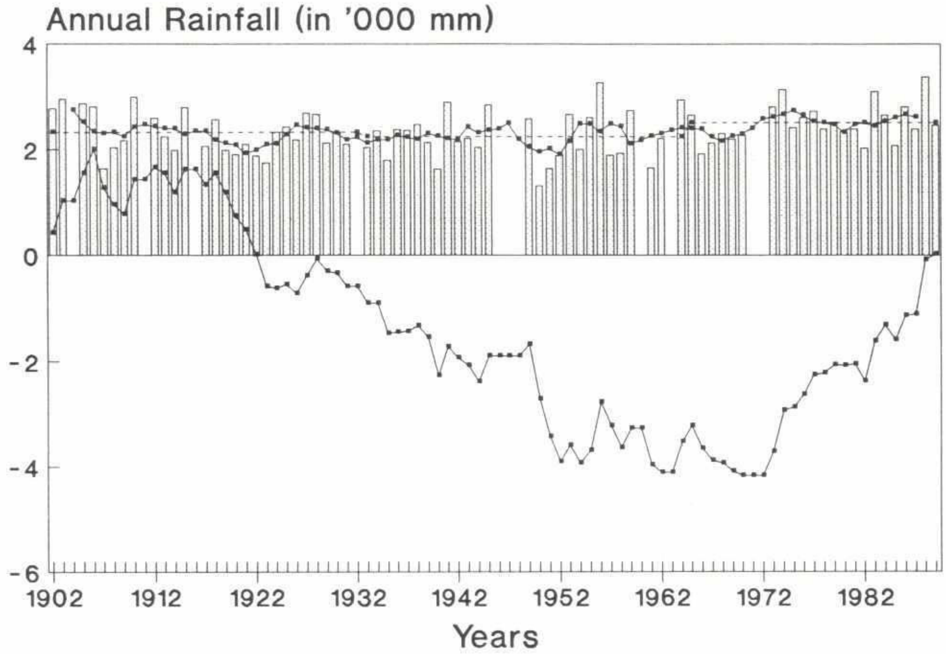
KISHOREGANJ

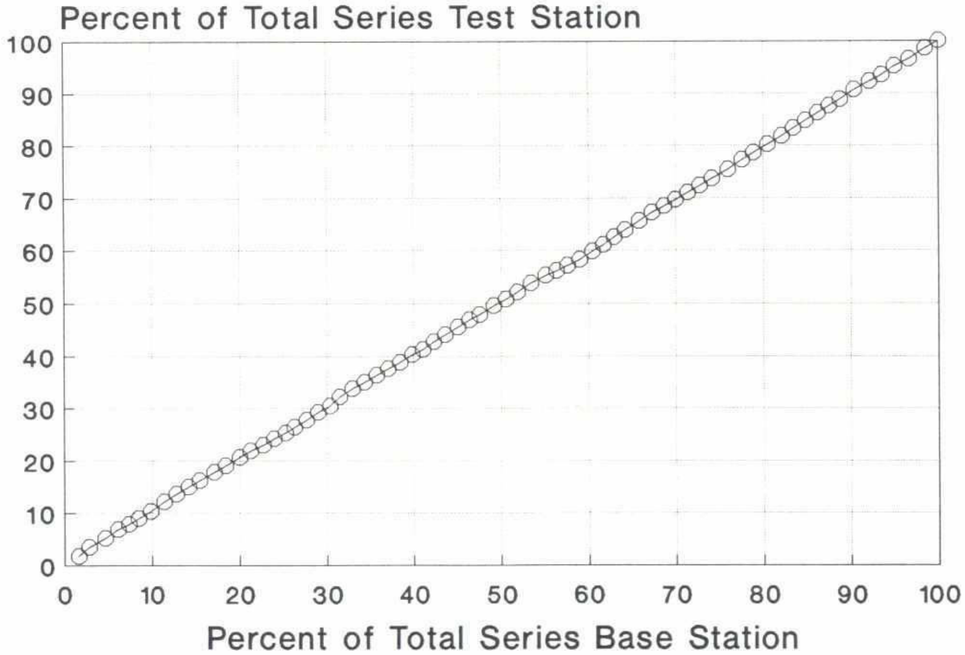




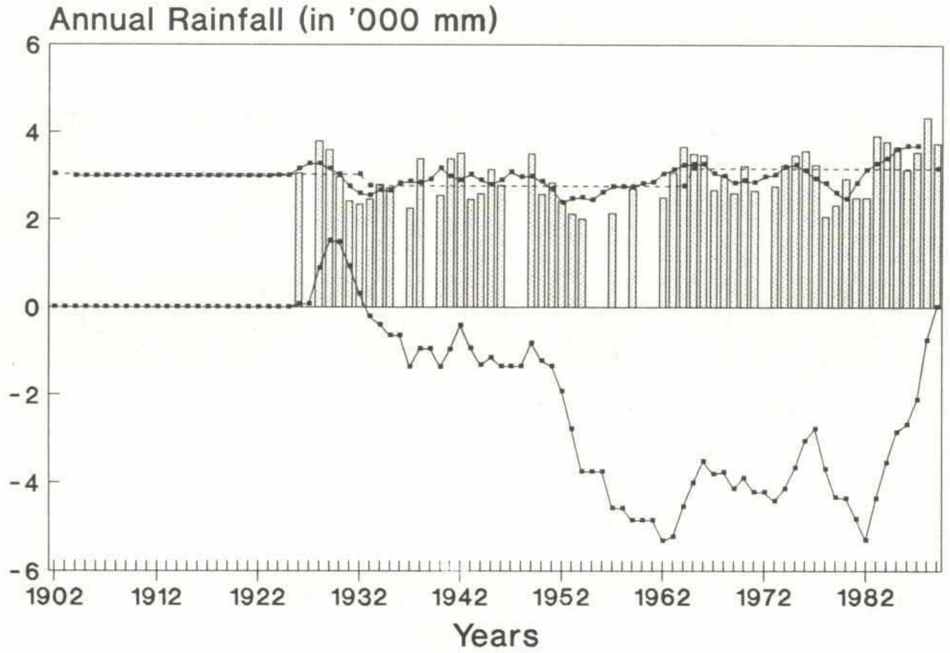
58

MYMENSINGH

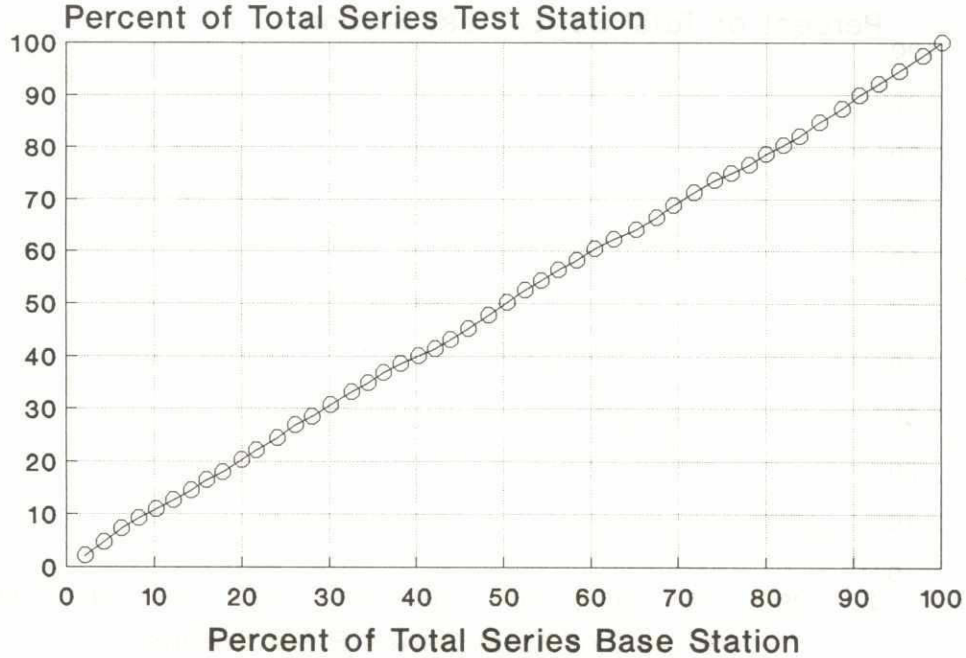




CHANDBAG



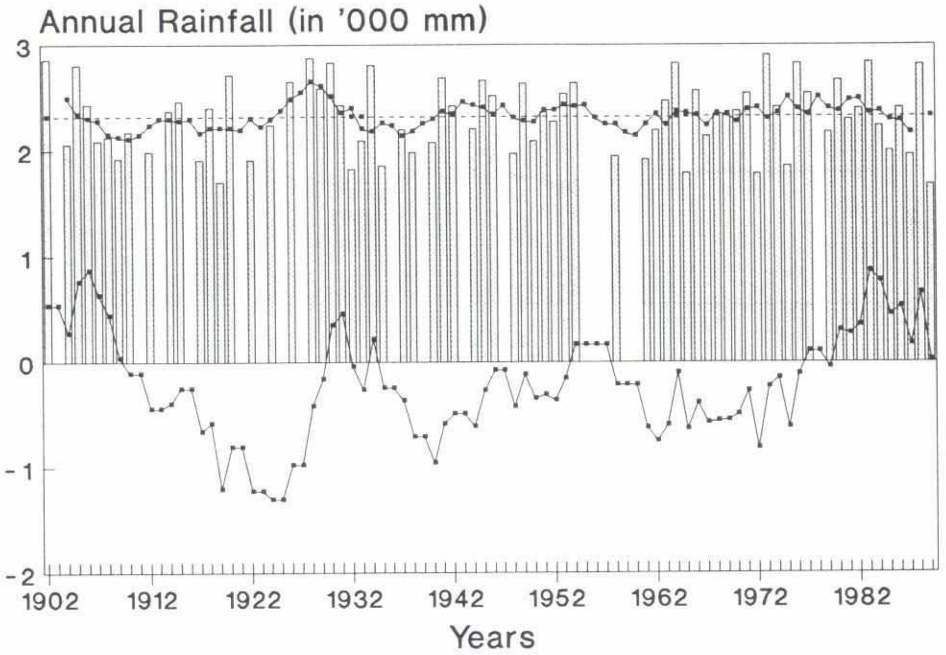
Annual Rainfall (in '000 mm)
6
4
2
0
-2
-4
-6
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years

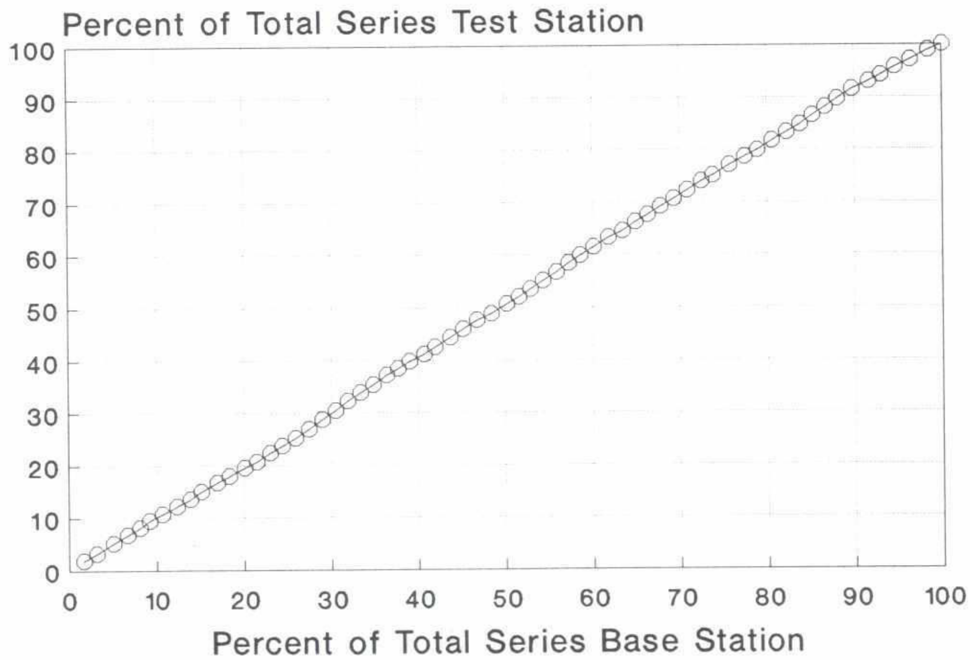


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

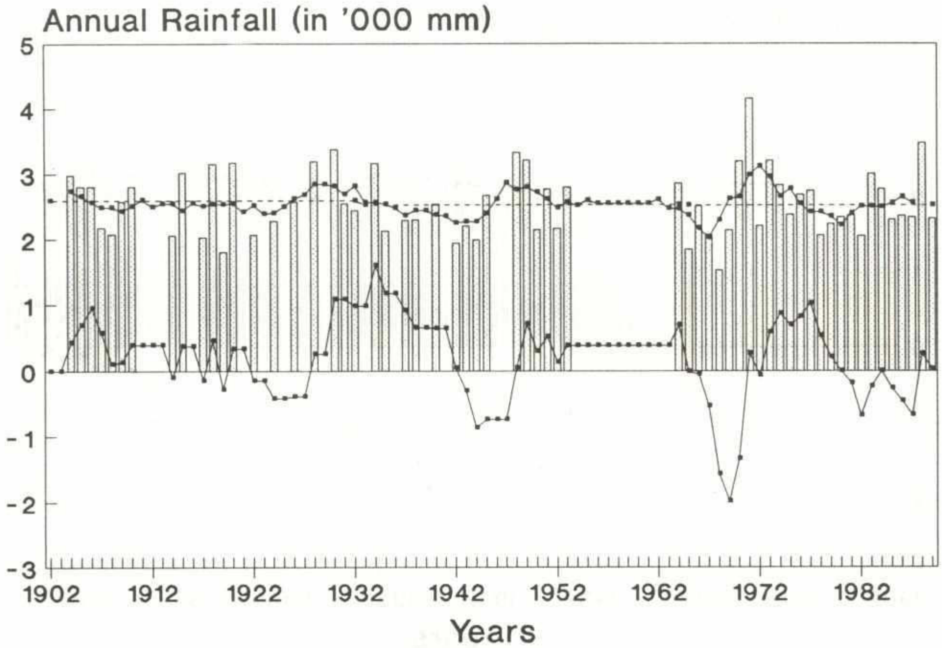
67

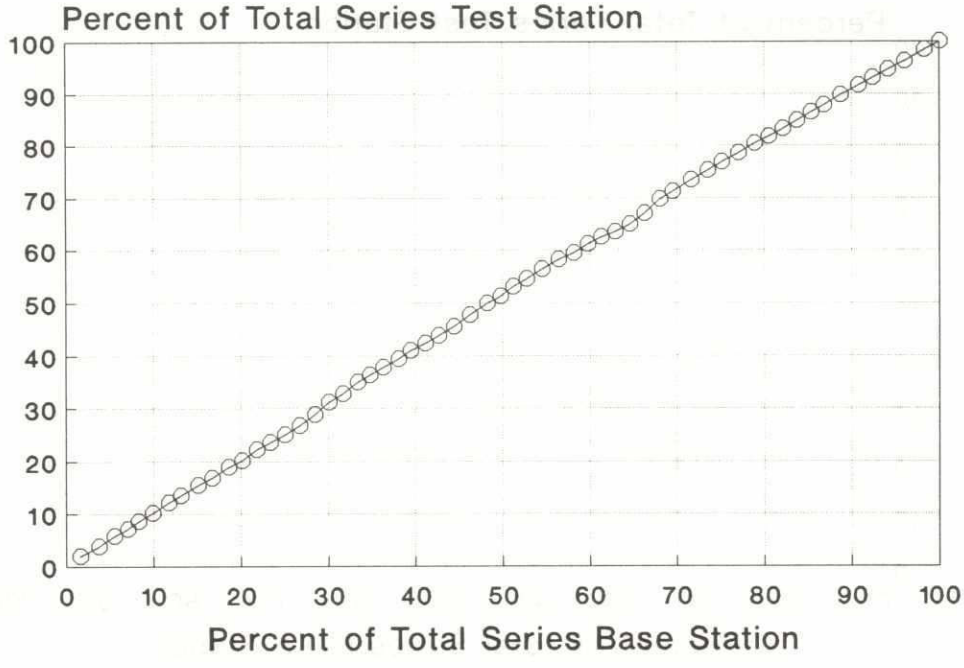
CHANDPUR BAGAN



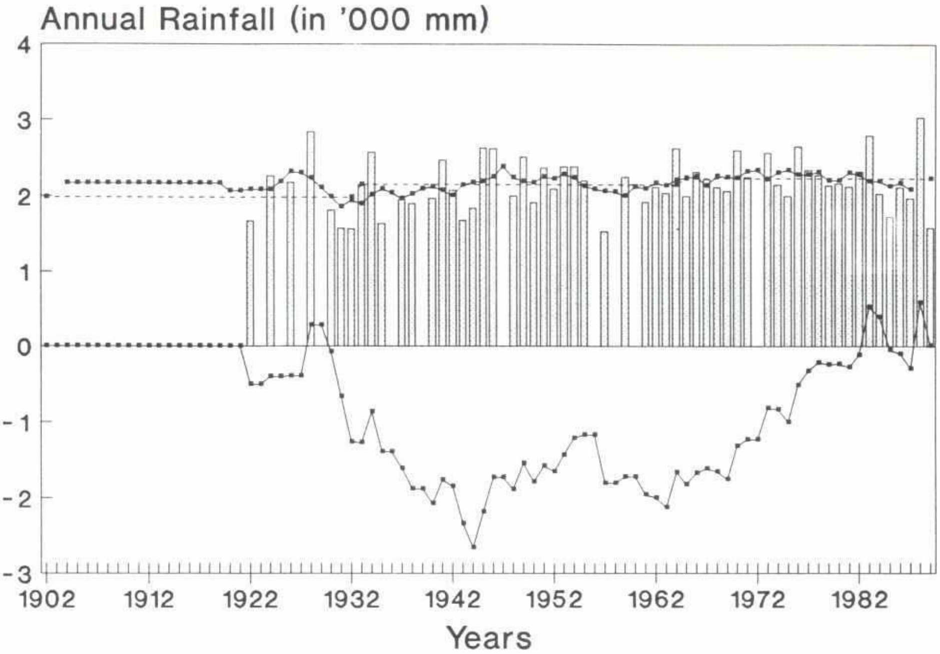


HABIGANJ

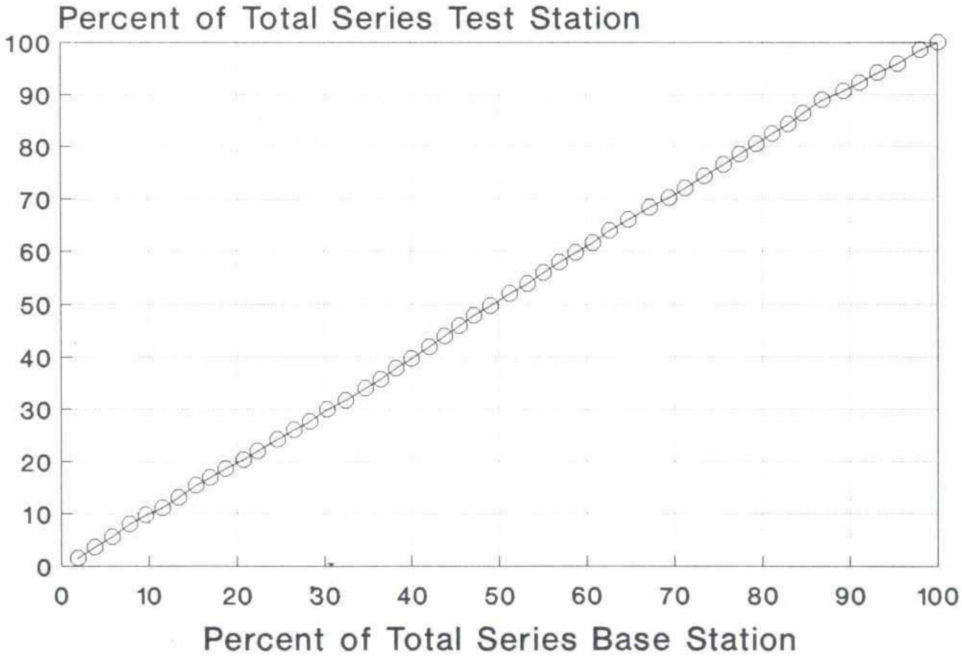

Annual Rainfall (in '000 mm)
5
4
3
2
1
0
-1
-2
-3
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

ITAKHOLA

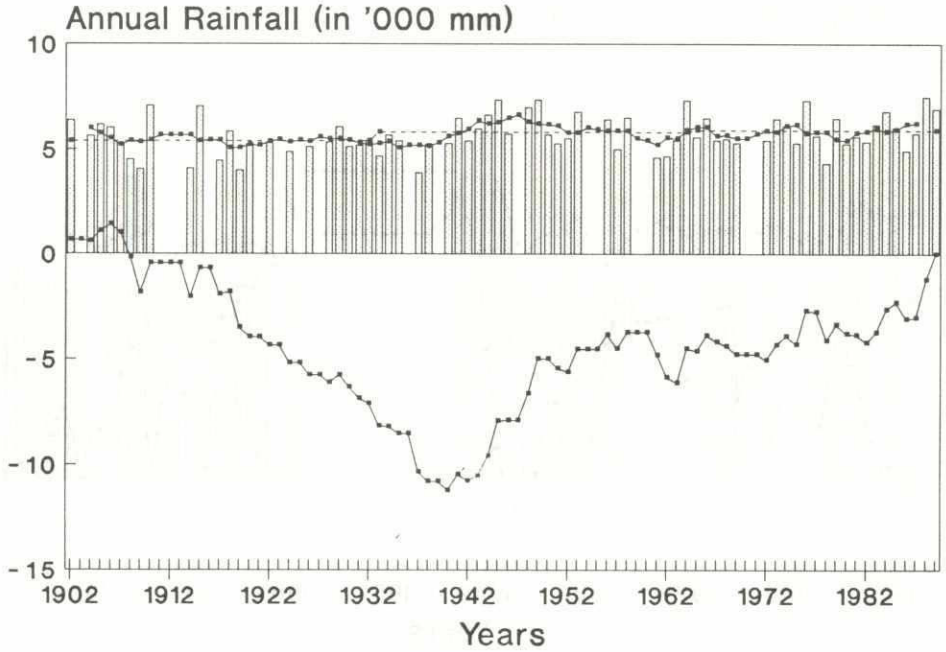


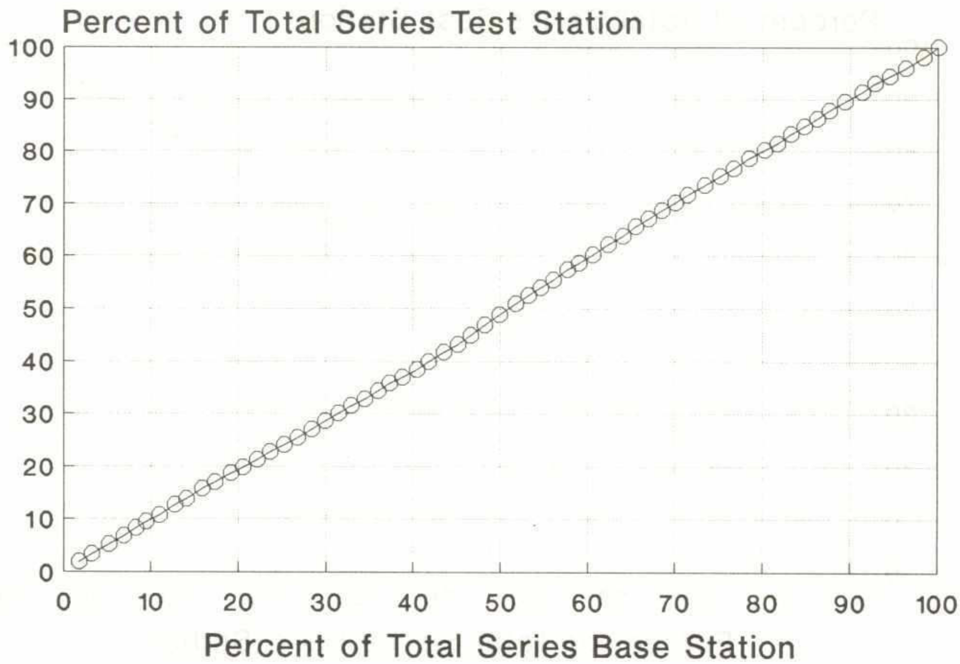
Annual Rainfall (in '000 mm)
4
3
2
1
0
- 1
- 2
- 3
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years



Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

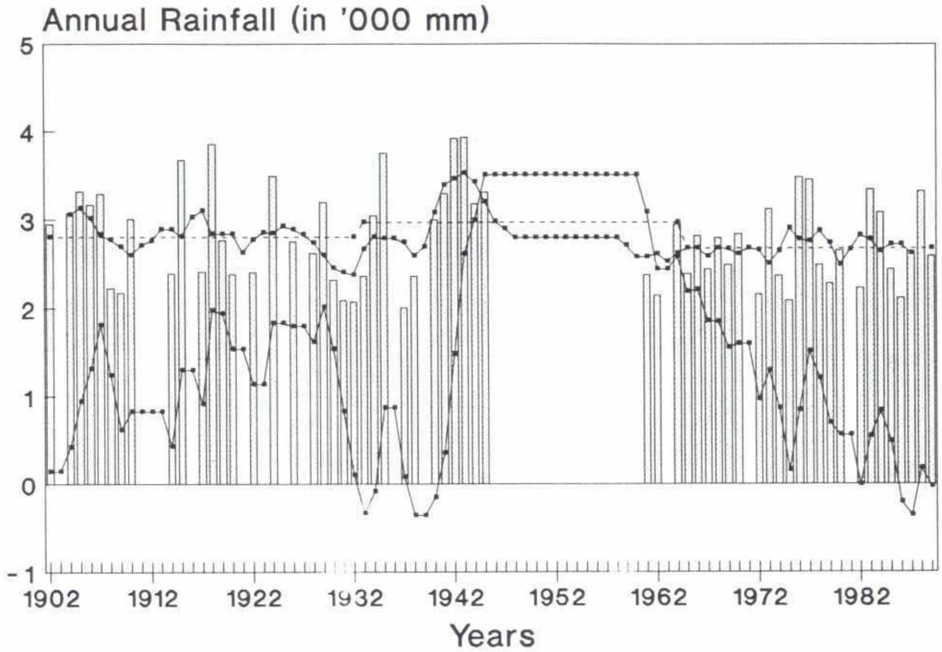
LALLAKHAL

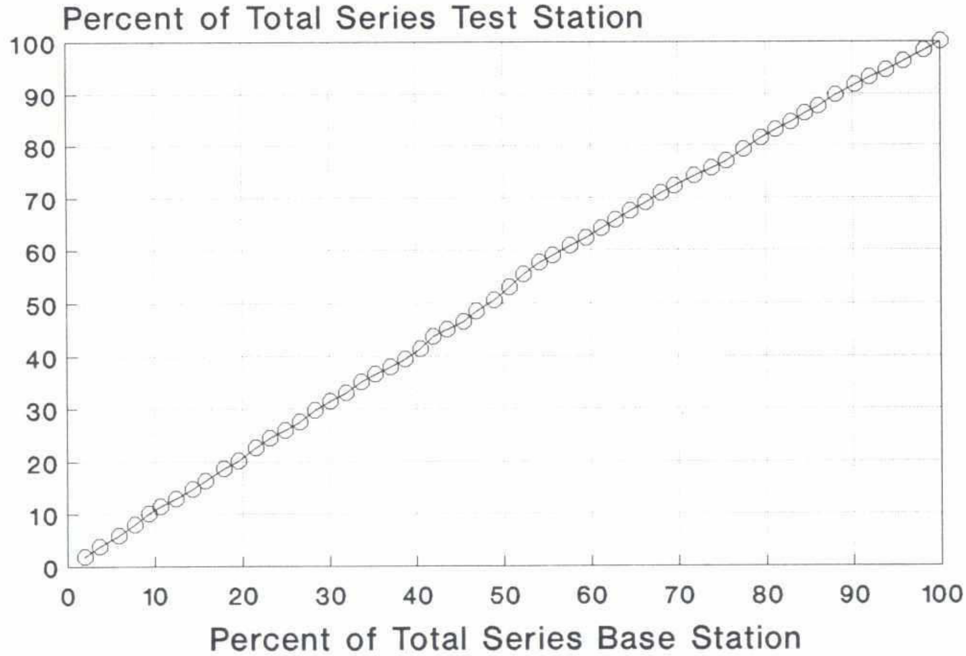

Annual Rainfall (in '000 mm)
10
5
0
-5
-10
-15
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

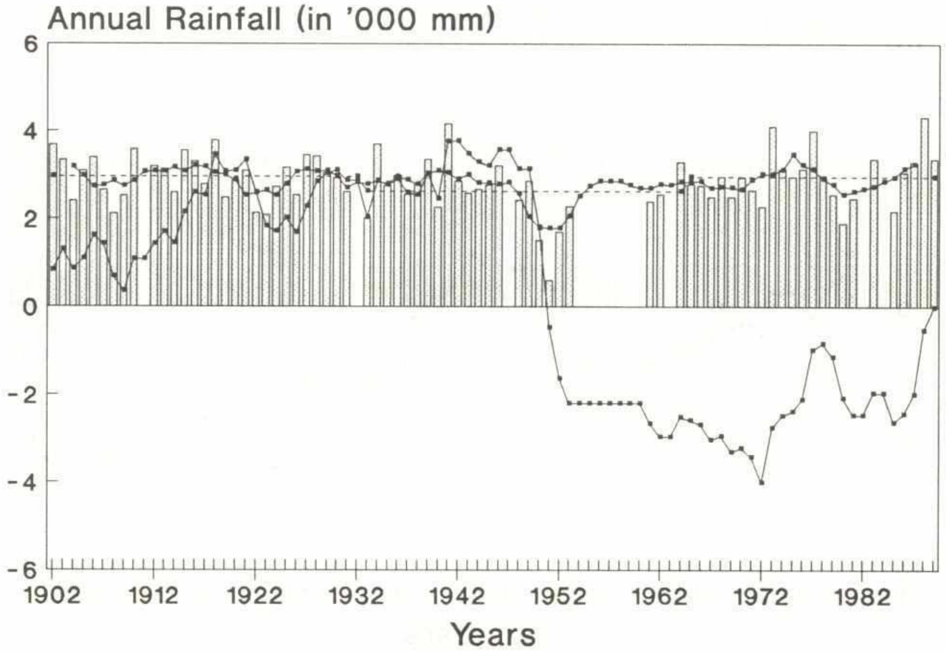
yD

MOULVI BAZAR

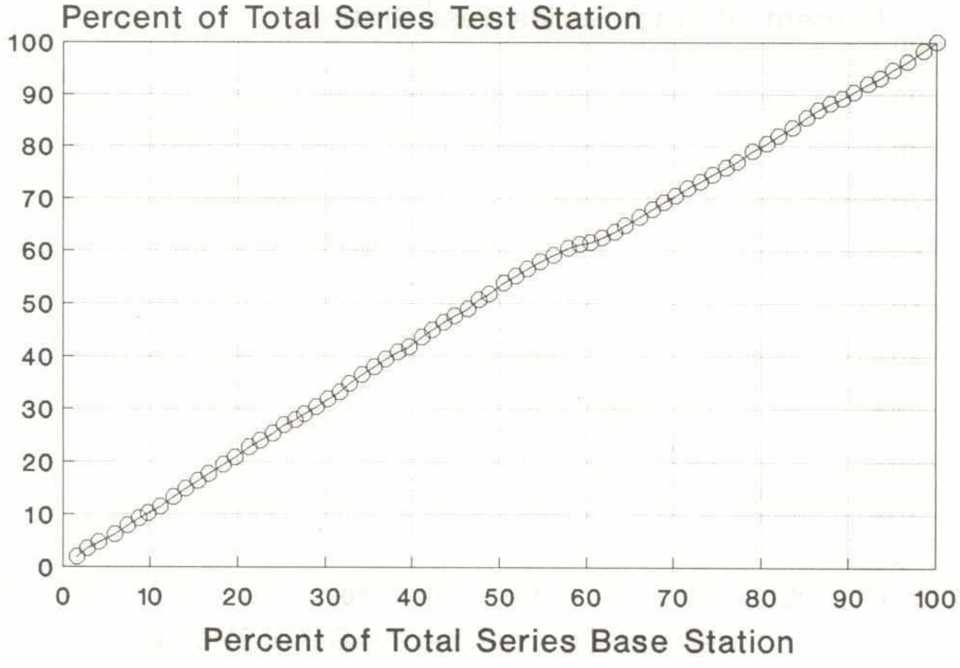




NETROKONA

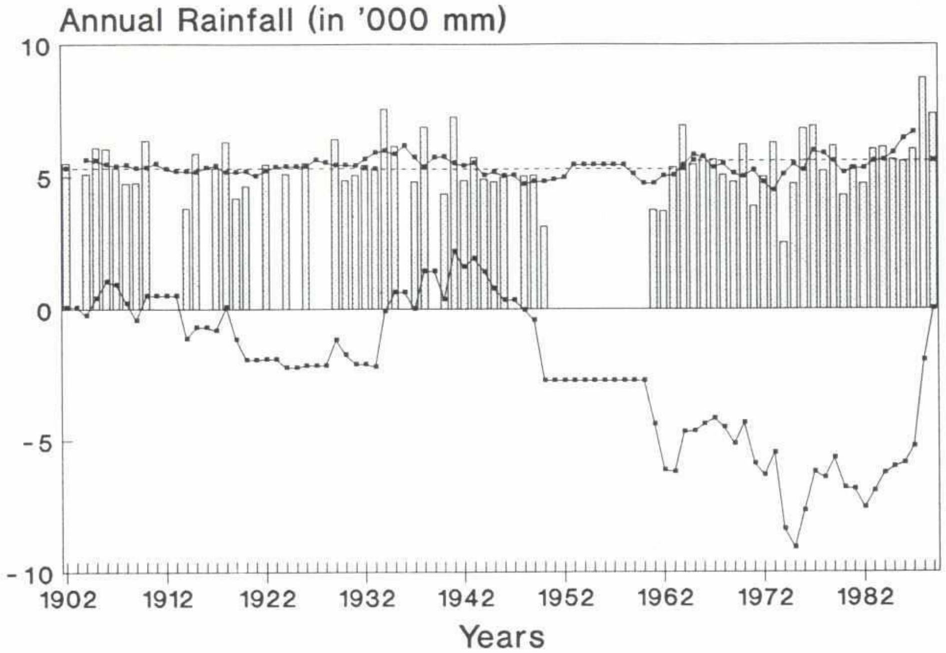


Annual Rainfall (in '000 mm)
6
4
2
0
-2
-4
-6
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years

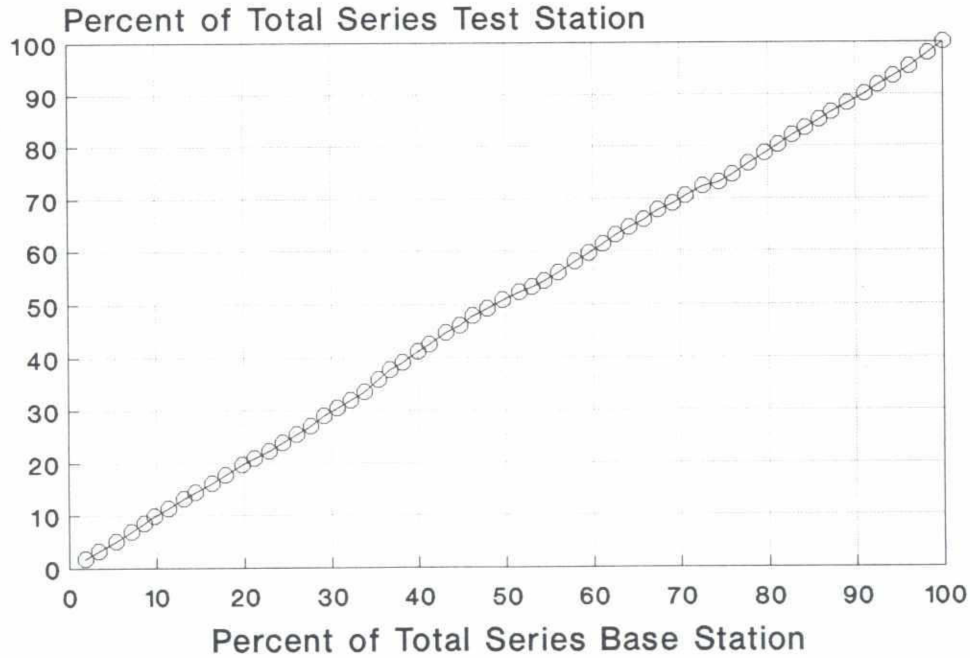


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

SUNAMGANJ

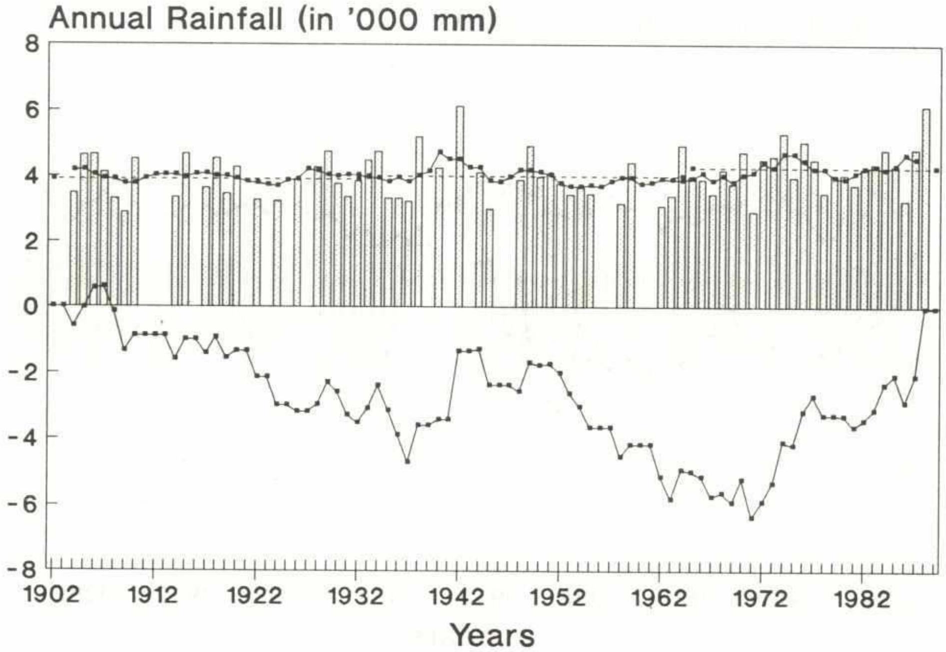


Annual Rainfall (in '000 mm)
10
5
0
-5
-10
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years

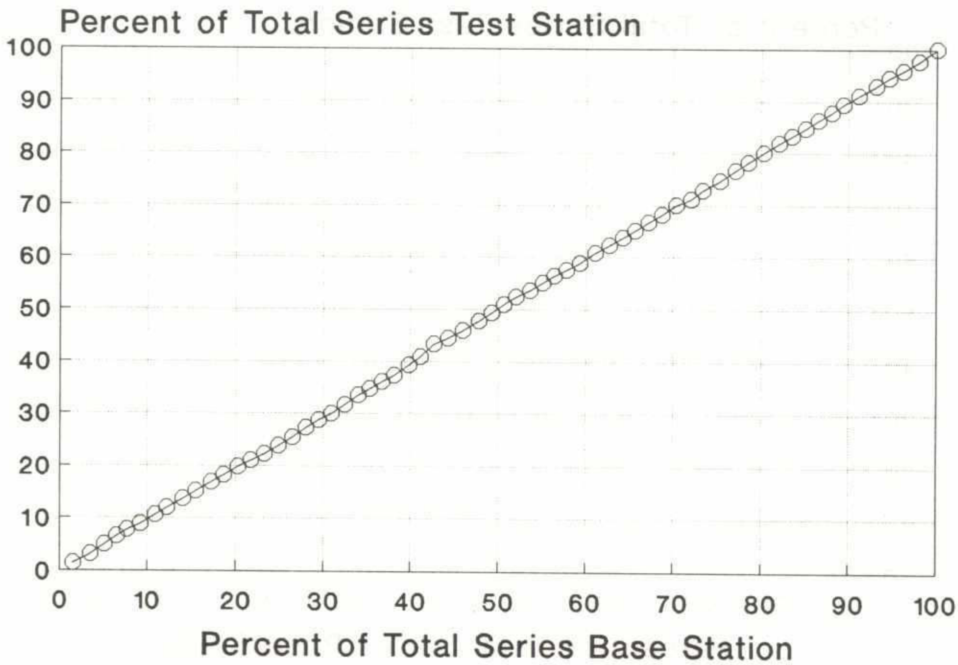


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

SYLHET

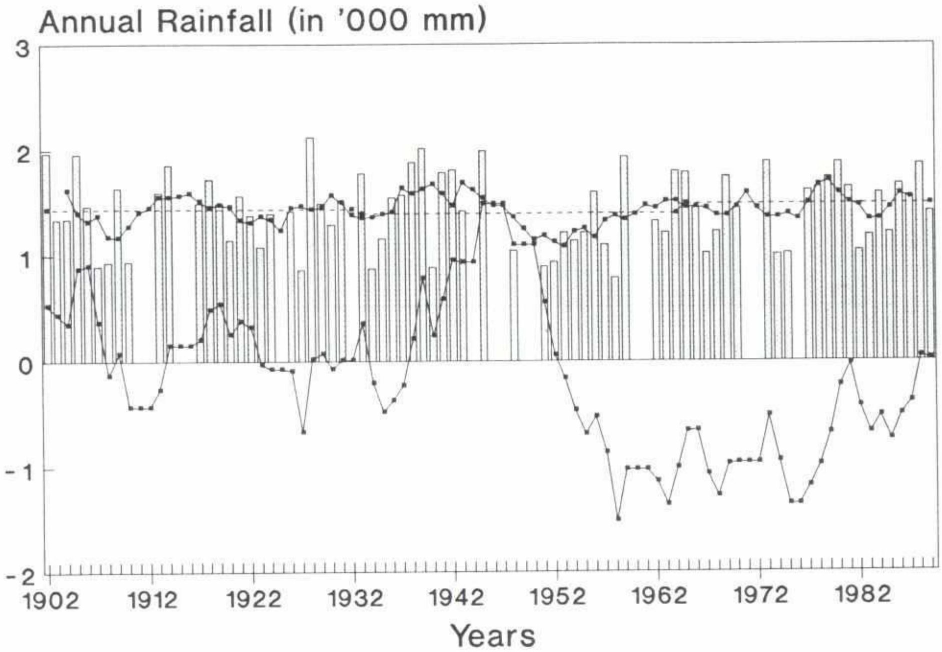


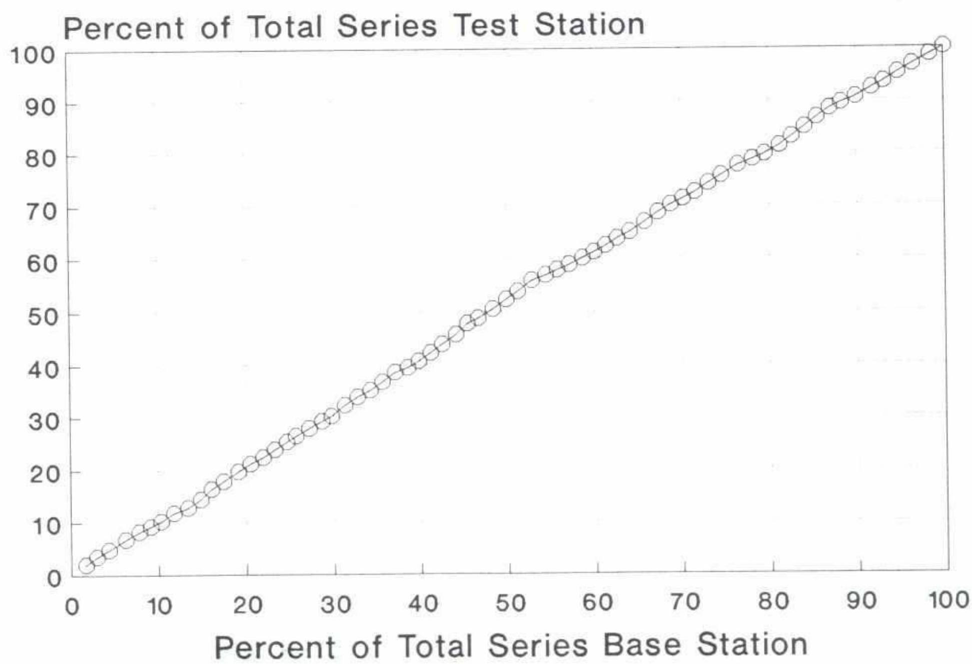
Annual Rainfall (in '000 mm)
8
6
4
2
0
-2
-4
-6
-8
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years



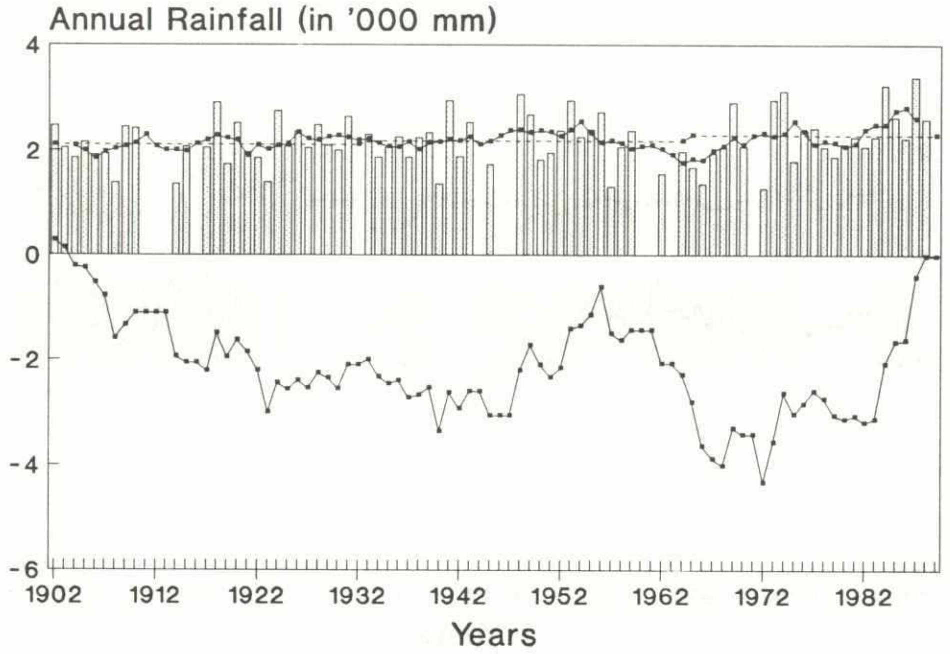
Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

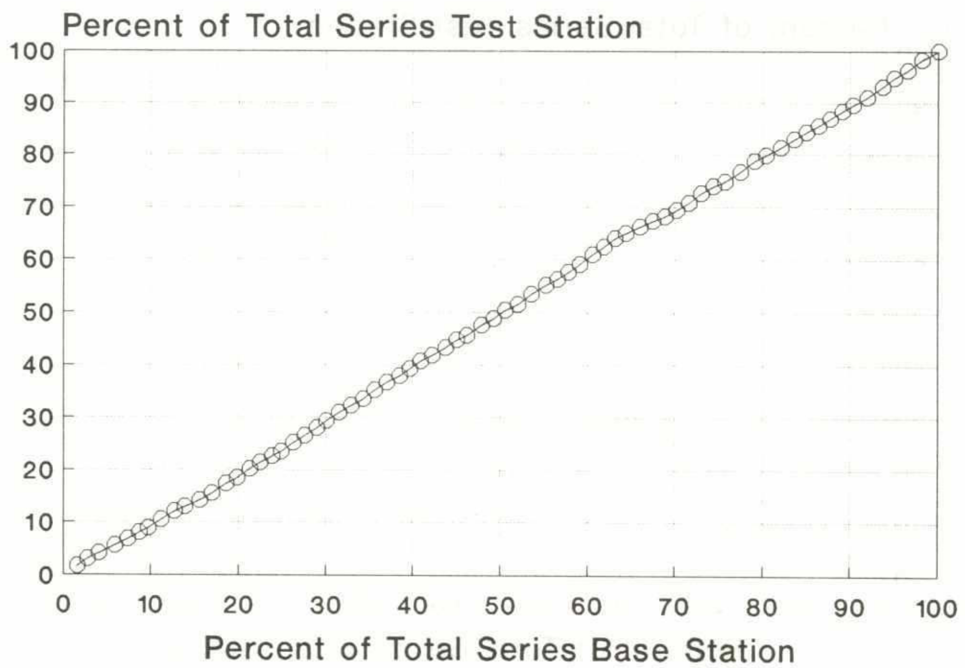
RAJSHAHI


Annual Rainfall (in '000 mm)
3
2
1
0
-1
-2
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years

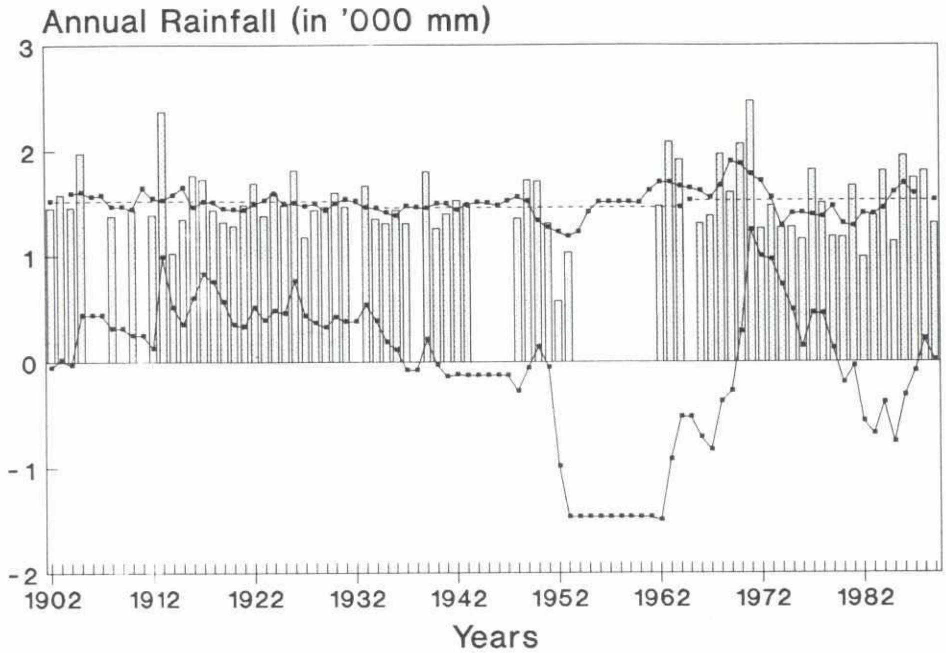

Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

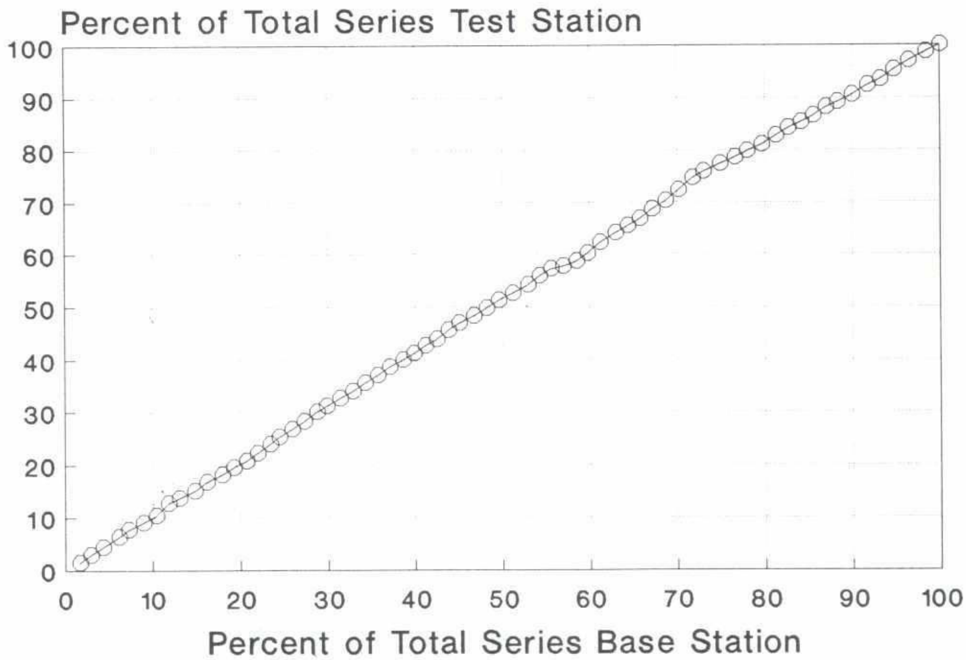
RANGPUR


Annual Rainfall (in '000 mm)
4
2
0
-2
-4
-6
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

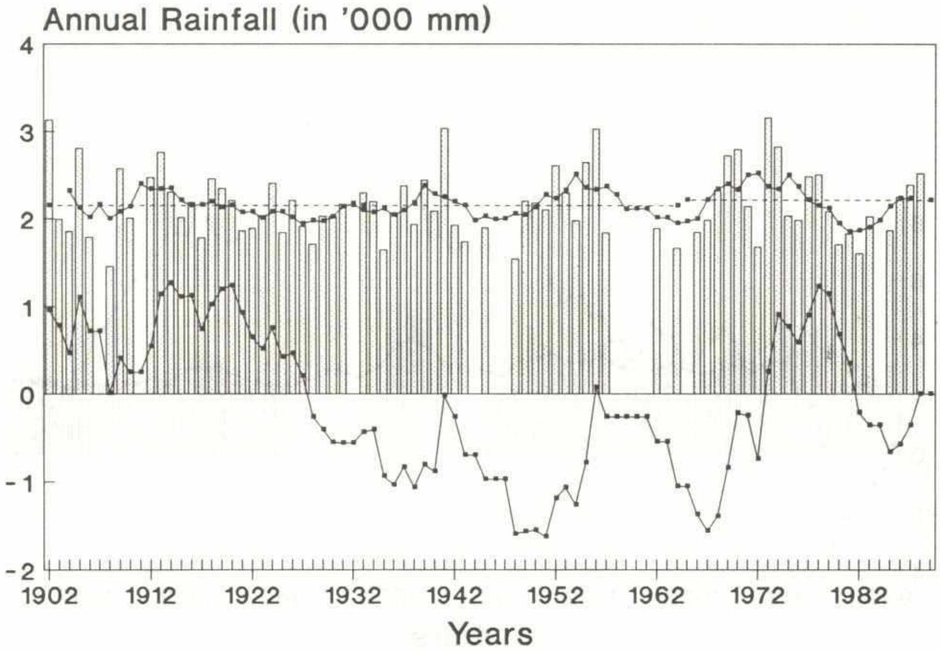
CHUADANGA

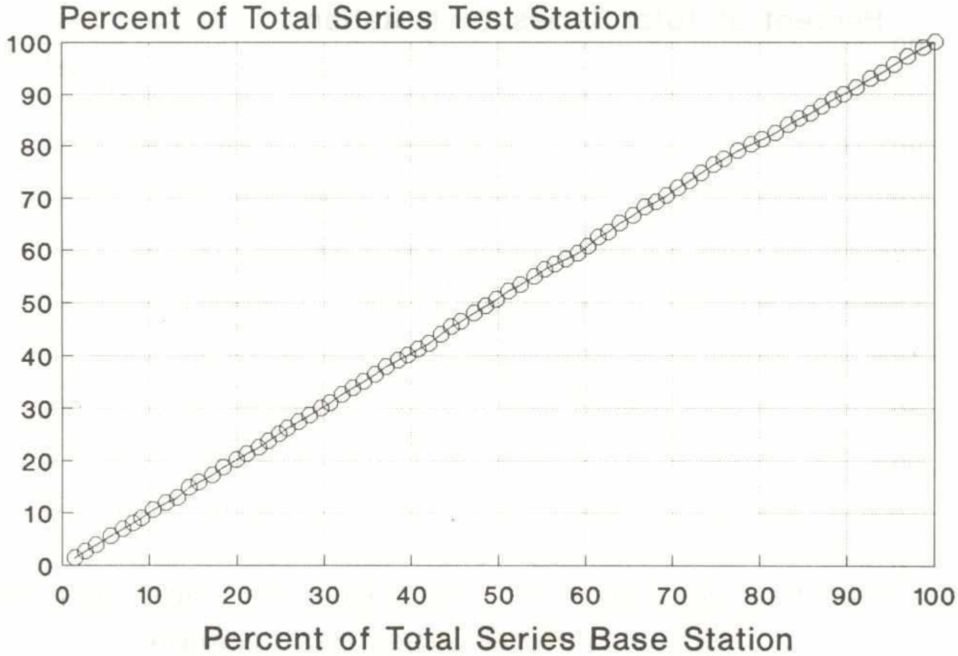

Annual Rainfall (in '000 mm)
3
2
1
0
- 1
- 2
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

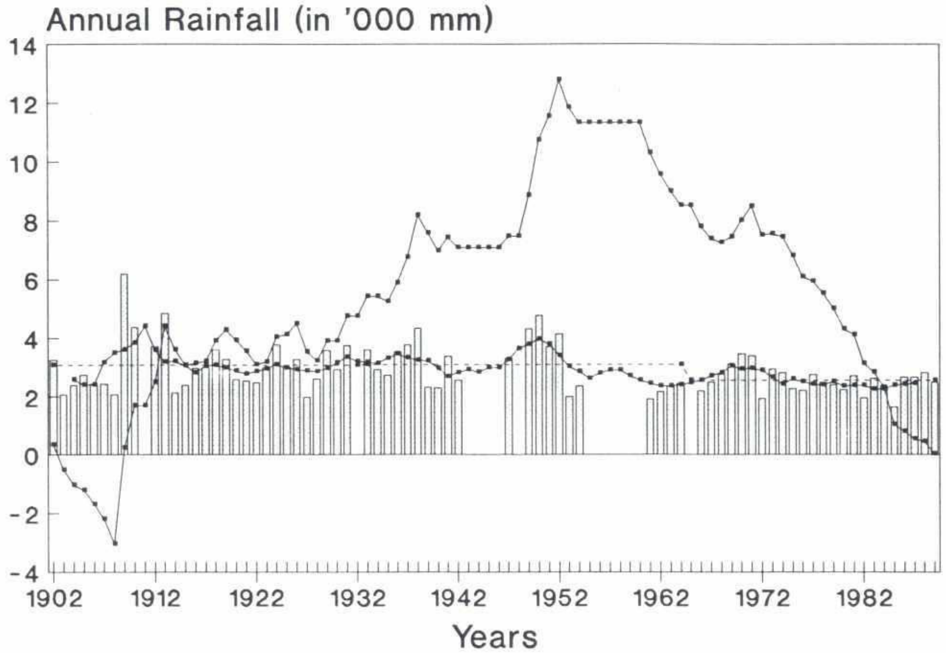
29

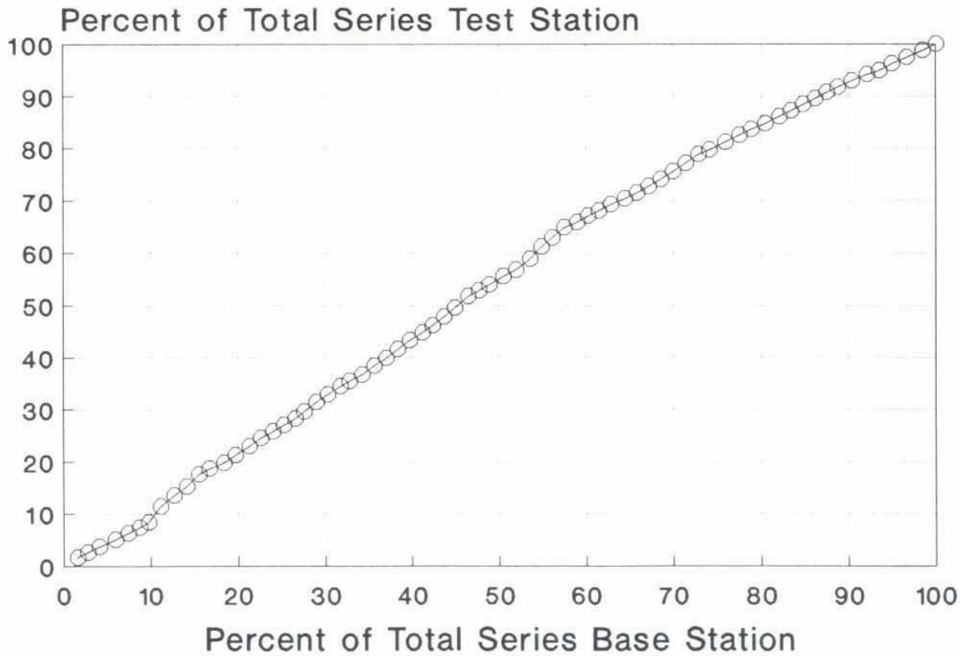
BARISAL


Annual Rainfall (in '000 mm)
4
3
2
1
0
-1
-2
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years

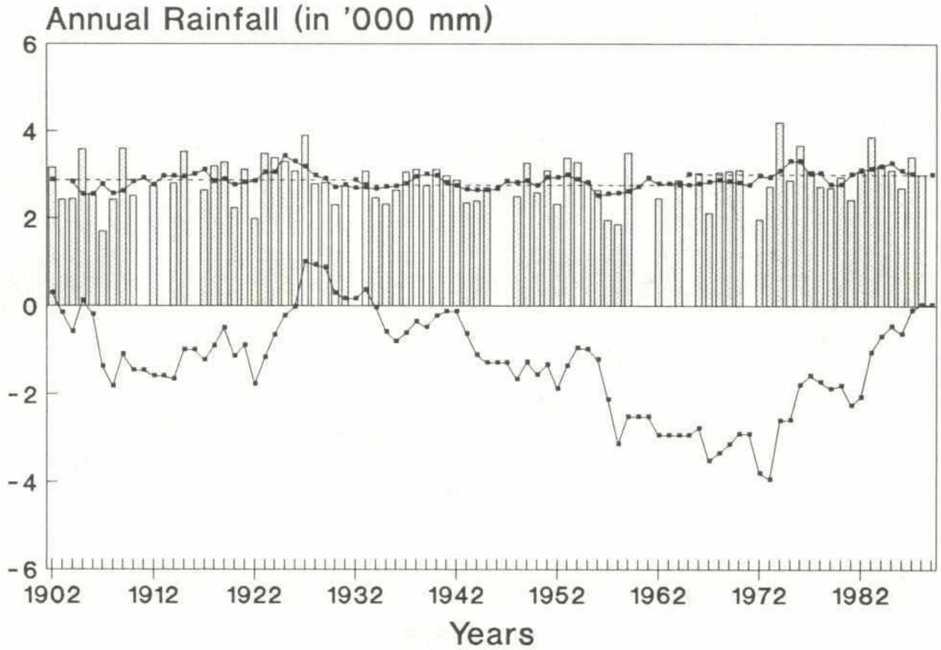

Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

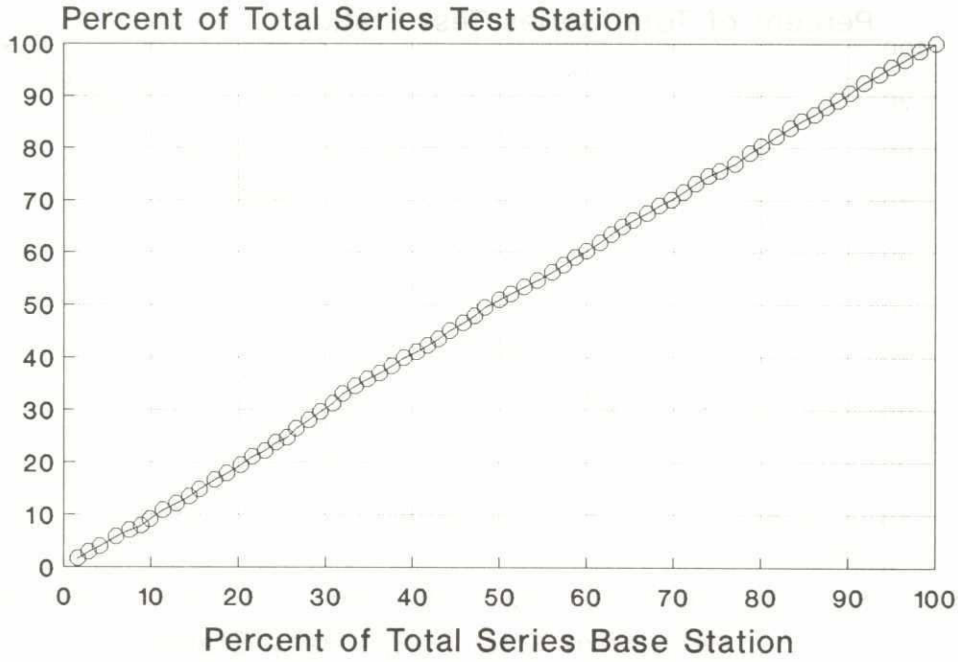
PATUAKHALI


Annual Rainfall (in '000 mm)
14
12
10
8
6
4
2
0
-2
-4
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

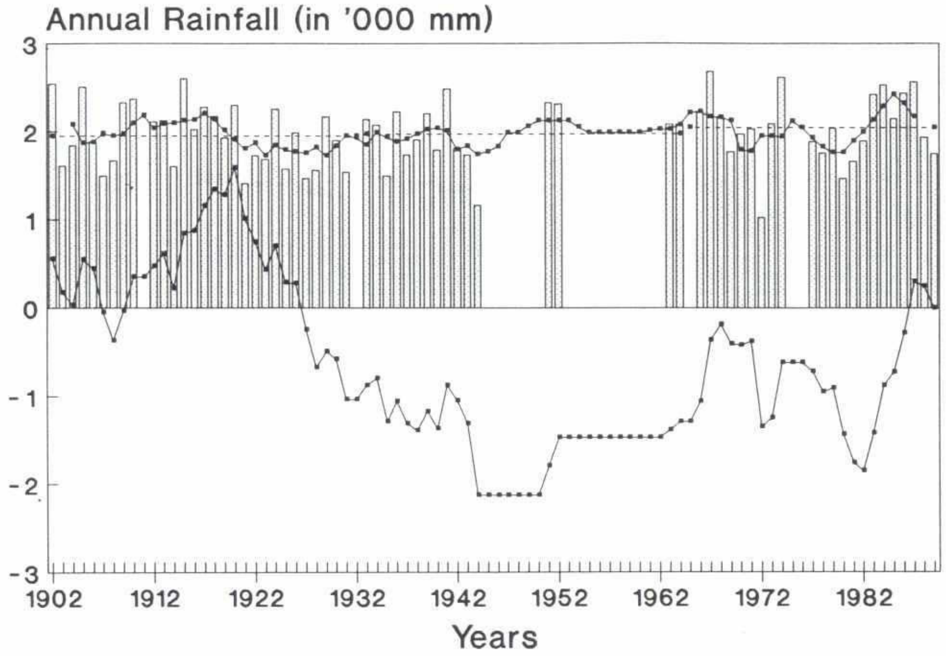
CHITTAGONG

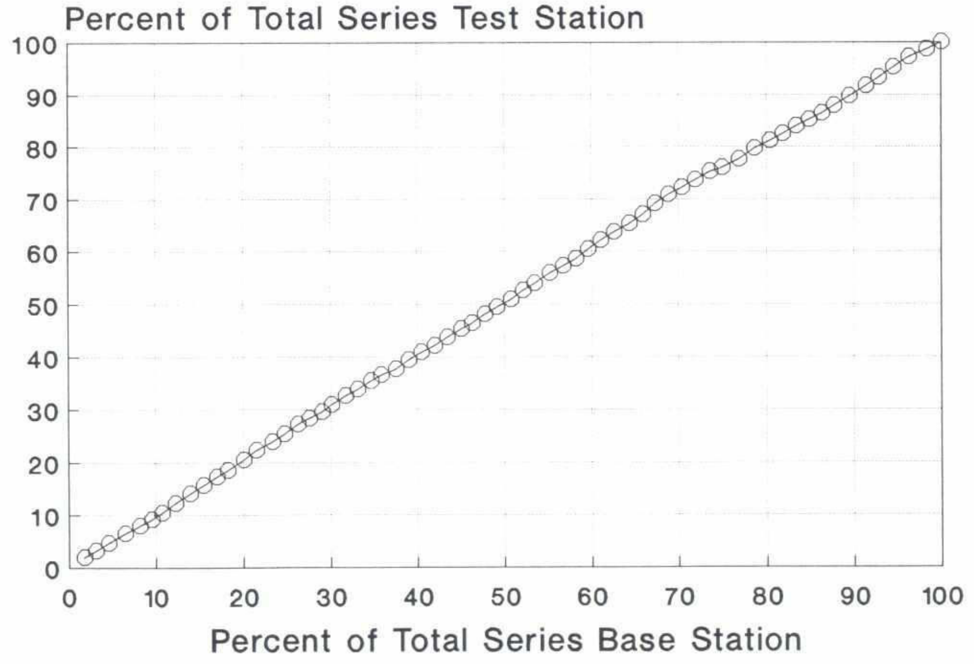

Annual Rainfall (in '000 mm)
6
4
2
0
-2
-4
-6
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

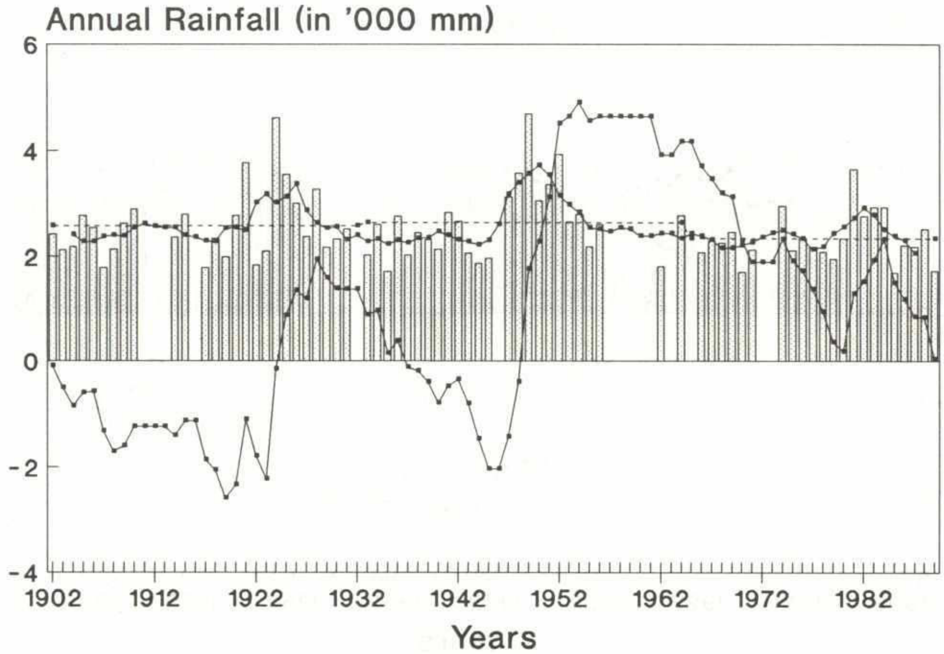
90

CHANDPUR

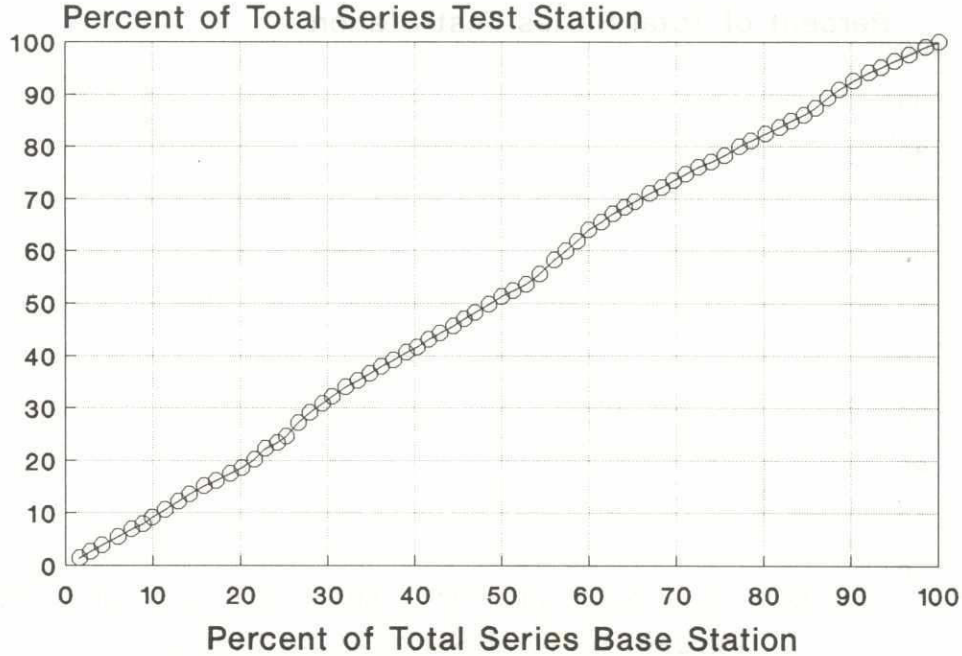

Annual Rainfall (in '000 mm)
3
2
1
0
-1
-2
-3
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

COMILLA

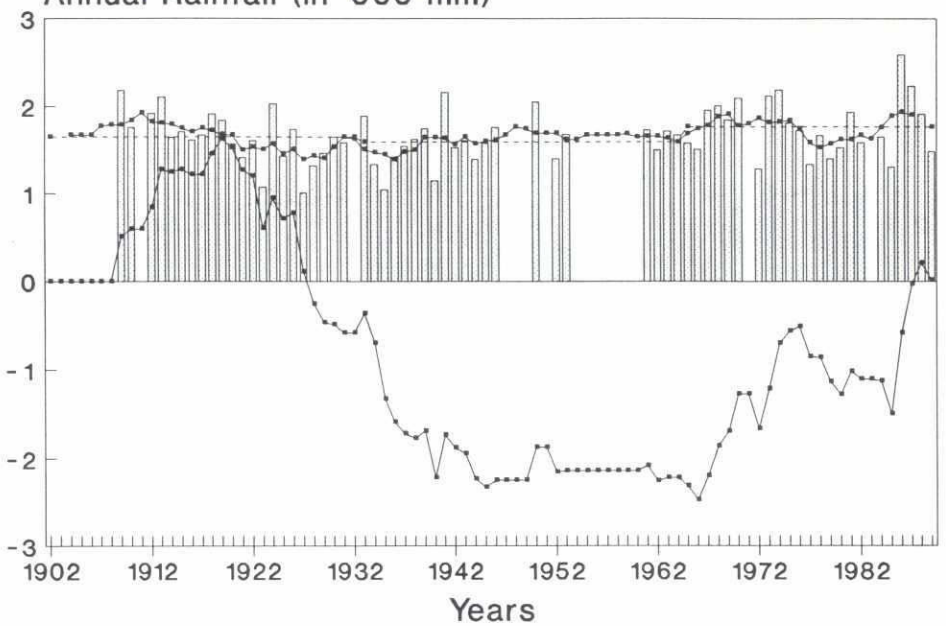


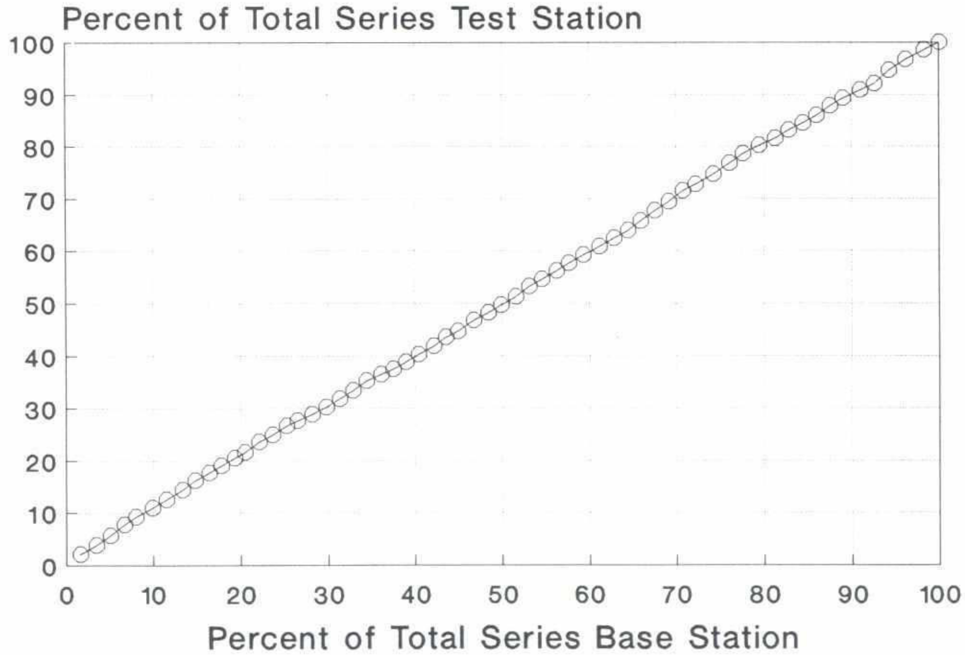
Annual Rainfall (in '000 mm)
6
4
2
0
-2
-4
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years



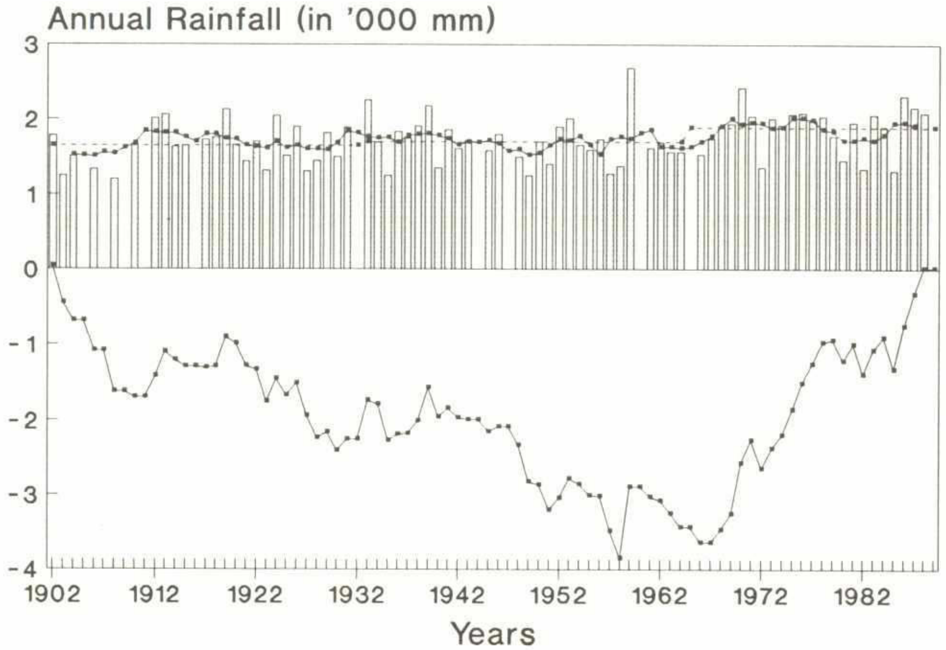
Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

HARIDASPUR

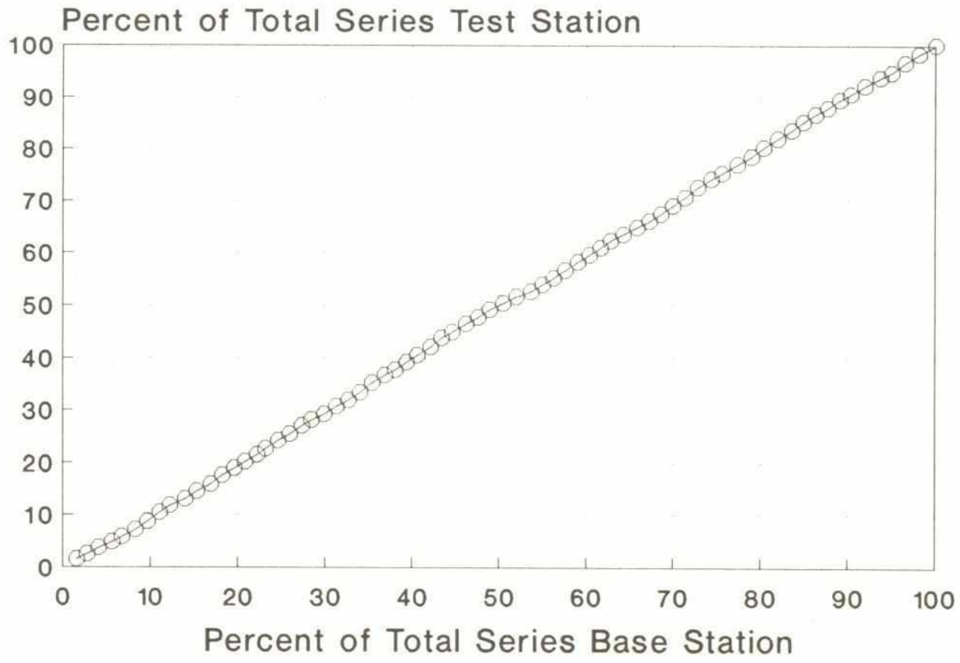

Annual Rainfall (in '000 mm)
3
2
1
0
-1
-2
-3
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

KHULNA



Annual Rainfall (in '000 mm)
3
2
1
0
- 1
- 2
- 3
- 4
1902
1912
1922
1932
1942
1952
1962
1972
1982
Years



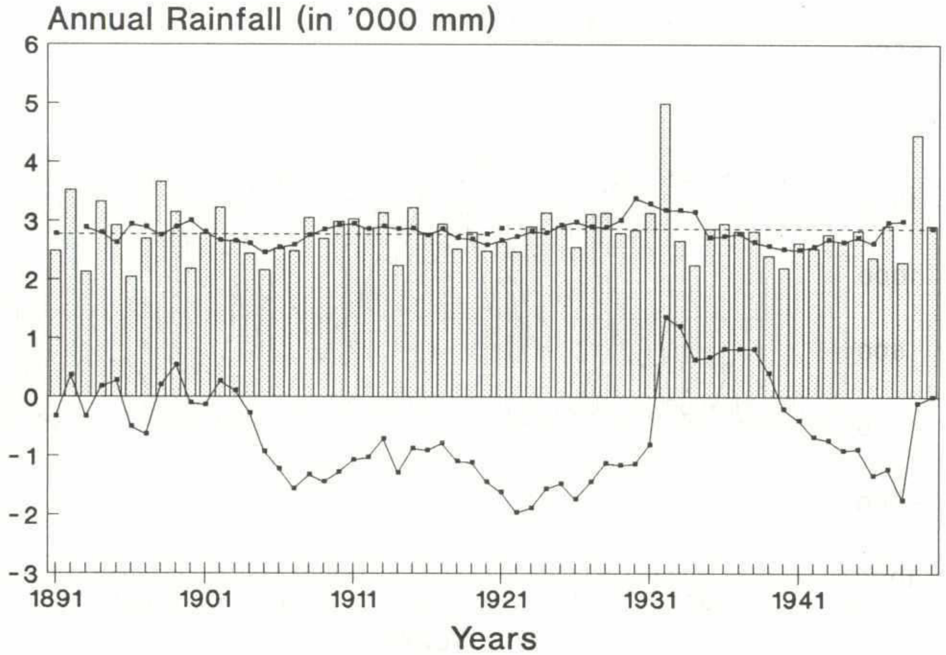
Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

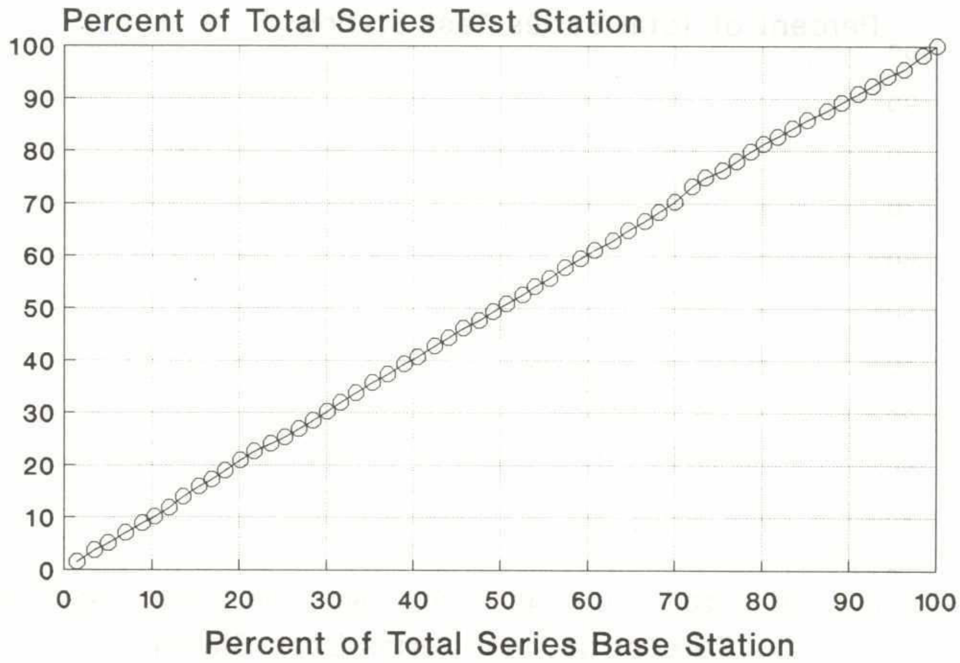
98

STATIONS IN EASTERN INDIA

98

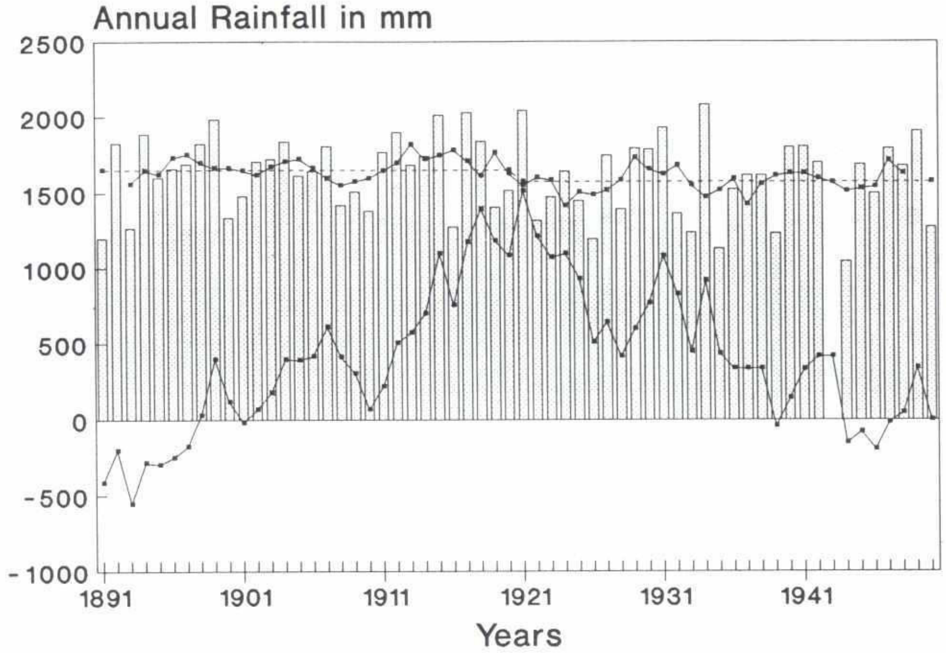
DIBRUGARH



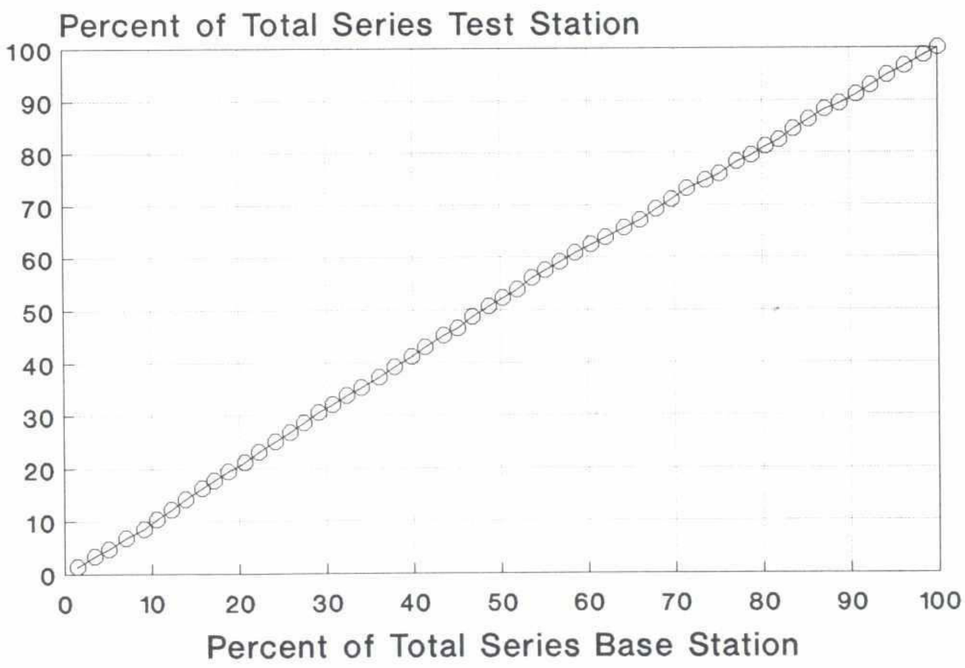


Q3

GAOHATI

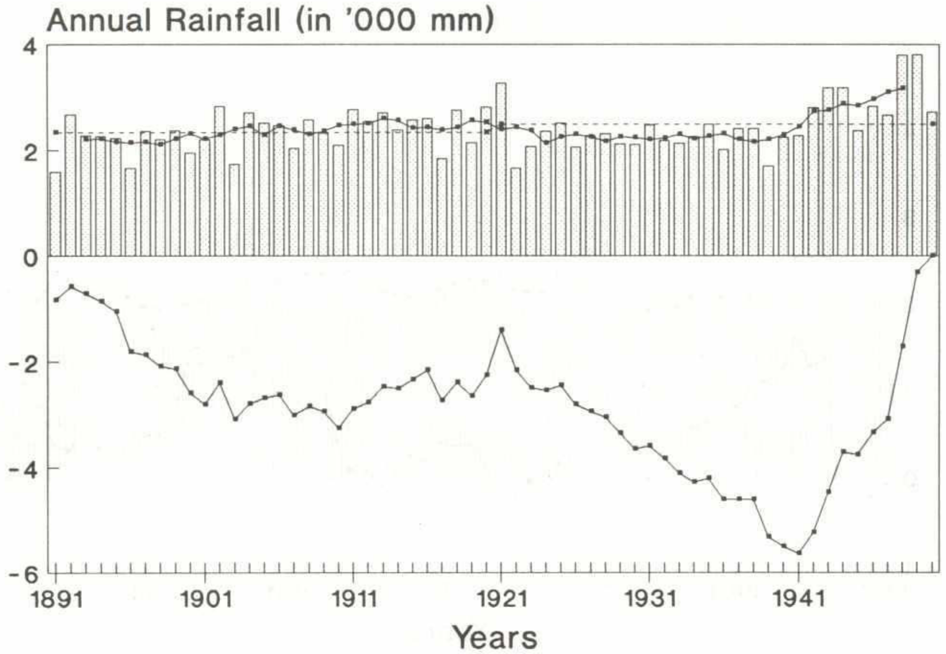


Annual Rainfall in mm
2500
2000
1500
1000
500
0
-500
-1000
1891
1901
1911
1921
1931
1941
Years

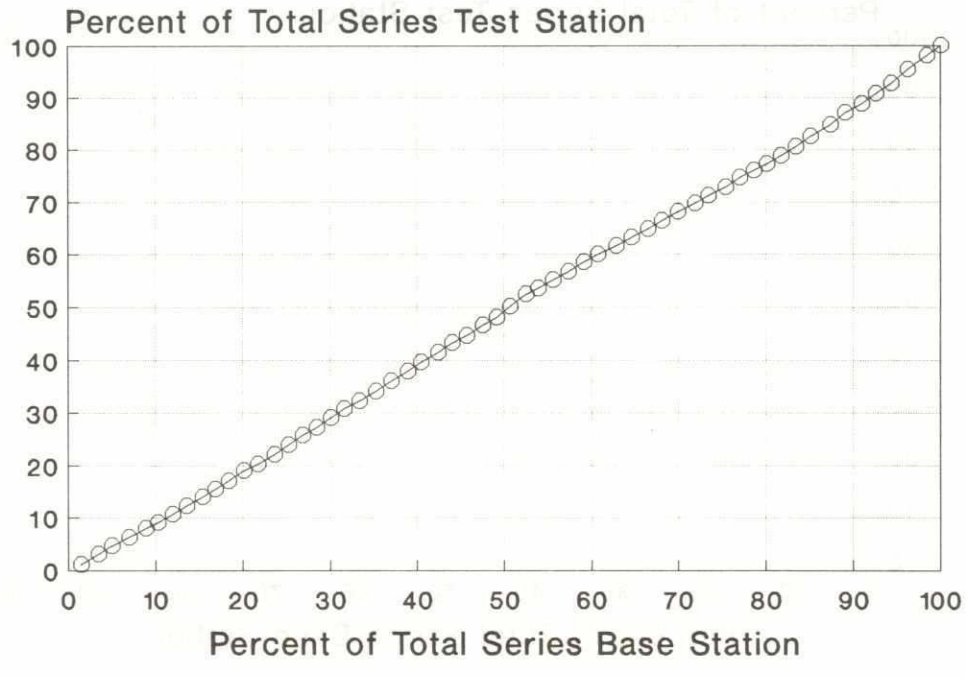


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

GOALPARA



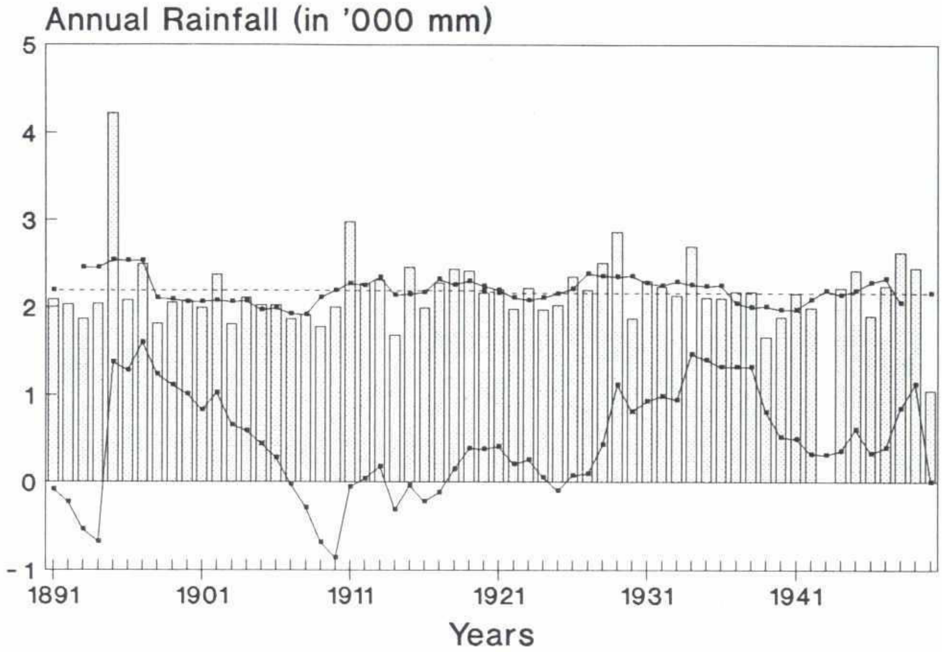
Annual Rainfall (in '000 mm)
4
2
0
-2
-4
-6
1891
1901
1911
1921
1931
1941
Years



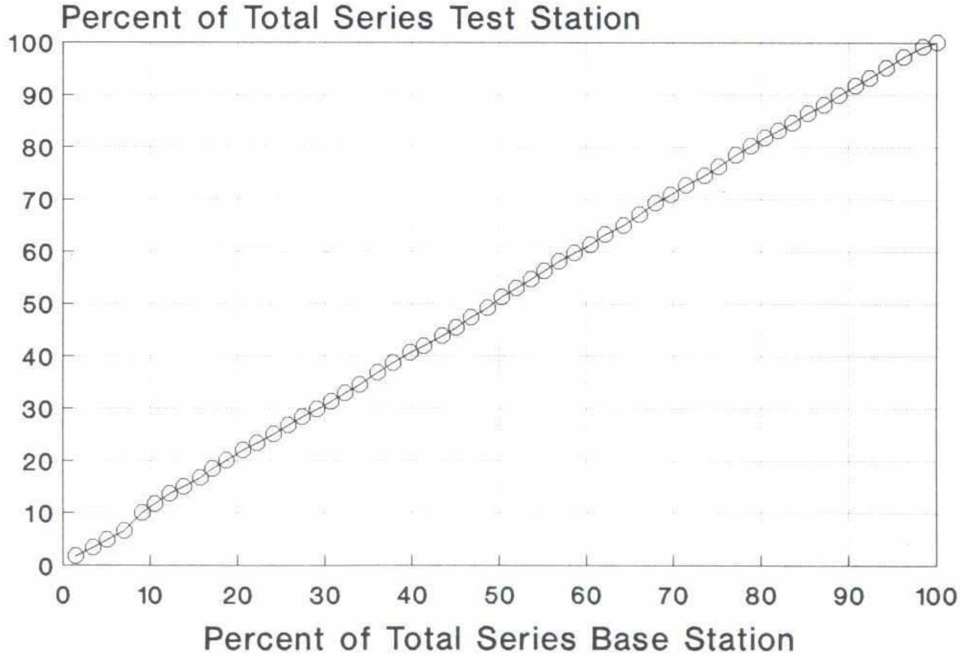
Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

98

JORHAT



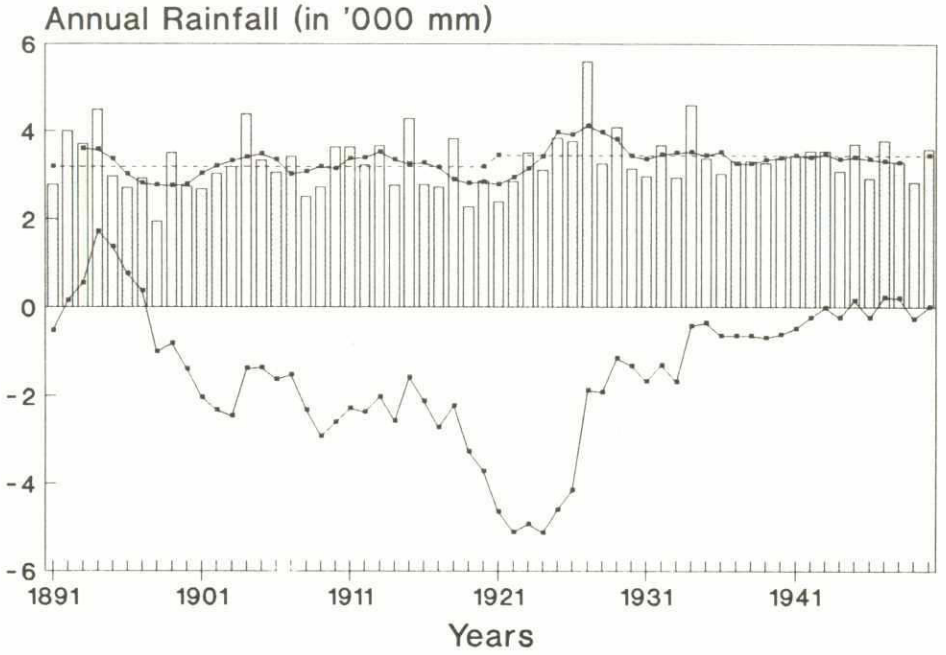
Annual Rainfall (in '000 mm)
5
4
3
2
1
0
-1
1891
1901
1911
1921
1931
1941
Years

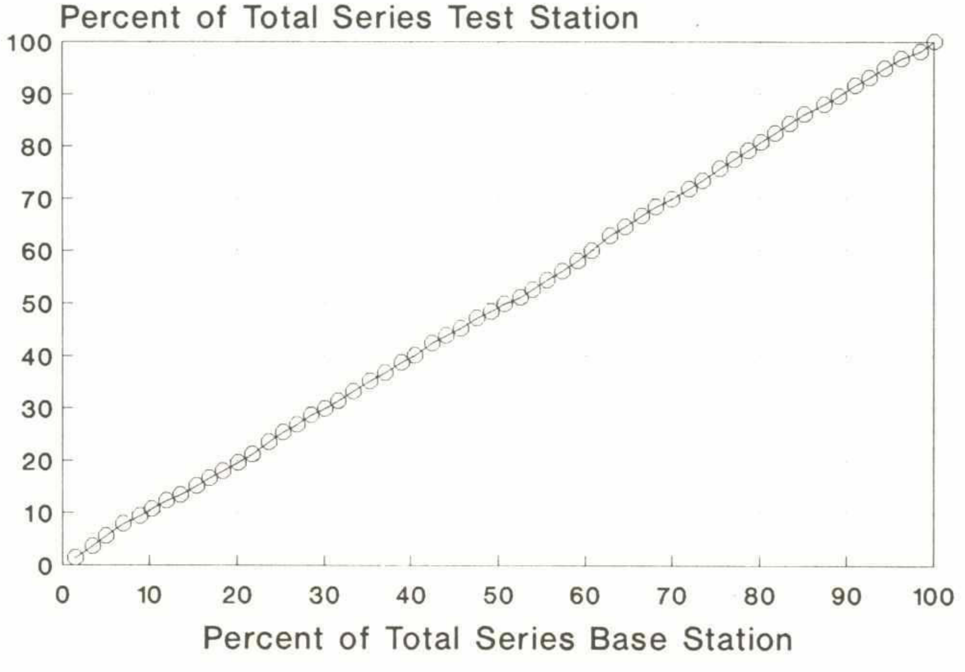


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

९२

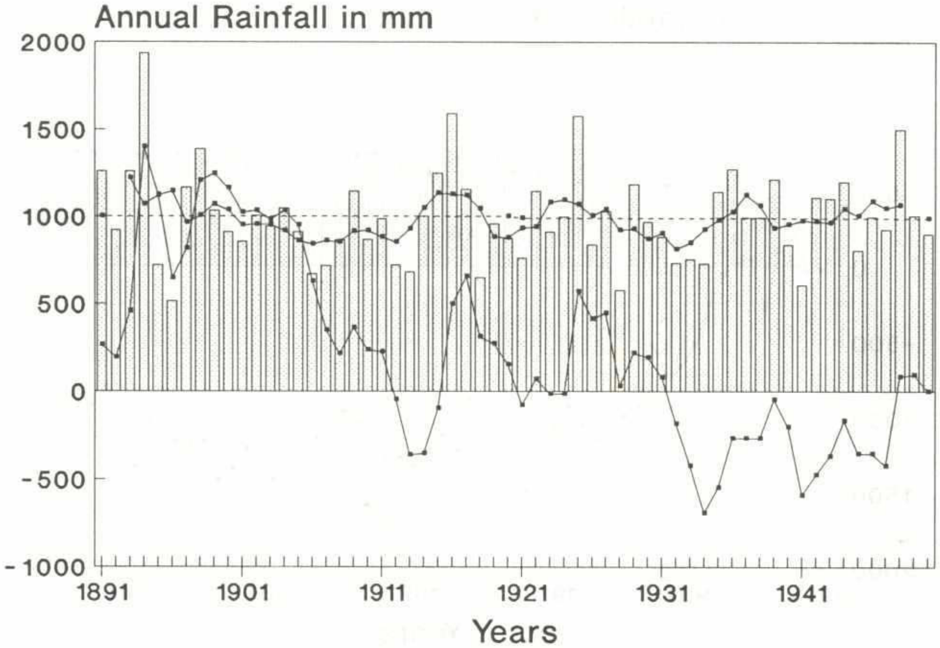
SILCHAR

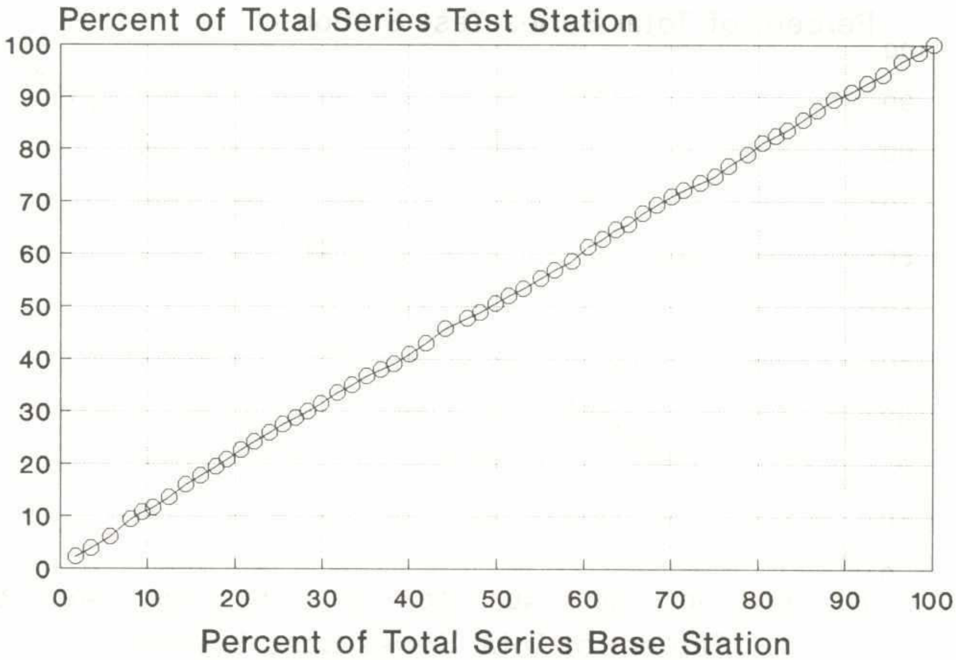

Annual Rainfall (in '000 mm)
6
4
2
0
-2
-4
-6
1891
1901
1911
1921
1931
1941
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

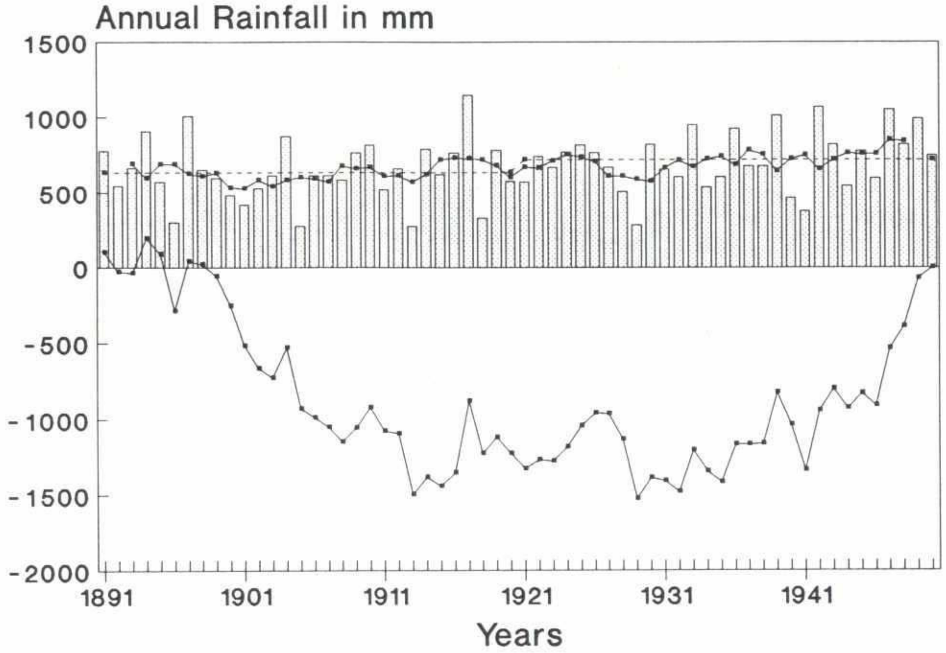
STATIONS IN WESTERN INDIA

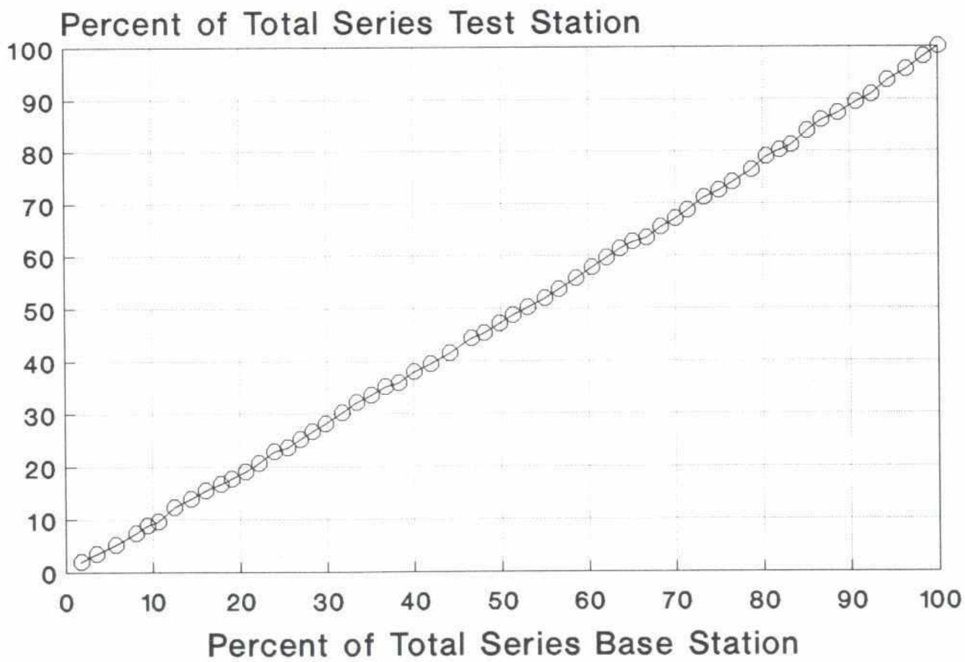
ALLAHABAD


Annual Rainfall in mm
2000
1500
1000
500
0
-500
-1000
1891
1901
1911
1921
1931
1941
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

AGRA


Annual Rainfall in mm
1500
1000
500
0
-500
-1000
-1500
-2000
1891
1901
1911
1921
1931
1941
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
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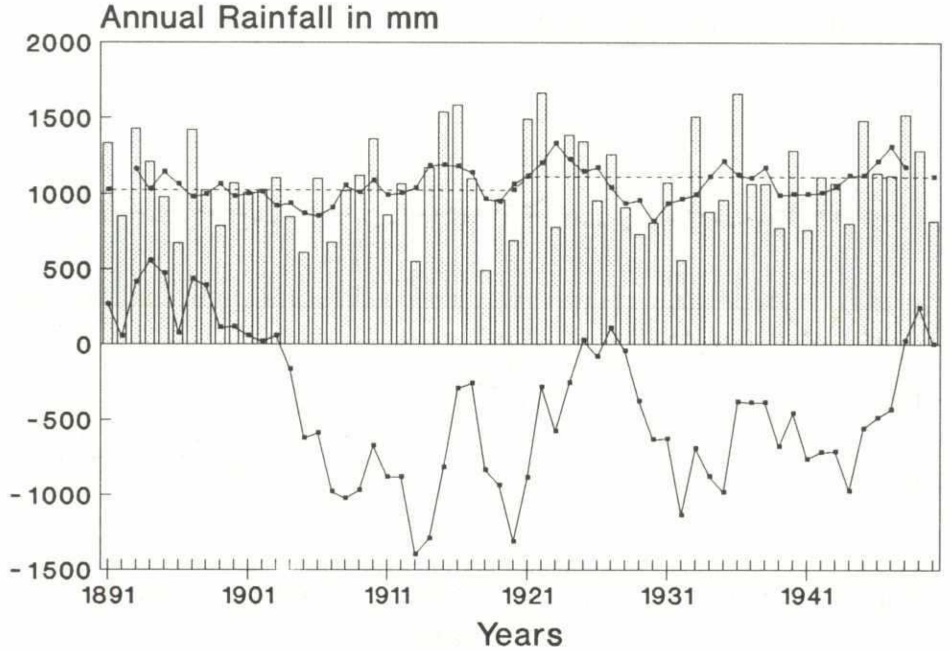
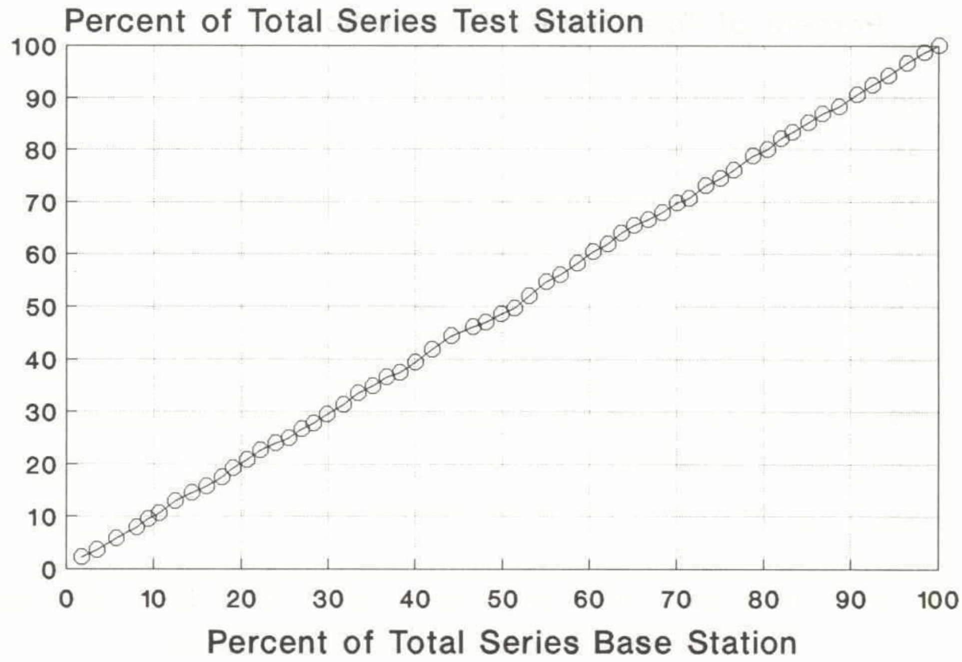
60
70
80
90
100
Percent of Total Series Base Station

BAREILY



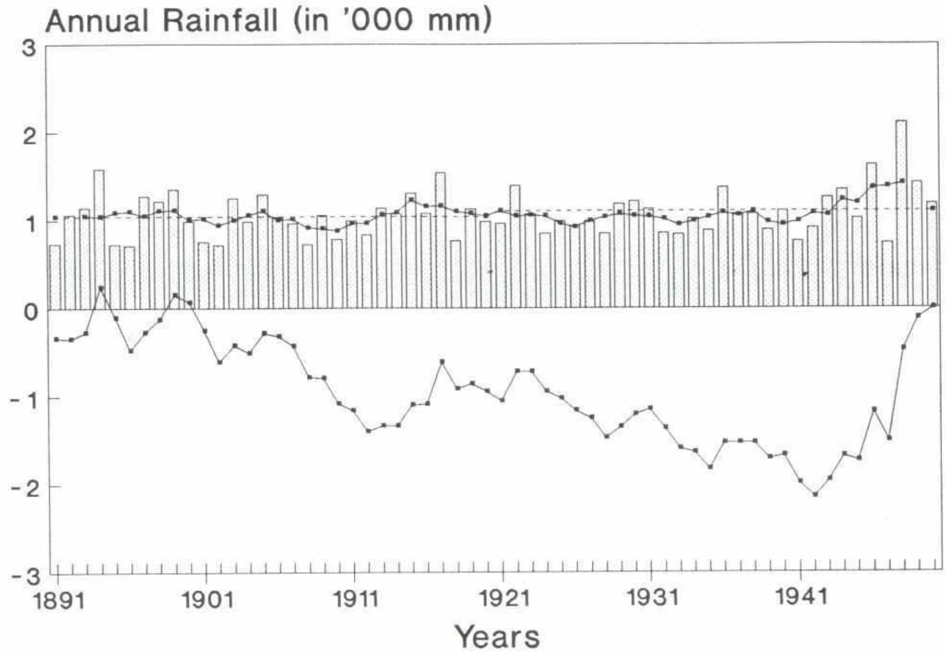
Annual Rainfall in mm
2000
1500
1000
500
0
-500
-1000
-1500
1891
1901
1911
1921
1931
1941
Years



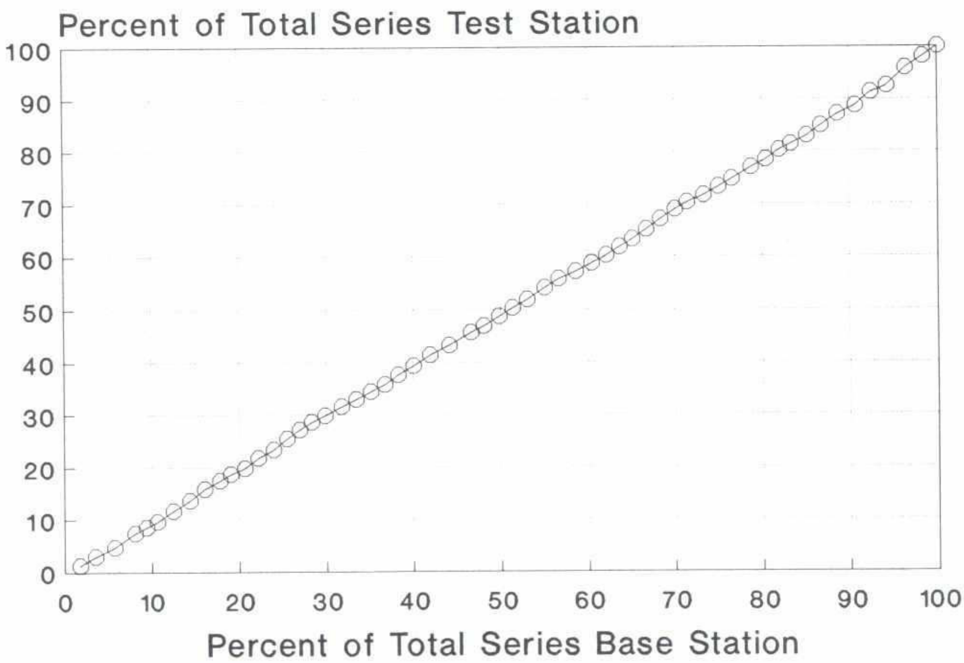
Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

68

BENARAS



Annual Rainfall (in '000 mm)
3
2
1
0
-1
-2
-3
1891
1901
1911
1921
1931
1941
Years



Percent of Total Series Test Station
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90
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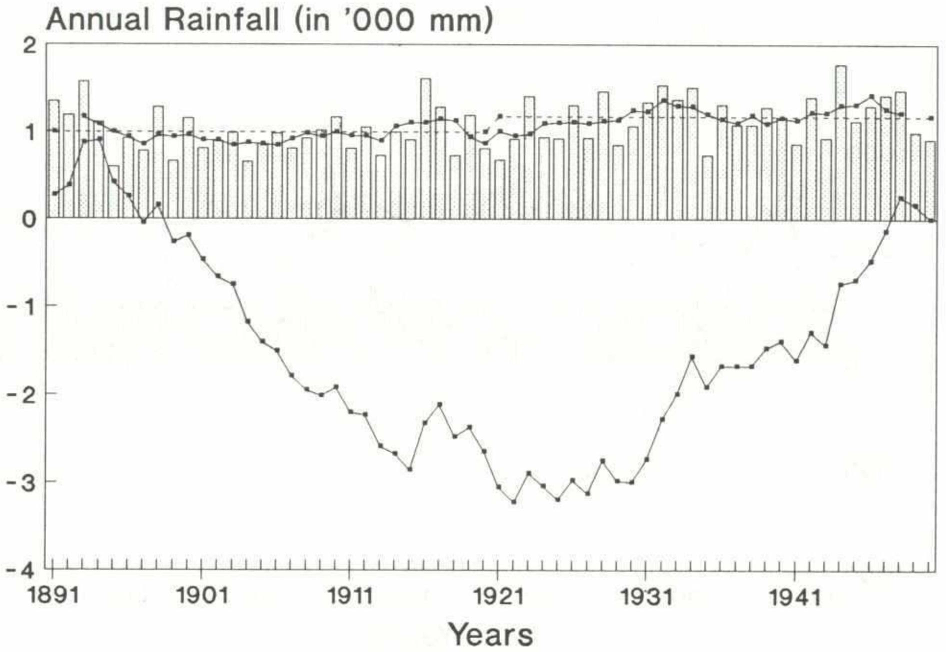
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

BHOPAL


Annual Rainfall (in '000 mm)
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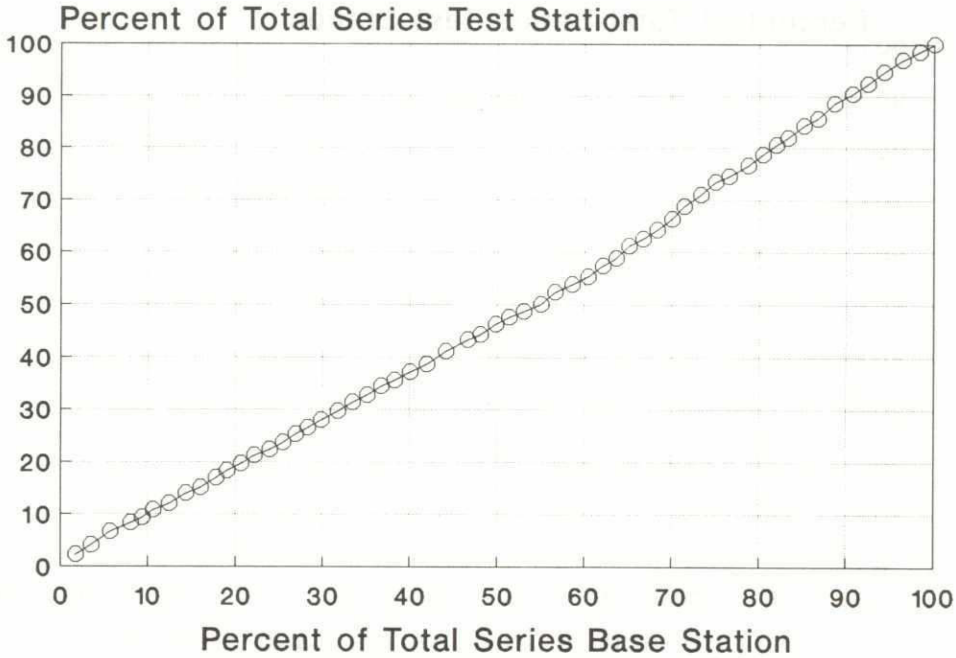
1
0
-1
-2
-3
-4
1891
1901
1911
1921
1931
1941
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
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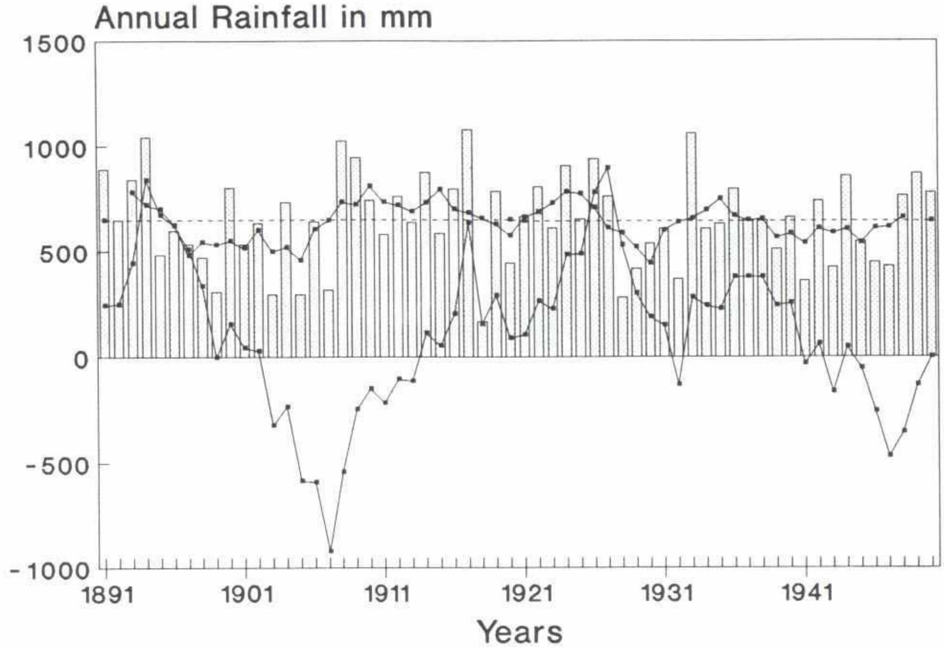
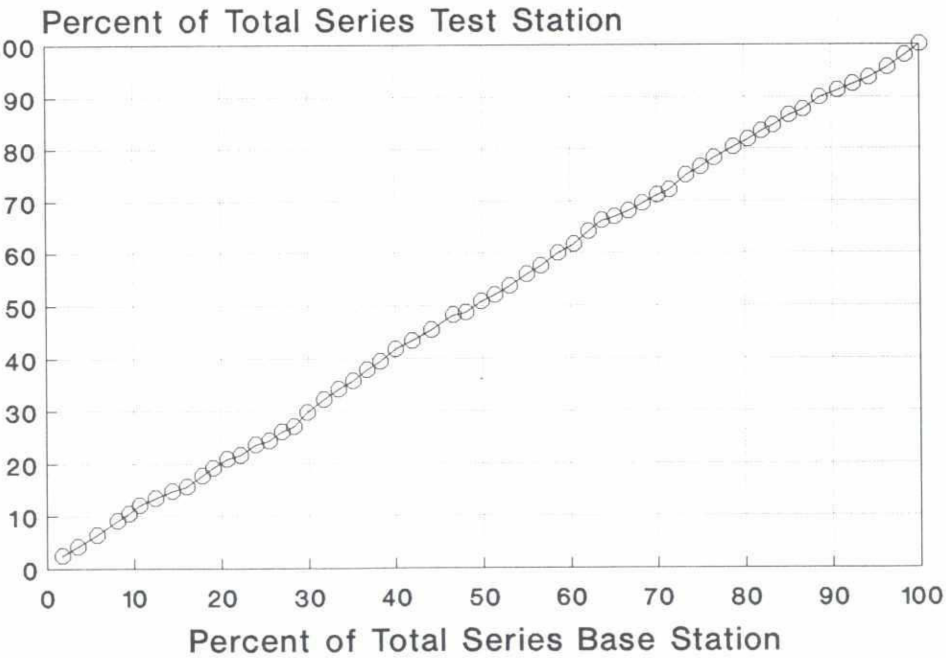
70
80
90
100
Percent of Total Series Base Station

DELHI


Annual Rainfall in mm
1500
1000
500
0
-500
-1000
1891
1901
1911
1921
1931
1941
Years


Percent of Total Series Test Station
100
90
80
70
60
50
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30
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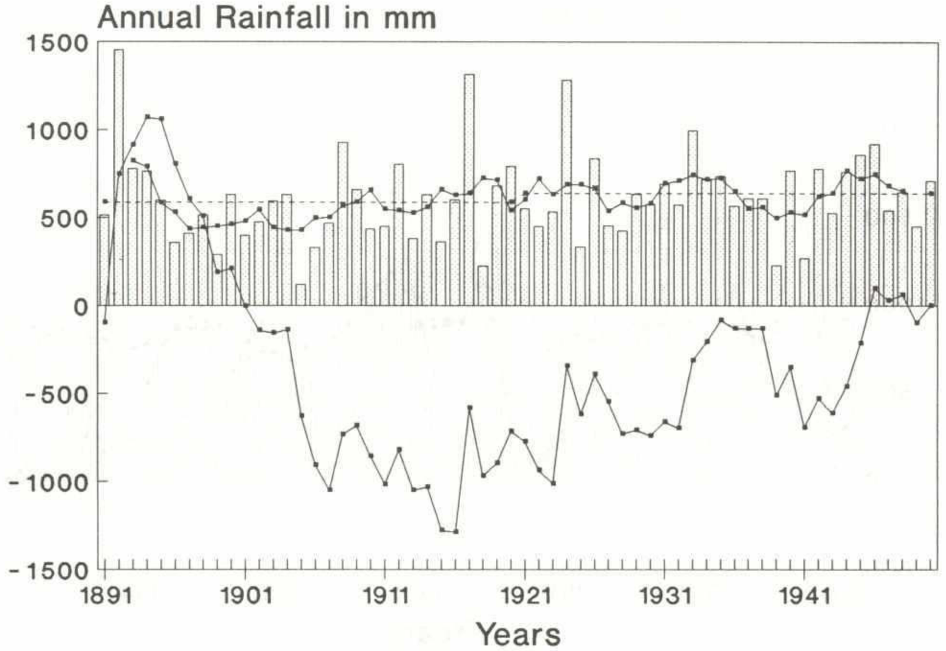
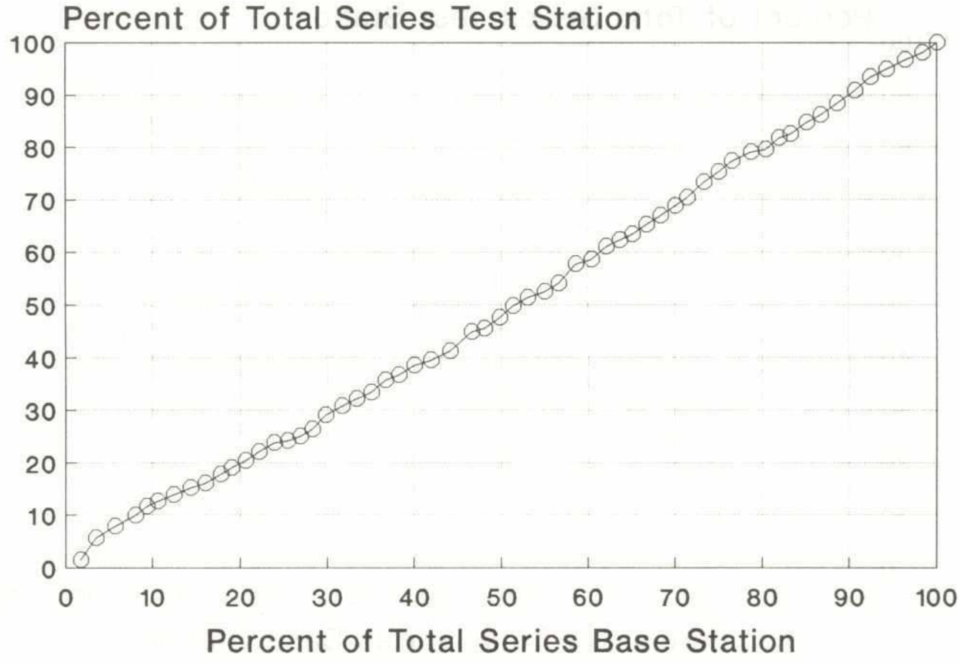
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

JAIPUR

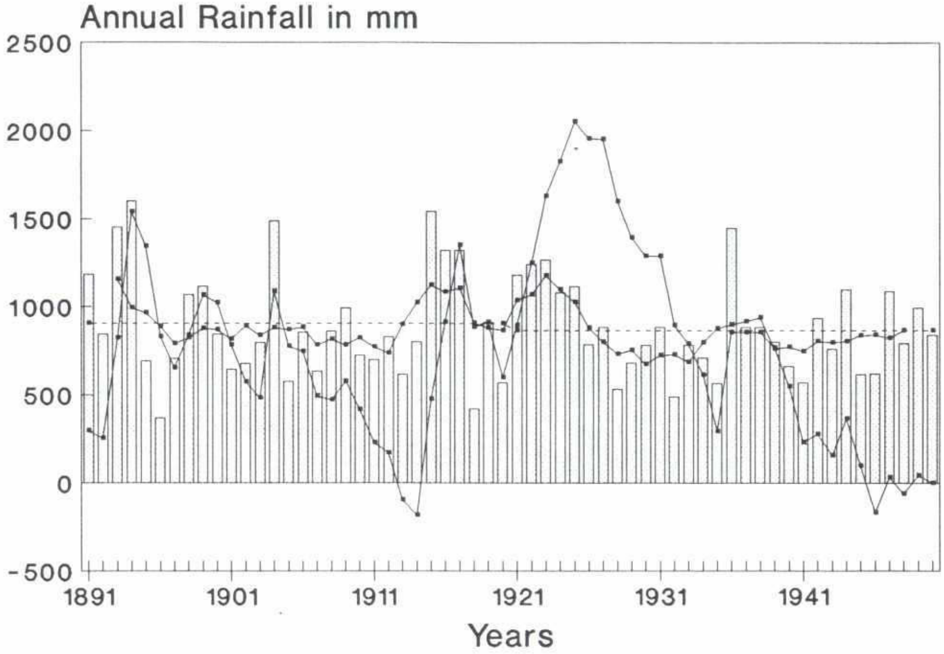


Annual Rainfall in mm
1500
1000
500
0
-500
-1000
-1500
1891
1901
1911
1921
1931
1941
Years

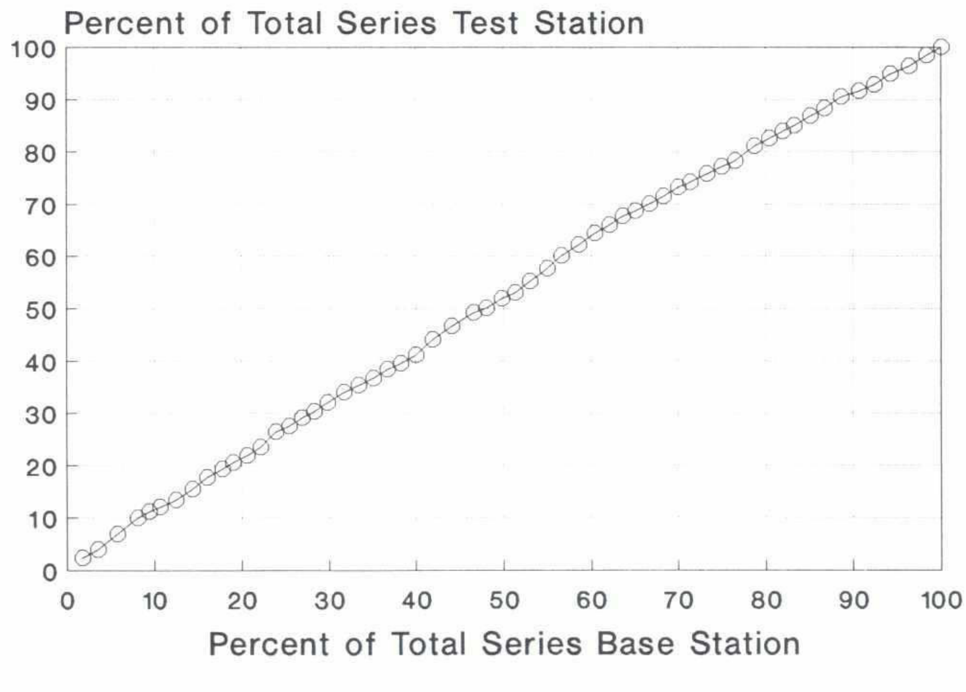


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

KANPUR

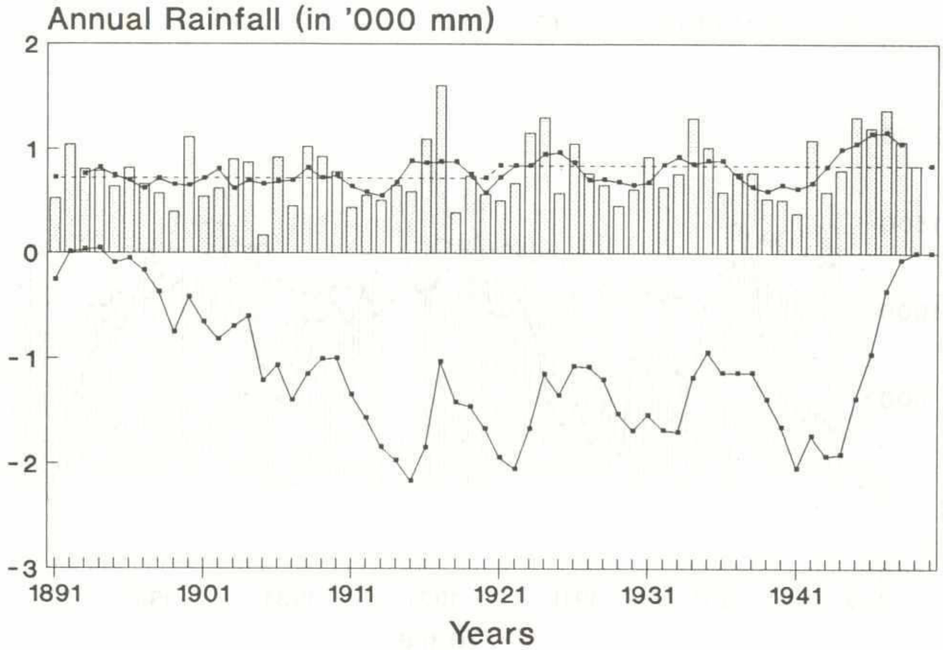


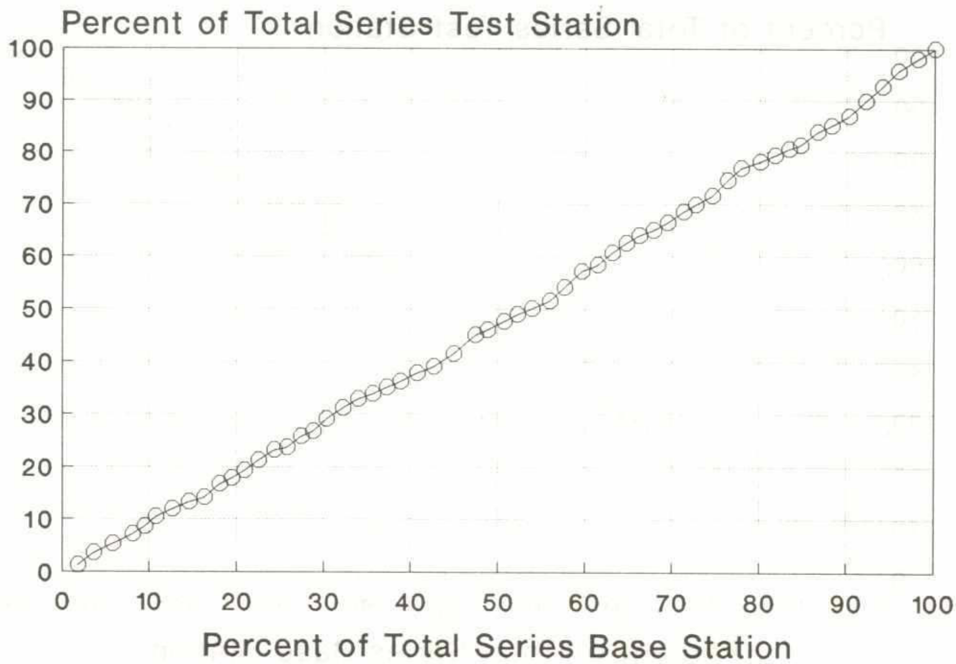
Annual Rainfall in mm
2500
2000
1500
1000
500
0
-500
1891
1901
1911
1921
1931
1941
Years



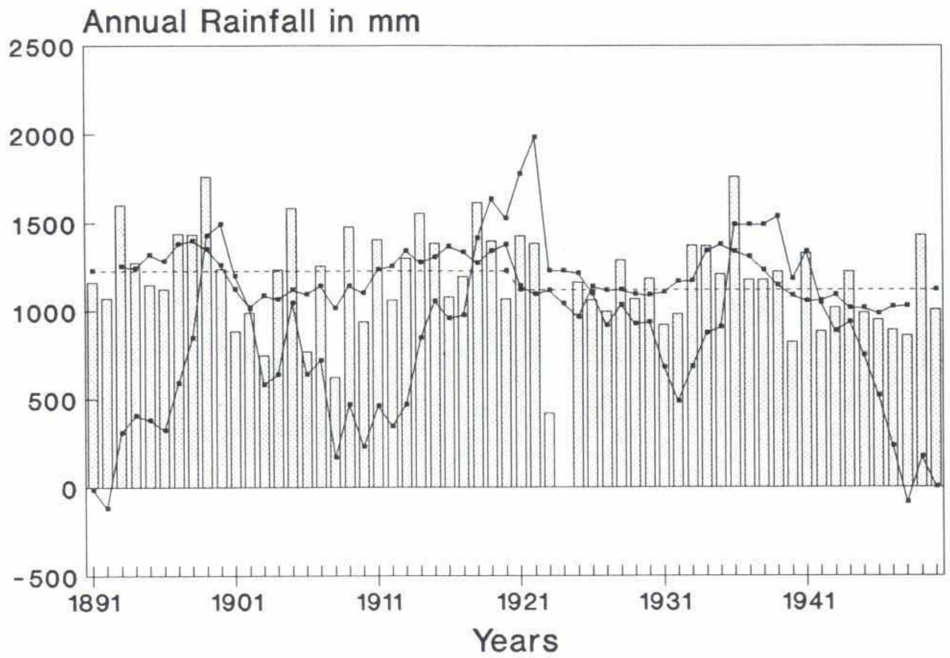
Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

KOTAH

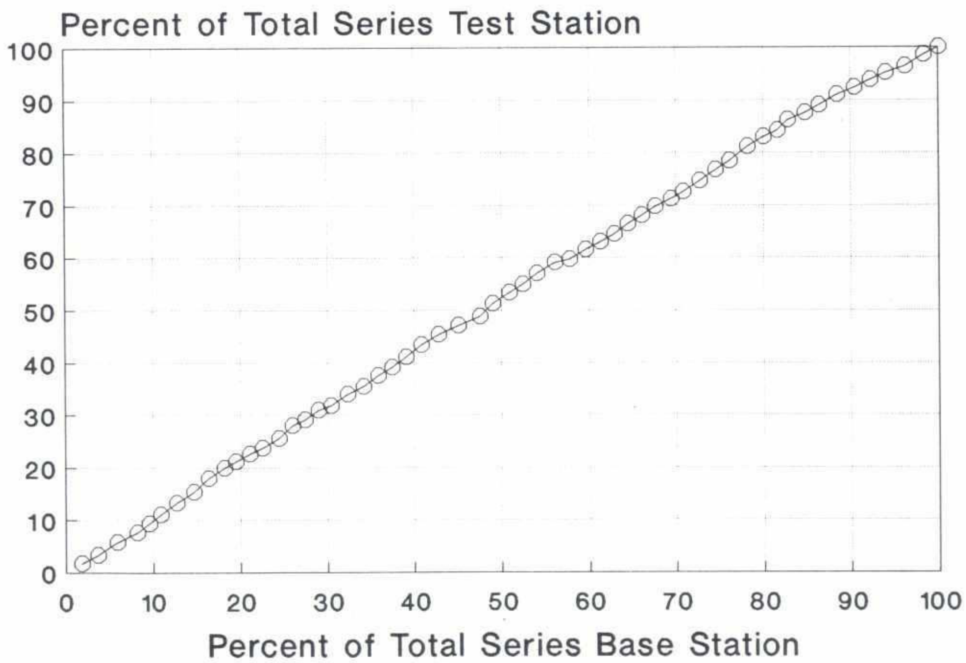

Annual Rainfall (in '000 mm)
2
1
0
-1
-2
-3
1891
1901
1911
1921
1931
1941
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

MONGHYR

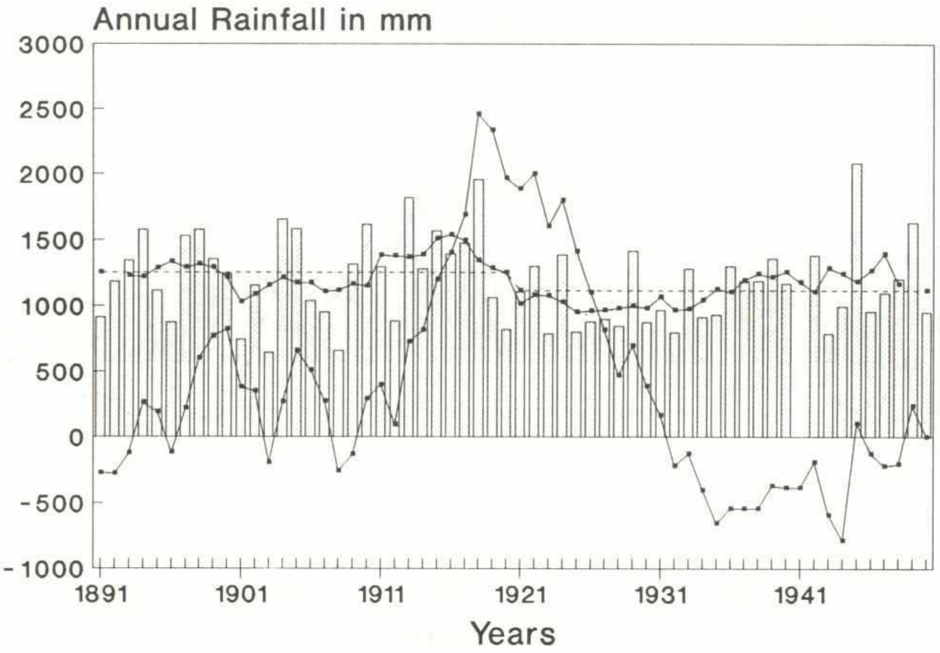


Annual Rainfall in mm
2500
2000
1500
1000
500
0
-500
1891
1901
1911
1921
1931
1941
Years

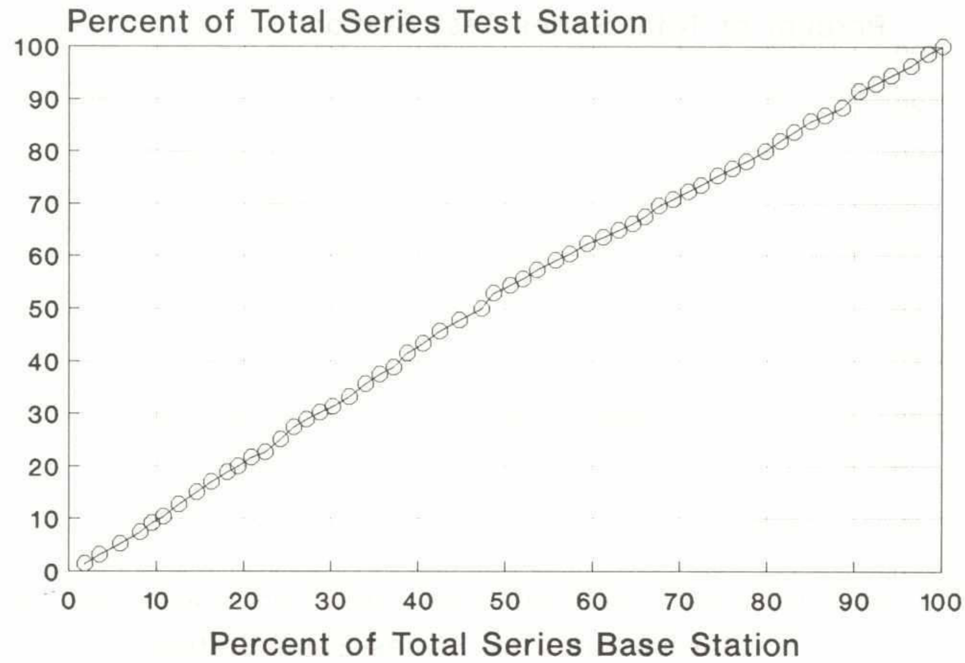


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

PATNA

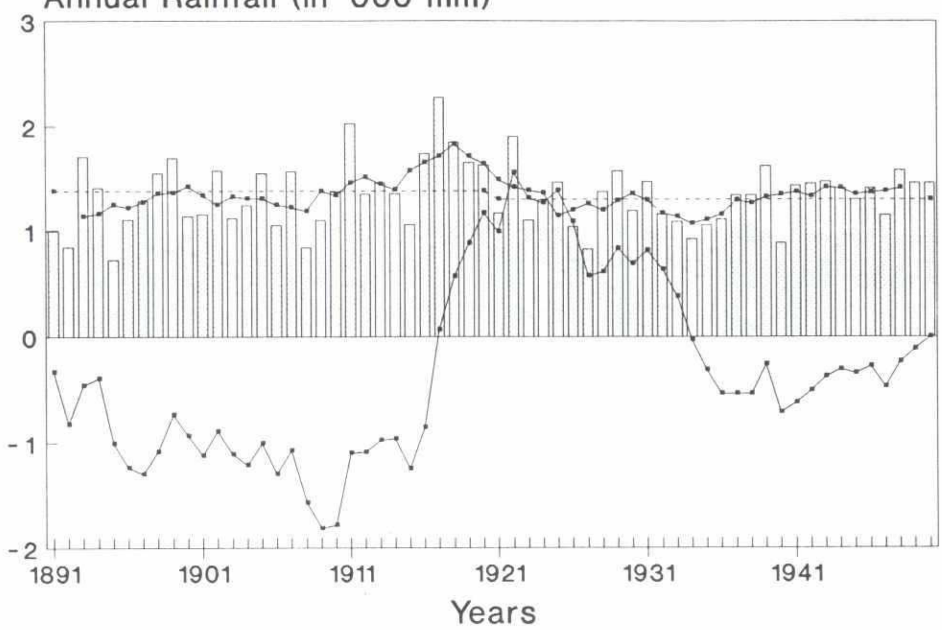


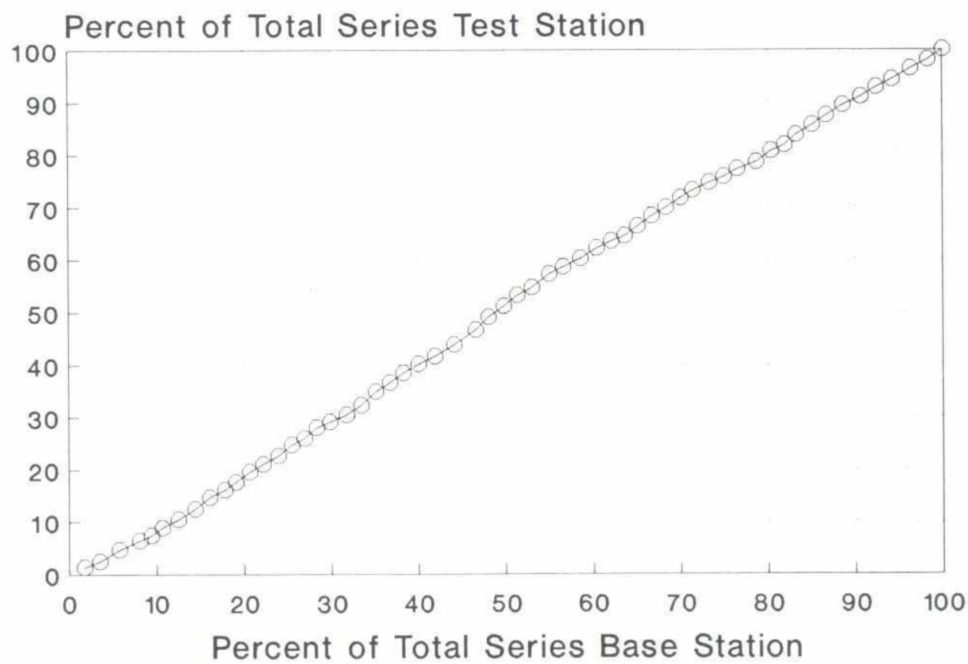
Annual Rainfall in mm
3000
2500
2000
1500
1000
500
0
-500
-1000
1891
1901
1911
1921
1931
1941
Years



Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

RAJMAHAL

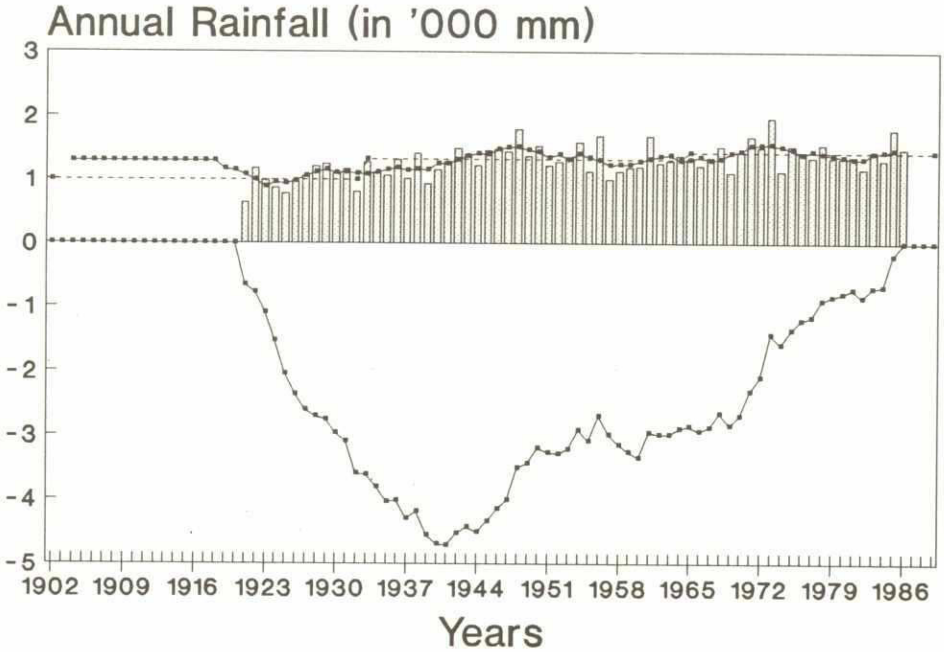

Annual Rainfall (in '000 mm)
3
2
1
0
- 1
- 2
1891
1901
1911
1921
1931
1941
Years

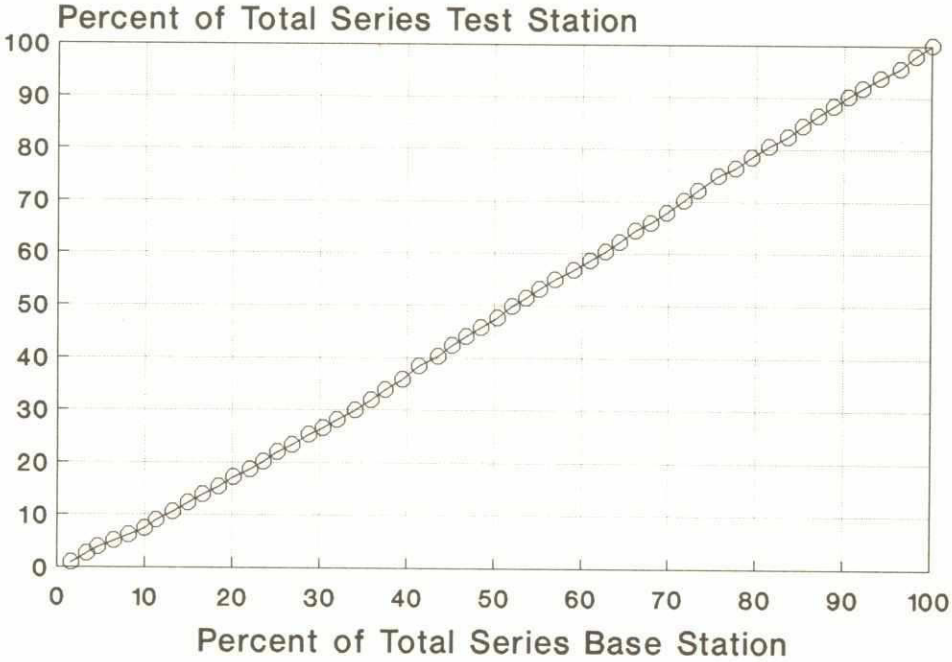

Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

26

STATION IN NEPAL

KATHMANDU


Annual Rainfall (in '000 mm)
3
2
1
0
-1
-2
-3
-4
-5
1902
1909
1916
1923
1930
1937
1944
1951
1958
1965
1972
1979
1986
Years


Percent of Total Series Test Station
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Total Series Base Station

ΝC

APPENDIX 4

List of Water Level Data Corrected

Appendix 4 presents tables with water level data corrected by the Flood Hydrology Study. The tables contain list of BWDB gauged data as were identified by FHS to have observation errors, and the corrected data after elimination of error types 1 to 3, cf Chapter 5 of the Main Report. These are shown in pages A.4-2 to A.4-5.

STATIONS ON MAJOR RIVERS

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STATION	YEAR	DATE	BWDB DATA	CORRECTION
HARDINGE BRIDGE	1965	JUL-11	10.005	11.005
	1966	AUG-06	12.365	12.850
	1967	NOV-27	8.705	9.050
	1970	APR-30	6.250	6.650
		SEP-17	13.825	13.525
	1973	OCT-20	13.955	12.955
		NOV-19	10.180	9.880
	1975	MAY-14	6.215	6.415
		MAY-15	6.215	6.415
		DEC-23	7.870	7.570
		MAR-13	5.685	5.445
	1976	DEC-26	8.745	7.545
		JUL-21	12.435	12.835
		JAN-12	6.420	6.500
GORAI RLY BRIDGE	1965	JUL-24	9.120	9.920
		SEP-25	11.955	10.955
		DEC-25	5.775	5.575
		JAN-25	4.955	5.260
	1967	JUN-21	6.930	5.930
	1973	JUL-29	11.755	12.000
	1976	JUN-13	5.625	5.825
	1981	JUL-10	10.665	10.865
SENGRAM	1969	APR-12	4.680	4.380
		MAY-28	5.070	5.770
		JUL-31	10.955	10.655
		SEP-24	10.940	10.640
		OCT-20	8.980	8.480
		SEP-5	12.115	11.820
		SEP-6	12.780	11.780
		NOV-10	6.150	6.750
	1974	SEP-5	12.115	11.85
		SEP-6	12.78	11.8
	1980	MAY-1	5.830	4.830
	1981	MAY-23	4.050	4.950
		DEC-19	5.915	5.015
		DEC-20	5.880	5.080
KAMARKHALI	1970	OCT-17	6.470	6.700
	1976	AUG-4	7.140	7.410
		DEC-1	3.745	3.475
	1979	JUL-22	6.436	6.736
		AUG-31	7.996	7.696
		DEC-3	3.230	3.270
		DEC-4	3.450	3.250
	1981	JUL-22	7.745	7.945
	1983	JAN-23	4.085	2.985
		JAN-24	3.431	2.931
	1984	JUN-6	3.880	3.680
		JUN-7	4.018	3.710
		JUL-13	6.892	7.492

STATIONS	YEARS	DATE	BWDB DATA	CORRECTIONS
FULCHARI	1969	MAR-24	12.790	12.590
	1970	MAY-15	16.155	15.455
		OCT-31	15.890	15.690
		NOV-1	15.830	15.530
		NOV-2	15.625	15.425
		NOV-3	15.410	15.310
	1973	JUL-21	17.525	17.255
		JUL-22	17.040	17.240
		JUL-23	16.970	17.270
		JUL-24	17.025	17.325
		MAR-27	13.145	13.415
	1974	JUN-1	15.590	15.950
	1975	SEP-23	18.270	18.770
	1976	AUG-4	17.005	17.305
	1977	MAY-2	15.255	15.455
		MAY-27	16.000	16.200
		MAY-31	15.880	16.180
	1978	JUL-16	17.250	17.550
		JUL-17	17.450	17.750
	1982	AUG-29	17.130	17.630
		OCT-8	17.890	16.890
		OCT-9	17.705	16.705
		MAR-30	13.785	13.585
	1983	JAN-9	13.000	13.800
KAZIPUR	1969	OCT-31	10.660	10.360
	1974	JAN-9	9.910	9.610
		JAN-10	9.895	9.595
		APR-17	11.070	10.770
	1976	APR-16 to 23	Missing	Interpolated
		MAY 7 to 11	Missing	Interpolated
	1979	MAR 30 & 31	Missing	Interpolated
	1982	SEP-22	14.815	15.400
BAHADURABAD	1966	APR-17	14.325	14.125
	1976	JAN-18	13.560	13.260
	1981	APR-22	13.870	14.470
		APR-23	13.870	14.470
	1983	JUN-22	18.450	17.450
SERAJGANJ	1970	APR-5	7.765	8.465
		APR-6	8.480	8.780
	1972	SEP-18	12.950	12.650
	1973	JUL-23	11.610	11.810
		JUL-24	11.595	11.795
	1977	MAY-4	10.455	10.755
	1980	APR-4	7.150	7.450
KHOLABARICHAR	1980	AUG-1	19.629	19.929

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APPENDIX 5

Analyses of Suitable Probability Distributions

ODD

1. INTRODUCTION

This appendix describes in detail the analyses carried out with a view to identifying suitable probability distributions for various hydrological variables. Initially, it describes the methodology applied, including selection and characteristics of possible probability distribution, methods of parameter estimation and goodness-of-fit tests. Subsequently, the results of the analyses are detailed, providing documentation for the finally recommended distributions for annual maximum water level, annual maximum discharges, average seasonal discharges and total annual rainfall.

A summary of this appendix is provided in sections 6.1 - 6.2 of the Main Report.

2. SELECTION OF PROBABILITY DISTRIBUTIONS

2.1 Methodology

Prior to the systematic frequency analysis of water level, discharge and rainfall data, tests have been performed for the selection of the most appropriate probability distributions for use in Bangladesh.

For water levels and discharges focus has been on gauging stations along the main rivers. Even in these rivers particular statistical behaviour, induced by local hydraulic processes, may occur as observed for example for water levels at Hardinge Bridge, where the selected standard distribution is not applicable (Section 3.2). In such cases, specific distribution studies should be undertaken, following the methodology outlined in this section.

Rainfall probability distributions are generally not affected by particular local conditions and the distribution recommended by the FHS may be applied country wide.

The methodology used in this study for the selection of probability distributions is also recommended for application by other FAPs for feasibility studies and detailed design, at project specific locations. The methodology includes:

- Selection of possible probability distributions among the most widely used ones:

  * Gumbel (or GEV type I)
  * GEV type II
  * GEV type III
  * Log Normal
  * Pearson III
  * Log-Pearson III

- Selection of representative and reliable key-stations, well distributed over the study area (in the present study 5 stations);

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- Fitting of the various probability distributions for the selected key-stations, using the Maximum Likelihood method or another method of similar quality, and plotting of the results for visual inspection. Special attention should be given to eventual outliers or the eventual need for left censoring;

- Application of goodness-of-fit tests, such as the Kolmogoroff-Smirnov and Chi-square tests;

- Comparison of the extrapolation properties of the tested probability distributions;

- Selection of (an) appropriate distribution(s) for application in the project area.

In carrying out the analyses the plotting position formula proposed by Benard and Bos-levenbach has been applied, i.e $p=(m-0.3)/(n+0.4)$, where p is the assigned exceedance probability, m is the rank of the event and n is the total number of observations.

The standard applied in Bangladesh by the BWDB is the generally acknowledged Weibull formula: $p = m/(n+1)$. The reason for using the Benard and Bos-Levenbach formula in the FHS is simply because this is the formula used in HYMOS.

The selection of plotting position formula is very much a matter of taste and to justify one in favour of the other is very difficult. In the actual case, where the period in question (1965-89) contains two major floods, 1987 and 1988, probably with higher return periods than 25 years, it may be argued that the use of the Weibull formula is conservative, while the Benard and Bos-Levenbach formula attach a return period, which is closer to the (unknown) true period of these events.

For comparison of the extrapolation properties of various distributions, extrapolated values have been plotted for the fitted distributions up to the 1,000 year return period. It is acknowledged that such an extrapolation is certainly not needed for the FAP, and has little value as such, considering the available short observation periods (only 24 years). However, probability distributions used to estimate 100-year design events or levels, should preferably produce also realistic 1,000-year events. If the latter appear not to be realistic (for example a 1,000-year maximum water level of more than 2 m above the 1988 maximum water level), there is no guarantee that extrapolations towards the 100 year events can be relied upon.

The above methodology has been applied for the following hydrological variables:

- annual maximum water levels;

- annual maximum discharges;

- average seasonal discharges;

- total annual rainfall.

The analyses have been carried out using HYMOS, a hydrological data management and processing package developed by DEFLT HYDRAULICS.

2.2 Characteristics of Selected Distributions

The Gumbel distribution implies the estimation of only 2 parameters, which is an advantage in the event of short data series. The function is generally useful for estimating extreme annual events. Its limitation is that its skewness is fixed, which reduces its flexibility.

The next four distributions mentioned in Section 2.1, require the estimation of 3 parameters, viz. a location (threshold), scale and shape parameter. This provides sufficient flexibility for practical purposes.

The Log-Pearson distribution has in fact 4 parameters (also in the way it is used in the National Water Plan (NWP)), which makes its use in the event of only short series of observations less attractive.

The first three distributions all belong to the GEV family. In HYMOS this family was split up into its three members on purpose. The Gumbel or GEV type I distribution has neither an upper limit, nor a lower one. The GEV type II has a lower threshold and is therefore useful for hydrological parameters exhibiting no clear upper limits, such as for example maximum hourly rainfall data or annual maximum discharges. The use of the GEV type III, with an upper threshold, for such parameters is questionable, which is the reason that a particular GEV type can be selected in HYMOS.

The range of annual maximum water levels in Bangladesh exhibits on the contrary a kind of upper limit. During extreme floods huge spills into the flood plains occur, the country is nearly totally flooded and at some stage water levels can hardly rise anymore. In such case the GEV type III may, but not necessarily, be an appropriate choice.

Mean values of hydrological parameters, such as mean annual or mean (sub)seasonal flows or rainfalls generally exhibit a low skewness. The log-normal or GEV type III distributions are appropriate in these cases.

The tests, discussed in the following sections, showed that the Pearson III distribution generally produced results very similar to those for the log-normal distribution. The latter is, however, much easier in its application and is therefore preferred.

For the preparation of the National Water Plan, MPO has used the Log-Pearson III distribution for annual maximum discharges, seemingly without providing any justification of that choice. A disadvantage of this distribution is that it requires the estimation of four instead of three parameters, viz. two location parameters (one for the normal variable and one for its log-transformed values), a scale and a shape parameter. The need to reduce the normal values with a threshold before the logarithms are taken, is obvious for water levels. Two water level stations may well exhibit the same statistical distribution, but be

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located at different altitudes. Levels first have to be reduced with a certain reference level before they are transformed in the logarithmic domain.

With respect to annual maximum discharges a zero 'reference discharge' (location parameter) could be taken, but this also means in fact the choice of a fourth parameter, while the result will generally be poor in that case. For example, annual maximum discharges at Bahadurabad nearly always exceed 40,000 m3/s and a non-zero location parameter for the discharges before taking the logarithms can be expected to produce better results in such case.

The estimation of four parameters on the basis of only 25 years data can hardly be expected to produce reliable results from a statistical point of view, even when the best parameter estimation method is used. Hence, the Log-Pearson III distribution faces a disadvantage in this respect compared to the other distributions, and should only be advocated if clear evidence for its appropriateness exists.

Recently, a study for the selection of a probability distribution applicable for annual maximum discharges in Bangladesh was carried out at the Institute of Flood Control and Drainage Research of the Bangladesh University of Engineering and Technology, see Ref.1. It concludes that both the GEV and the Log-Pearson III distributions are suitable for use in Bangladesh. No clear preference for one of the two distrubutions could be assessed.

It is noted that these studies are also based on short records of observations, viz. 20 to 30 years. Hence, likewise the Chi-square and other test, as well as visual inspection of goodness-of-fit, such studies based on short records of data can never properly assess the most adequate probability distribution for estimation of design events in the order of 100 years or more. Therefore, other considerations and physical evidence have to be used as an additional basis for selecting a distribution for application in the FAP.

In the FHS, therefore, the criterion was adopted that the recommended distribution should produce seemingly realistic design events for a 1,000 year return period. The tests, as discussed in the following sections, have shown that the fitted Log-Pearson III distributions generally exhibit rather poor extrapolation properties, in a sense that non realistic (or at least always on the high side) 1,000-year events are produced by this distribution. This, together with the need to estimate four parameters on the basis of only 25 years of data, prompted the FHS to ultimately not recommend this distribution. Nevertheless, it has been tested for all concerned hydrological parameters.

2.3 Methods of Parameter Estimation

It is stressed that parameter estimation methods based on the first two or three moments, although attractive from a computational point of view, should never be used under the prevailing conditions, given that generally only short records of observed or simulated events will be available, in the order of 25 years. In such cases these methods may induce a considerable bias in the derived design conditions. Instead, methods identical to or of similar quality as those used in the FHS are recommended, viz.:

- Maximum Likelihood methods (in some cases a slight modification is necessary);
- Probability Weighted Moment methods, or
- other methods of proven similar quality, if any.

Minor differences between the results of various equally good parameter estimation methods are of no significance, in particular in view of the errors embedded in observations and model results and due to the statistical uncertainty related to the generally short records of observations (as given by confidence intervals). Moreover, strong statistical tests to recommend on one distribution in favour of another on the basis of only minor differences are not available.

For the FHS (modified) Maximum Likelihood method has been used, as embedded in the HYMOS system. This method of parameter estimation is, generally, considered to be solid and accurate. Full information is available in the FAP 25 office.

2.4 Goodness-of-fit Tests

Reference is made to standard text books for a description of the Chi-square test for testing the goodness-of-fit of theoretical probability distributions. One particular aspect related to the number of class intervals should, however, be pointed out here. The minimum number of observations in each class should, generally, not be less than 5. Hence, with 24 observations available, the number of classes NCL should be at maximum 4. However, the number of degrees of freedom NDF of the test statistic should also at least be 1. NDF is calculated from:

NDF = NCL - NPAR - 1

where NPAR denotes the number of parameters to be estimated. This yields for the tested probability distribution functions the following minimum number of classes and number of observations (n = 24/NCL) in each interval, given NDF = 1:

Distribution	NPAR	min. NCL	n
Gumbel	2	4	6
Log-Pearson III	4	6	4
Other 4 distrib.	3	5	5

The Chi-square test only provides useful results when the number of classes is similar for each of the tested distributions, where NDF may vary with the number of estimated parameters. Consequently, the probabilities of exceedance of the test statistics, obtained in the present analyses for the Gumbel and the Log-Pearson distributions, can not be compared with those for the other four distributions.

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The Kolmogoroff-Smirnov considers only the largest difference between observed and theoretical cumulative probabilities. It does not suffer similar limitations as the Chi-square test for small samples. However, this test has limited value since its ability to discriminate between various distributions is extremely weak. This is confirmed by the results in the subsequent sections and its use is not recommended.

3. RECOMMENDED PROBABILITY DISTRIBUTIONS

3.1 Summary

This section summarizes the results of the systematic analysis of suitable probability distributions for frequency analysis of hydrological variables in Bangladesh. The recommendations, in particular valid for the main river system, are as follows:

- the 3-parameter log-normal distribution is appropriate for the statistical analysis of annual maximum water levels and average annual, seasonal and sub-seasonal discharges (flood volumes);

- the 3-parameter GEV-2 and the 2-parameter Gumbel distribution are appropriate for the analysis of annual extreme discharges. The GEV-3 distribution may be considered, but it should be noted that this member of the GEV-family has an upper threshold, which may not be very realistic for the considered variable;

- the 3-parameter log-normal distribution is appropriate for the analysis of annual, seasonal and sub-seasonal rainfall data. It has been outside the scope of the FHS to determine the most appropriate distribution for short term maximum rainfall data (hourly or daily).

The Log-Pearson III distribution, as applied for maximum discharges in the NWP, gives simular results as the GEV for low to medium return periods. For higher return periods (more than 100 years) the distribution gives higher peak discharges than any other tested distributaries and is thus probably somewhat conservative. It has the additional disadvantage that it has four parameters, the estimation of which is doubtful based on such short records as are available in Bangladesh.

The Pearson III, as applied for annual maximum water level in the NWP, usually yields the same results as the log-normal distribution. The latter is preferred for its easiness in application.

It is stressed that the above recommendations should not be applied rigidly, without precaution. Probability analysis is too much a matter of judgement to justify application of such recommendations as if they would represent the only truth. They may be considered no more and no less than guidelines.

Nevertheless, it is recommended that all FAPs choose their design criteria in the same manner. For example, design levels for the Right and Left Embankments of the Jamuna should be established in the same way.

It is noted that the choice of a particular distribution function is hardly relevant for a design period of say less than 50 years. Most theoretical distributions produce more or less the same design values. However, the actual choice of a distribution may substantially affect the 100-years design events.

In some cases, in particular when local conditions induce a particular statistical behaviour other than the one(s) observed in the main river system of Bangladesh, it may be necessary to repeat the full analysis for the complete set of potentially appropriate distributions for some key-stations in an area, along the lines indicated in Section 2.1. Hence, it is recommended that other FAPs, who are not working along the major rivers and require design levels for higher return periods (75-100 years), perform a similar analysis for their project area in feasibility and detailed design stage, to confirm the validity of the above results for each particular region and secondary river system.

The above precautions are valid for each of the considered hydrological variables, and are therefore not repeated in the subsequent sections.

3.2 Distribution of Annual Maximum Water Levels

All distributions mentioned in Section 2.1 were tested on annual maximum water levels at five stations along the main river system in Bangladesh:

- Bahadurabad on the Jamuna;

- Serajganj on the Jamuna;

- Baruria on the Padma;

- Mawa on the Padma;

- Bhairab Bazar on the Meghna.

Due to the necessity of a severe left censoring of maximum water levels at Hardinge Bridge, only the Gumbel distribution could be easily used in that case.

The results for each of the above five stations are plotted for comparison in Figures A.5.1 a) to A.5.1 e). All tested distributions fit fairly well and it is evident that a single visual inspection is not conclusive.

The results of the "goodness of fit" tests are summarized in Table A.5.1 and extrapolations of the tested distributions for the various stations are shown in Figure A.5.2. It is noted that Table A.5.1 shows the probability of exceedance of the test statistic. The highest value relates to the best fit.

Table A.5.1: Maximum Water Level Frequency Analysis; Goodness-of-fit Tests.

Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Bahadur-abad	KS	0.980	0.991	k<.01	0.986	0.998	0.998
	CHI2	0.109	0.288		0.288	0.288	0.129
Sirajganj	KS	0.938	0.936	k<.01	0.979	0.991	0.944
	CHI2	0.056	0.234		0.445	0.445	0.317
Baruria	KS	0.992	0.976	k<.01	0.993	0.996	0.975
	CHI2	0.414	0.234		0.234	0.445	0.480
Mawa	KS	0.900	0.956	k<.01	0.985	0.997	0.964
	CHI2	0.079	0.277		0.394	0.277	0.340
Bhairab Bazar	KS	0.924	k>-.01	0.867	0.858	0.916	0.878
	CHI2	0.083		0.317	0.317	0.445	0.025

Notes :
1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

The following observations can be made:

- Log-Pearson III often yields unlikely high extrapolated values for high return periods; it is also not recommended for other reasons discussed in section 2.2.

- Pearson III produces usually the same results as the log-normal distribution, which is preferred for its easiness in application.

- GEV type II, due to possible large negative values of the shape parameter k may yield very high extrapolated values for high return periods.

- Gumbel and GEV type III often produce the same results and may lead to very low extrapolated values for high return periods.

Considering the above, the log-normal distribution is recommended for the statistical analysis of annual maximum water levels. It shows relatively good goodness- of-fit tests, seems to produce reasonable extrapolated values for very high return periods and is easy to use.

A separate analysis was made of annual maximum water levels at Hardinge Bridge, where the lower annual maxima obviously belong to another parent distribution than the highest maxima, cf Figure A.5.1 f). A substantial left censoring has to be applied in this case, discarding all levels below a certain threshold (chosen at 14.8 m). Only the Gumbel distribution was selected for this case, given the theoretical difficulties in applying a substantial censoring for other distributions.

3.3 Distribution of Annual Maximum Discharges

The distributions mentioned in section 2.1 were tested for annual maximum discharges at the following stations:

- Bahadurabad on Jamuna;
- Hardinge Bridge on Ganges;
- Bhairab Bazar on Upper Meghna;
- Baruria on Padma;
- Nilukhirchar on Old Brahmaputra.

Table A.5.2 : Maximum Discharge Frequency Analysis;
Goodness-of-fit tests.

Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Bahadur-abad	KS	0.810	k>-.01	0.936	0.919	0.842	0.832
	CHI2	0.197		0.234	0.234	0.234	0.176
Hardinge Bridge	KS	0.637	k>-.01	0.919	0.946	0.858	0.442
	CHI2	0.564		0.037	0.134	0.037	0.046
Bhairab Bazar	KS	0.991	0.991	k<.01	0.991	0.991	0.971
	CHI2	0.273	0.480		0.480	0.480	0.317
Baruria	KS	0.877	k>-.01	k<.01	0.883	0.789	0.710
	CHI2	0.124			0.028	0.028	0.022
Nilukhi-rchar	KS	0.988	k>-.01	0.988	0.988	0.980	0.955
	CHI2	0.157		0.111	0.111	0.111	0.057

Notes :
1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

The results are plotted in Figures A.5.3 a) to A.5.3 e) for visual inspection. A fairly good fit is obtained for all distributions and stations. The results of the goodness-of-fit tests are summarized in Table A.5.2 and extrapolations of all distributions for all stations are shown in Figure A.5.4.

No clear preference for either the GEV or the log-normal distributions can be assessed on the basis of the probability graphs and the Chi-square statistics.

Although the Log-Pearson III distribution shows as such a satisfactory fit, it generally yields lower goodness-of-fit results (Kolmogoroff-Smirnov) and produces less likely extrapolated values for high return periods. Its use appears to be more conservative.

Given the considerations elaborated in section 2.2, and the results of studies contained in Ref. 1, the FHS recommends the use of the GEV distribution for the statistical analysis of annual extreme discharges in the FAPs, in particular types I and II (note that the Gumbel distribution is to be taken if the shape parameter k approaches zero). The GEV type III may also be taken, but it should be recalled that this member of the GEV family has an upper limit, which may be less likely for the distribution of annual extreme discharges (see also its extrapolations for very high return periods, as contained in Figure A.5.4).

3.4 Distribution of Seasonal Discharges

A similar analysis was made for the 6 months (May to October) average discharge. Results are plotted on Figures A.5.5 a) to A.5.5 e), results of goodness-of-fit tests are summarized in Table A.5.3 and extrapolations are shown in Figure A.5.6.

Table A.5.3: Average seasonal (May-Oct) Discharge Frequency Analysis; Goodness-of-fit Tests.

Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Bahadur-abad	KS	0.912	k>-.01	0.905	0.866	0.913	0.916
	CHI2	0.083		0.445	0.079	0.445	0.445
Hardinge Bridge	KS	0.408	k>-.01	0.982	0.886	0.783	0.328
	CHI2	0.157		0.445	0.317	0.079	0.025
Bhairab Bazar	KS	0.756	0.745	k<.01	0.764	0.773	0.745
	CHI2	0.248	0.050		0.050	0.050	0.005
Baruria	KS	0.471	k>-.01	0.730	0.729	0.617	0.454
	CHI2	0.079		0.022	0.022	0.022	0.057
Nilukhi-rchar	KS	0.454	k>-.01	0.673	0.714	0.578	0.344
	CHI2	0.527		0.025	0.008	0.025	0.046

Notes :
1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

The skewness of the Log-Pearson III, the GEV type II and the Gumbel distributions is generally to pronounced for fitting probability distributions of variables representing average hydrological conditions (see also the extrapolations for very high return periods as depicted in Figure A.5.6).

A visual inspection of the probability plots, Figure A.5.5, nor the results of the goodness-of-fit tests point to a particular preference for either one of the other distributions, viz. the GEV III, the log-normal and the Pearson-III distributions. However, the GEV type III distribution may tend to underestimate extremes for rather high return periods, Figure A.5.6, while the log-normal distribution is easy to use compared to the Pearson-III distribution. It is therefore recommended to use the log-normal distribution for the statistical analysis of average seasonal or sub-seasonal discharges.

3.5 Distribution of Total Annual Rainfall

Tests were carried out on total annual rainfall data for five stations distributed over Bangladesh, viz Dhaka (R009), Sylhet (R128), Khulna (R510), Bogra (R006) and Chittagong (R306).

The results are displayed in Figures A.5.7 a) to A.5.7 e) and A.5.8 and Table A.5.4. Visual inspection suggests that the best fit is obtained with the log-normal distribution. This is confirmed by the goodness-of-fit tests, as presented in Table A.5.4. The log-normal distribution tends to produce 'reasonable' extrapolated values. This distribution is recommended for all annual or sub-seasonal rainfall frequency analysis in Bangladesh

Table A.5.4: Annual Rainfall Frequency Analysis; Goodness-of-fit Tests.

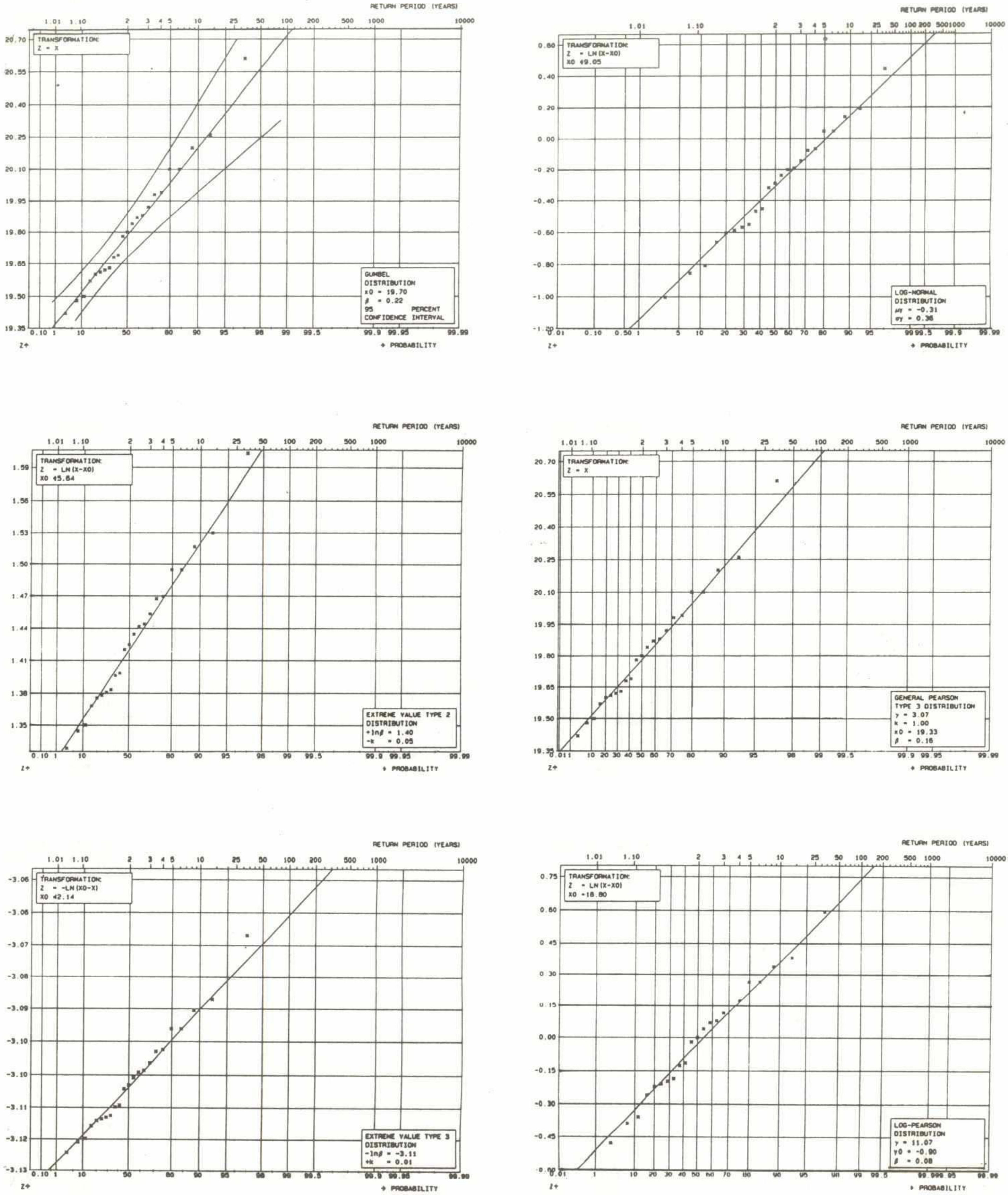
Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Dhaka	KS	0.626	k>-.01	0.805	0.919	0.916	0.722
	CHI2	0.122		0.258	0.484	0.418	0.115
Sylhet	KS	0.692	k>-.01	0.611	0.575	0.644	0.624
	CHI2	0.596		0.187	0.247	0.294	0.155
Khulna	KS	0.648	k>-.01	0.787	0.809	0.780	0.645
	CHI2	0.046		0.109	0.109	0.109	0.057
Bogra	KS	0.280	k>-.01	0.615	0.689	0.606	0.327
	CHI2	0.017		0.009	0.009	0.009	0.007
Chittagong	KS	0.531	k>-.01	0.874	0.714		0.426
	CHI2	0.192		0.106	0.166		0.139

Notes : 1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

4. REFERENCES

1. Karim, Md.A. and Chowdhury, J.U.:

Selection of Frequency Distribution Function for Annual Maximum Discharges in Bangladesh. 36th Annual Convention of the Institute of Engineers Bangladesh, Dhaka, January 1992.



FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Water Level at Bahadurabad	
	JUNE 1992	FIGURE A.5.1 a)

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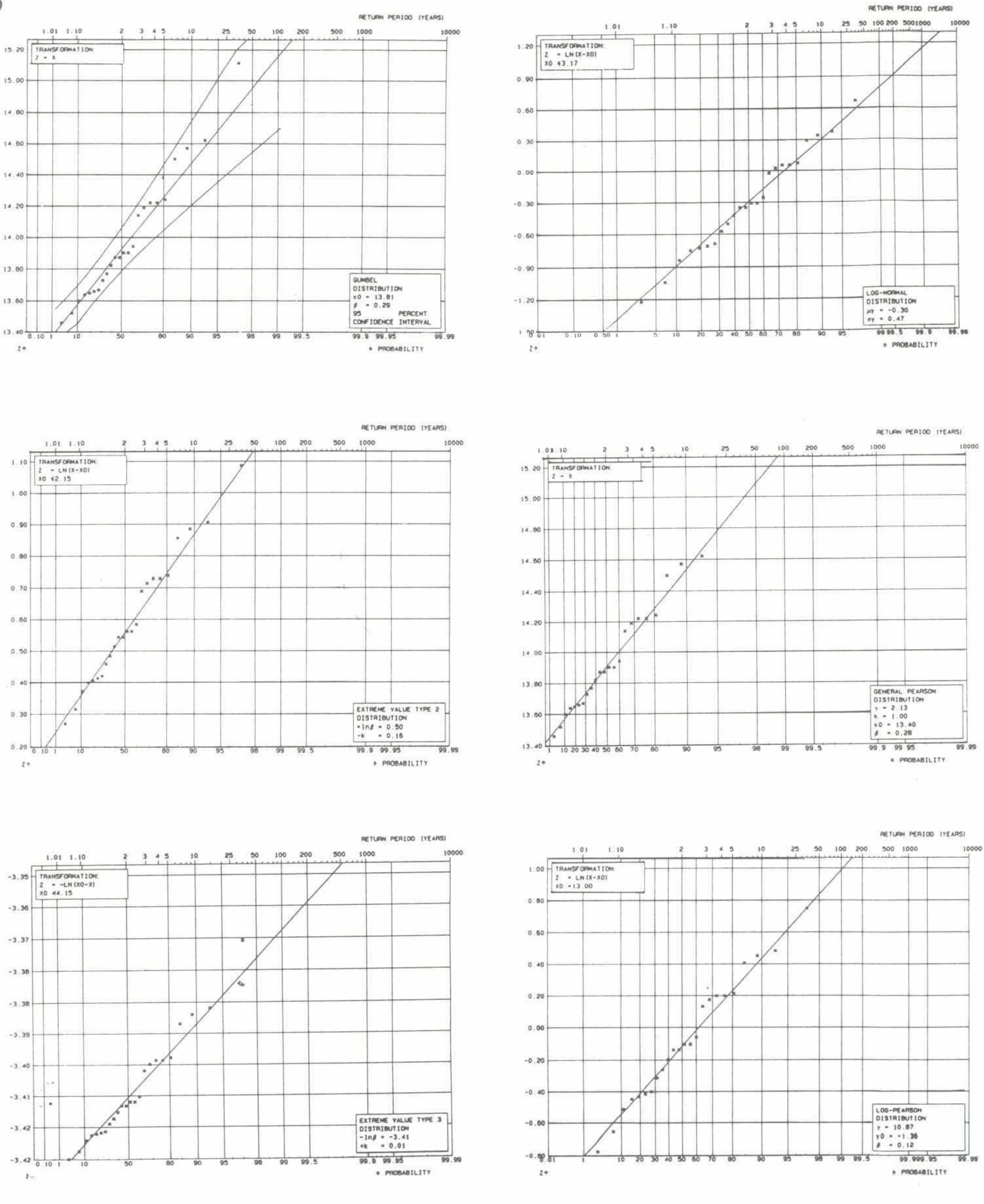


FAP25

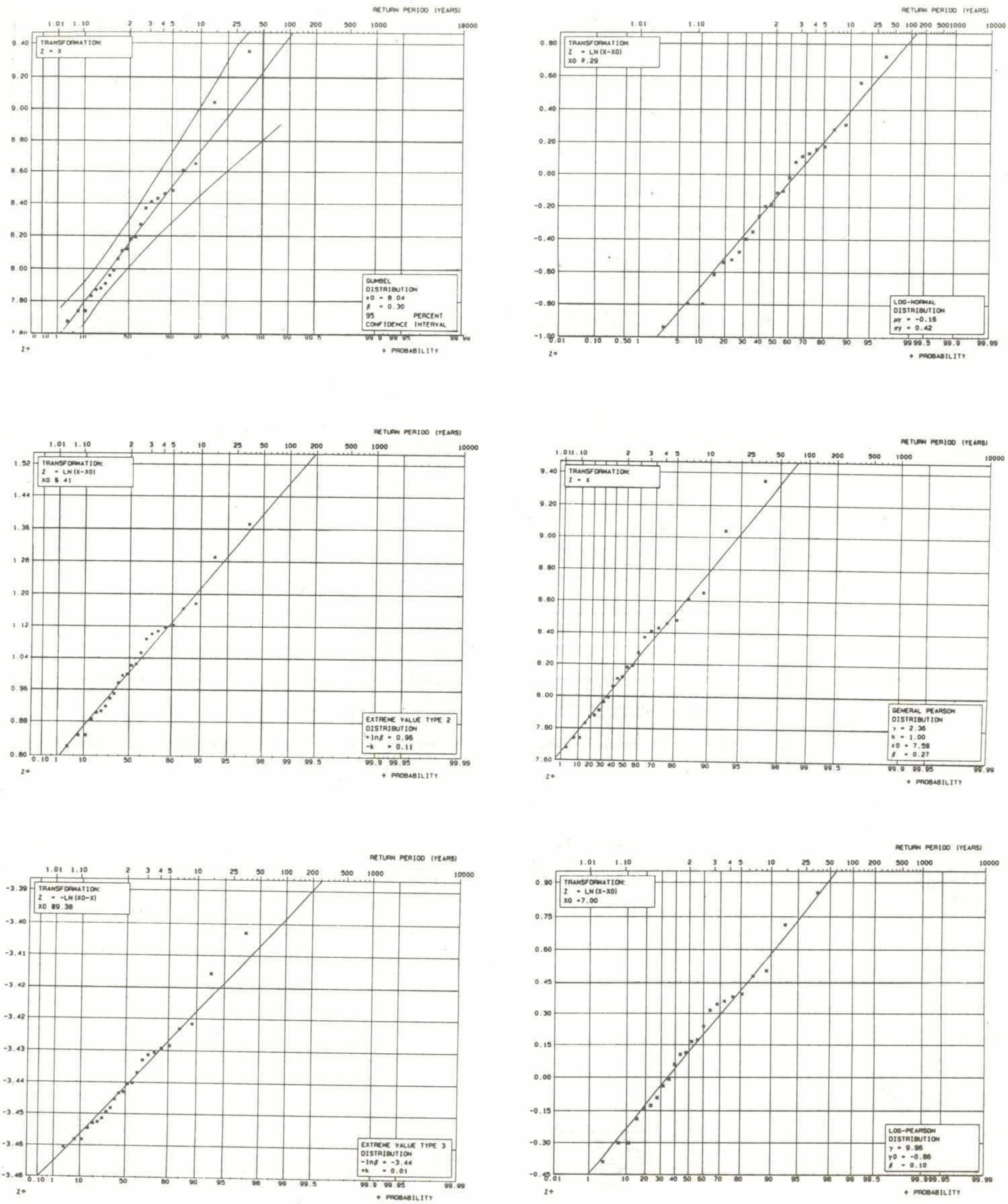
FLOOD MODELLING & MANAGEMENT

FLOOD HYDROLOGY STUDY

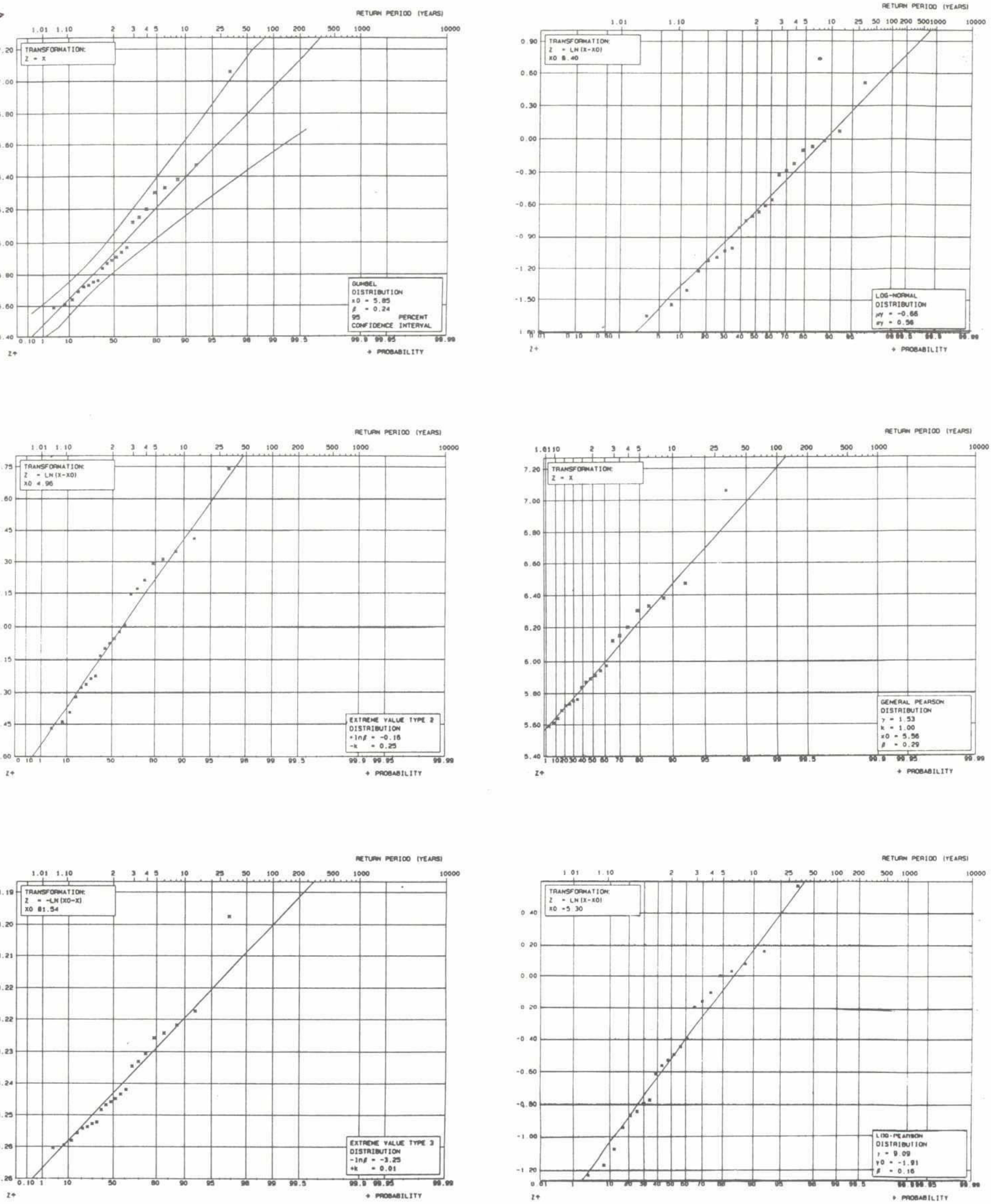
Fitting of 6 Different Probability Distributions for Peak Water Level at Serajganj

JUNE 1992

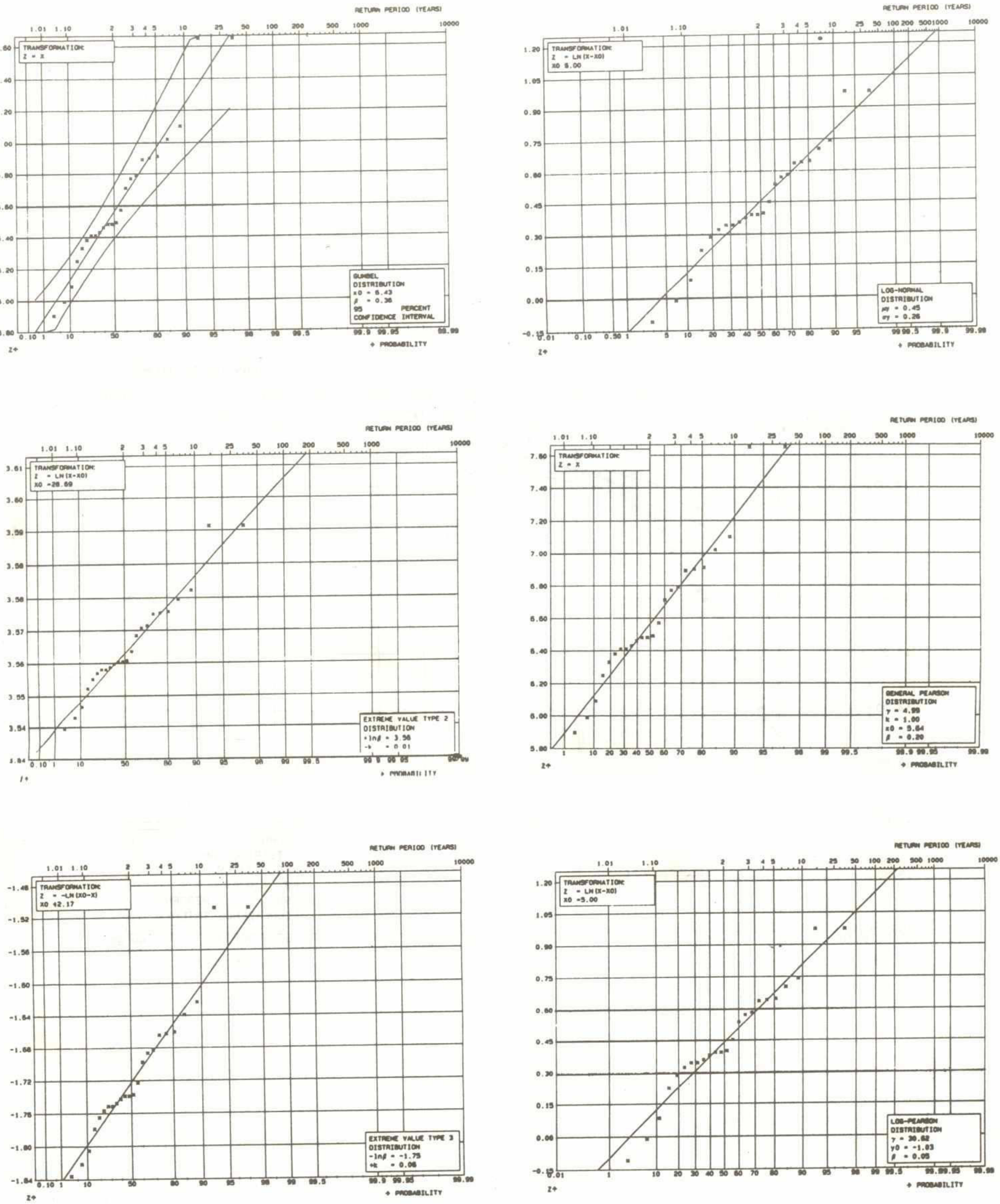
FIGURE A.5.1 b)



FAP25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Fitting of 6 Different Probability Distributions for Peak Water Level at Baruria
JUNE 1992	FIGURE A.5.1 c)



FAP 25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Water Level at Mawa	
	JUNE 1992	FIGURE A.5.1 d)



FAP 25 **FLOOD MODELLING & MANAGEMENT**	**FLOOD HYDROLOGY STUDY**
	Fitting of 6 Different Probability Distributions for Peak Water Level at Bhairab Bazar
	JUNE 1992 — **FIGURE A.5.1 e)**

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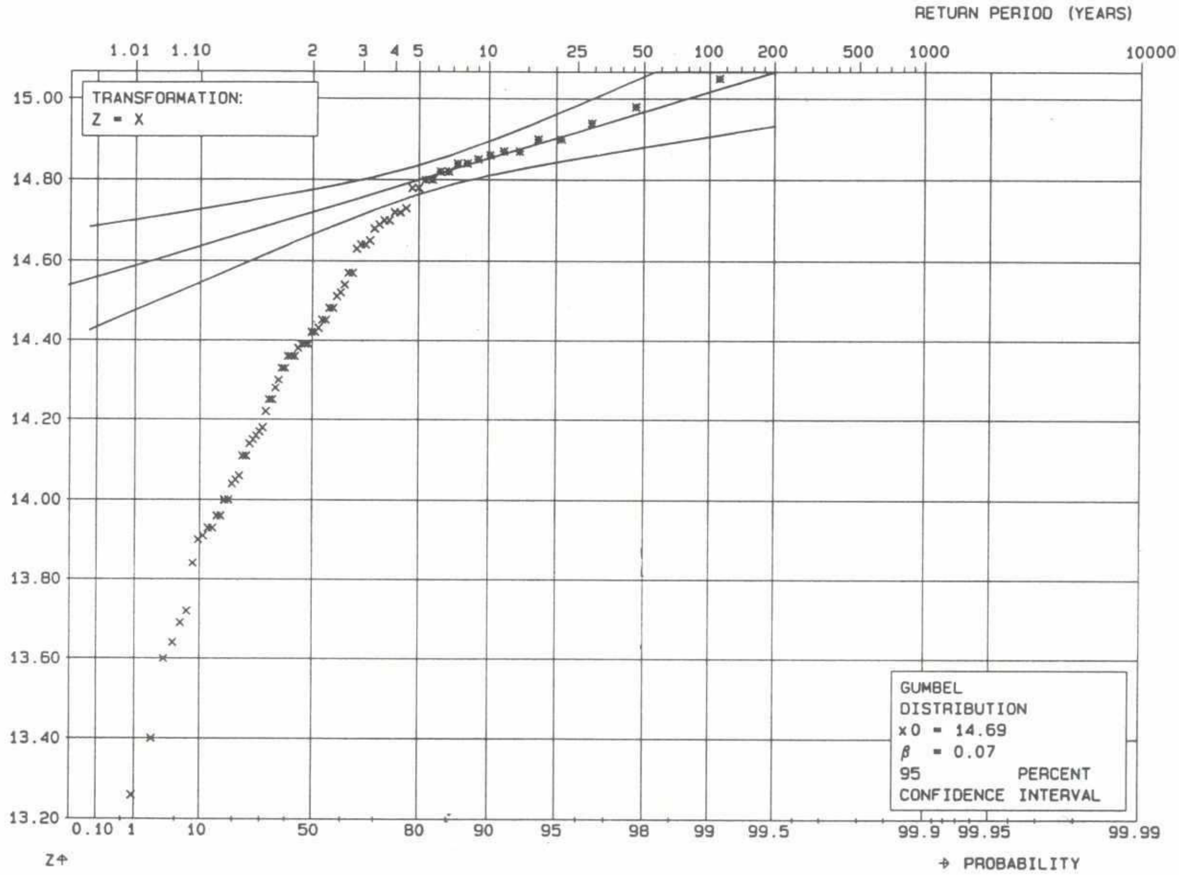
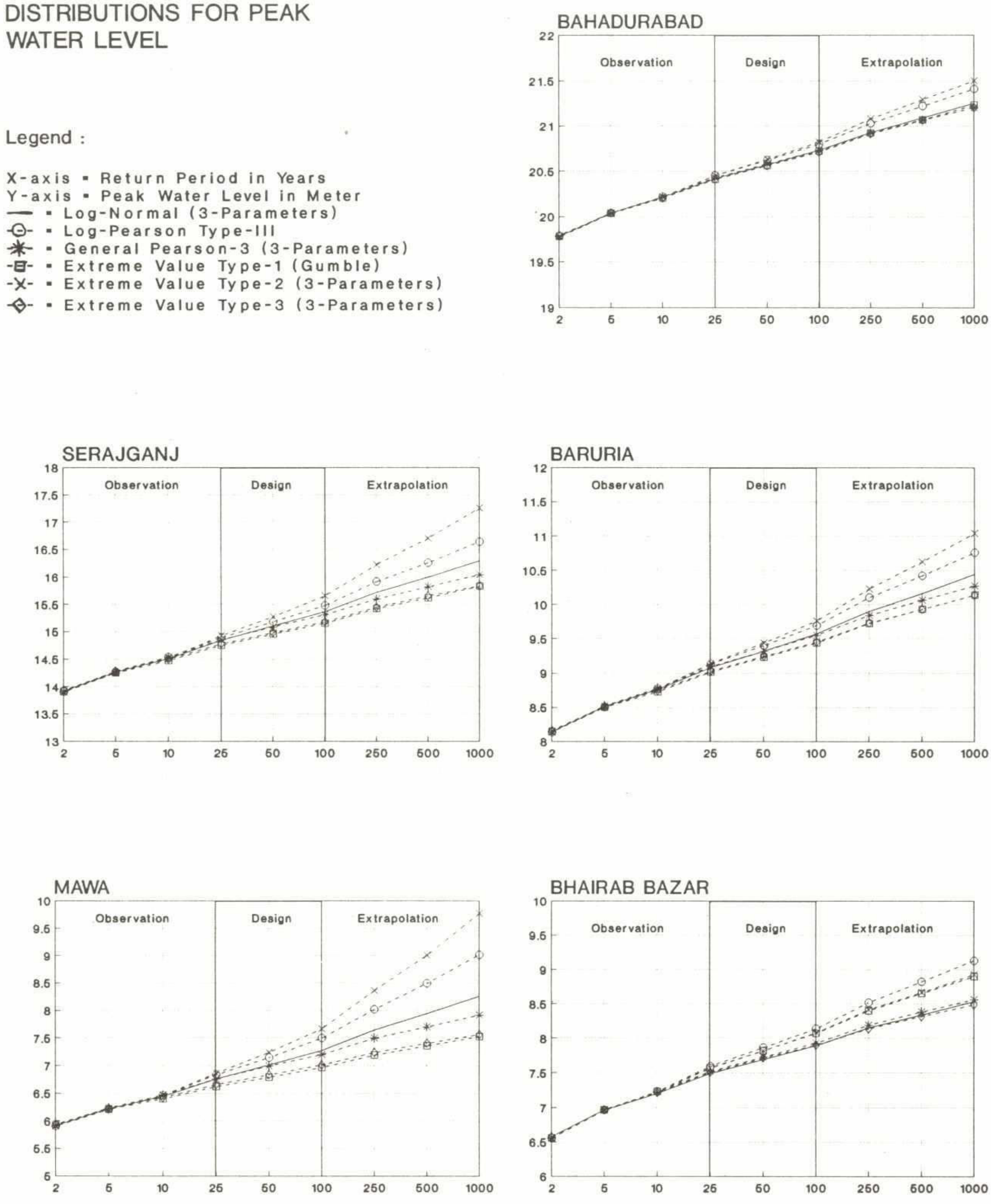
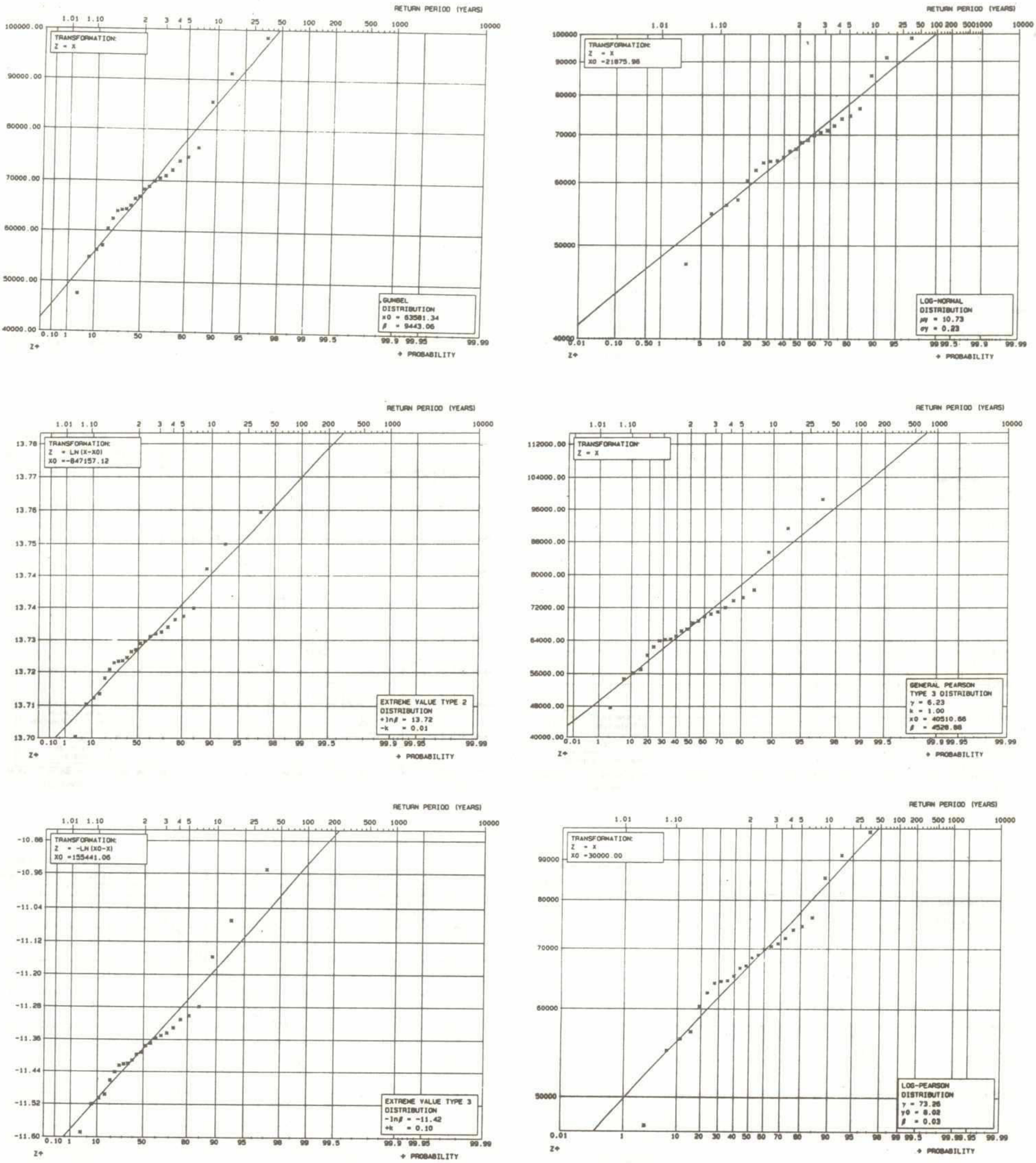


FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of Gumble Probability Distribution With Left Censoring for Peak Water Level at Hardinge Bridge	
	JUNE 1992	FIGURE A.5.1 f)

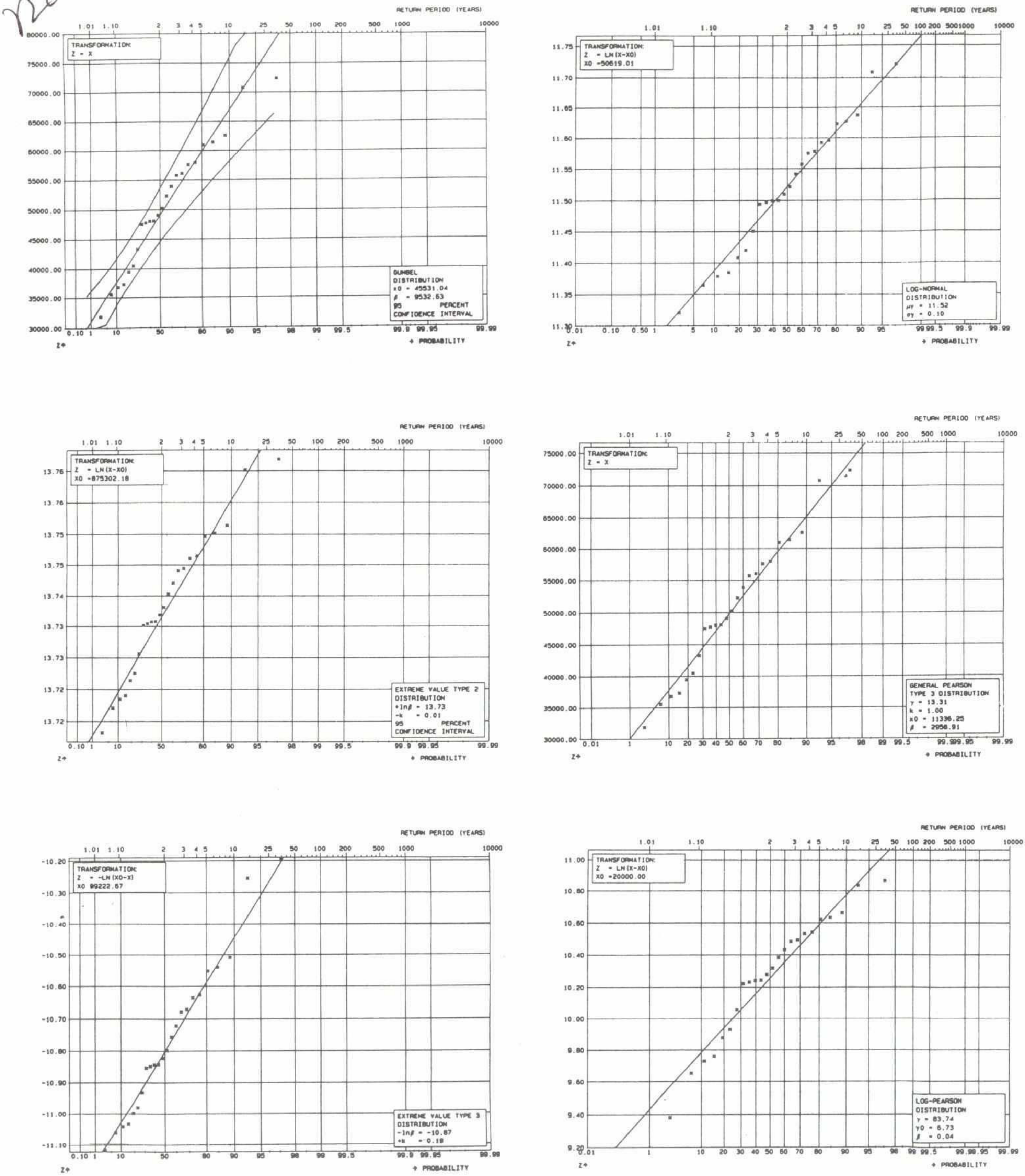
COMPARISON OF 6 DIFFERENT DISTRIBUTIONS FOR PEAK WATER LEVEL



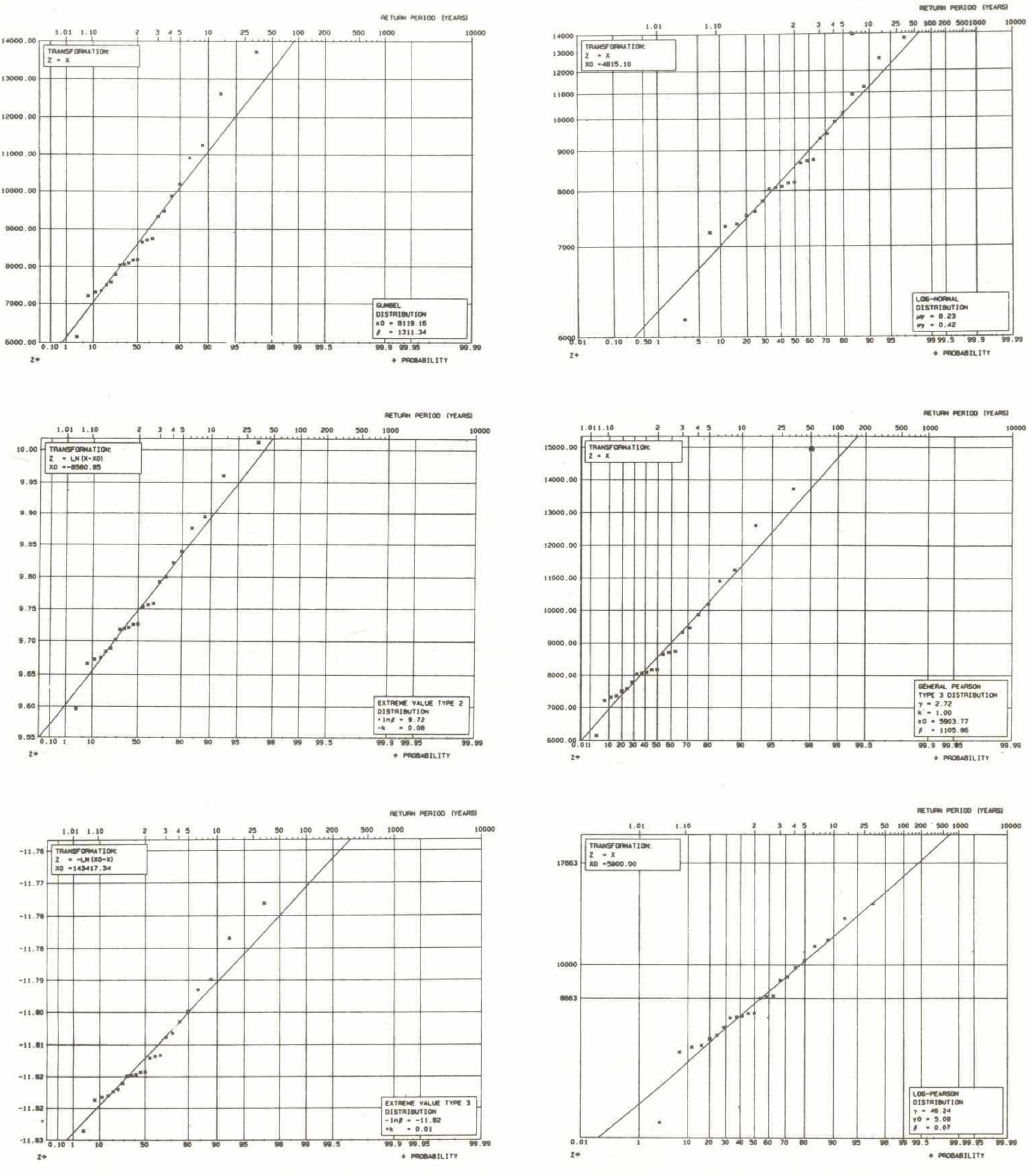
FAP25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Extrapolation Properties of 6 Different Distributions for Peak Water Level
JUNE 1992	FIGURE A.5.2



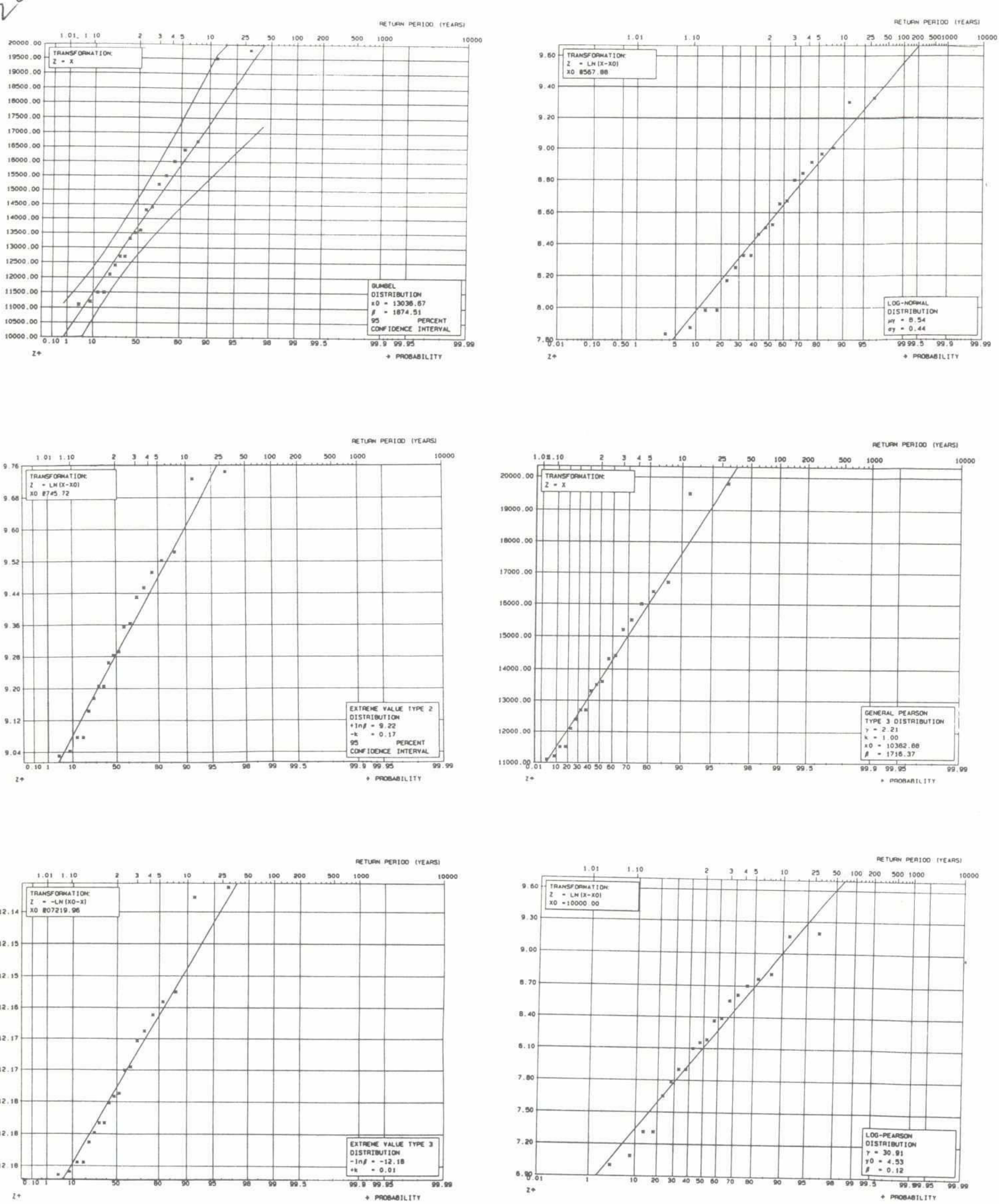
FAP25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Fitting of 6 Different Probability Distributions for Peak Discharges at Bahadurabad
	JUNE 1992 — FIGURE A.5.3 a)



FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Discharges at Hardinge Bridge	
	JUNE 1992	FIGURE A.5.3 b)



FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Discharges at Baruria	
	JUNE 1992	FIGURE A.5.3 c)



FAP 25

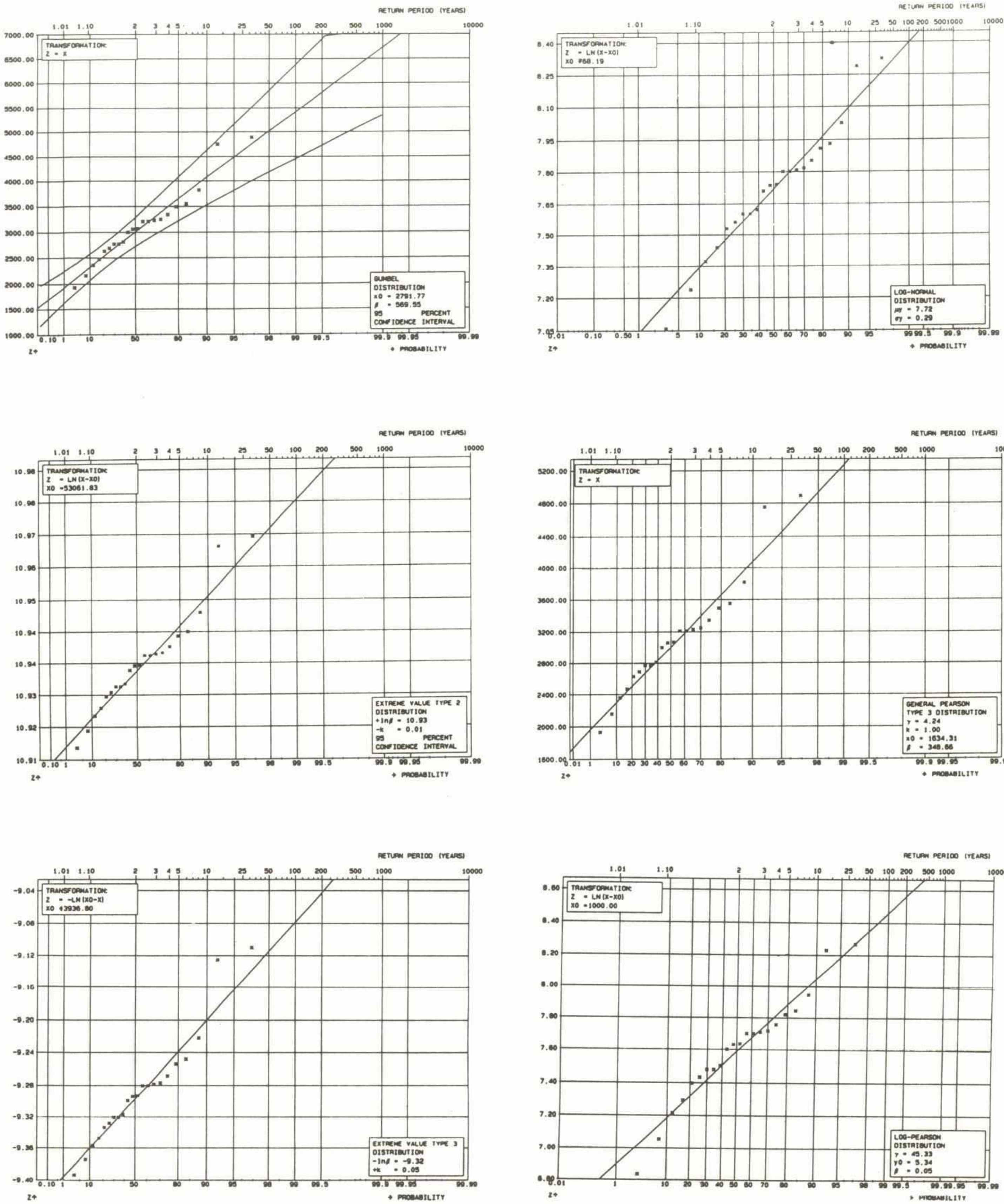
FLOOD MODELLING & MANAGEMENT

FLOOD HYDROLOGY STUDY

Fitting of 6 Different Probability Distributions for Peak Discharges at Bhairab Bazar

JUNE 1992

FIGURE A.5.3 d)



FAP25

FLOOD MODELLING & MANAGEMENT

FLOOD HYDROLOGY STUDY

Fitting of 6 Different Probability Distributions for Peak Discharges at Nilukhirchar

JUNE 1992

FIGURE A.5.3 e)

COASTAL STATIONS

YEARS	MISSING PERIOD	ACTION TAKEN
Water level for Golachipa (185)		
1970	Nov 8 to Nov 12	Interpolated value used
1973	Mar 31	Value of March 30 used as constant
1981	Apr 1 to Apr 4	Value of April 5 used as constant
	Jun 4	Interpolated value used
	Oct 1 to Mar 31	1982 same period value used
1982	Feb 13 to Feb 21	Interpolated value used
	Mar 27 to Mar 31	Value of March 26 used as constant
1985	Full Year	1984 full year value used
Water level for Daulatkhan (278)		
1972	Jul 7	Interpolated value used
1973	Jul 2	Interpolated value used
	Dec 10 to Dec 13	Interpolated value used
1975	Aug 15 to Aug 16	Interpolated value used
1976	Oct 22	Interpolated value used
80 to 82	Full years	Data generated by correlation with Chandpur (277) water level
Water level for Dasmunia (290)		
1969	Jul 31 to Aug 2	Interpolated value used
1970	Oct 23	Interpolated value used
	Nov 13 to Nov 23	Interpolated value used
1972	Sep 24 to Oct 28	1975 data used (same period)
	Nov 12 to Nov 19	Imterpolated value used
	Feb 10	. Interpolated value used
1978	Sep 11 to Sep 17	Interpolated value used
1979	Jun 15 to Jun 20	Interpolated value used
1980	Jun 11 to Jun 17	Interpolated value used
1981	Full Year	1980 full year value used
1982	Full Year	1987 full year value used

Notes : (1) The sign (-) is often neglected for daily high and low water level. This error has been corrected by checking the consitency between daily high and low water level and the range. These correction are not reported on this table.

(2) A systematic correction, suggested by SWMC, of + 0.75 m was applied to Daulat-Khan data.

YEARS	MISSING PERIOD	ACTION TAKEN
Water level for Patharghata (39)		
1977	Mar 1 to Mar31	1978 data used (same period)
1980	Oct 12 to Oct 18	Interpolated value used
	Mar 9 to Mar 21	Interpolated value used
1981	Apr 1 to Apr 4	Value of April 5 used as constant
1982	Apr 1 to Apr 3	Value of April 4 used as constant
	Mar 27 to Mar 31	Value of March 26 used as constant
1984	Feb 1 to Feb 28	- 1.8 m added
1987	Full year inconsistent	1988 value used
Water level for Mongla (244)		
1972	Apr 1 to Apr 23	- 1.0 m added
	Apr 24 to Apr 26	- 0.6 m added
	Apr 24 to Apr 30	Interpolated value used
	May 18 to May 25	- 0.5 m added
	Sep 1 to Sep 24	+ 0.5 m added
	Sep 10 to Sep 19	Interpolated value used
	Dec 31	Interpolated value used
1973	Feb 23 to Mar 31	- 0.6 m added
1974	Apr 1 to May 3	- 0.5 m added
	May 8 to Aug 2	- 0.5 m added
	Oct 1	Interpolated value used
	Nov 24 to Nov 30	Interpolated value used
	Feb 23 to Mar 1	Interpolated value used
1975	Jan 18 to Jan 28	- 0.5 m added
	Jan 30 to Jan 31	- 0.5 m added
1980	Dec 11 to Dec 21	Interpolated value used
	Jan 1	Interpolated value used
1982	Mar 20 to Mar 21	Interpolated value used
Water level for Rayenda (107.2)		
1982	Full Year	1983 value used
1989	Full Year	1988 value used

Notes : (1) The sign (-) is often neglected for daily high and low water level. This error has been corrected by checking the consitency between daily high and low water level and the range. These correction are not reported on this table.

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APPENDIX 5

Analyses of Suitable Probability Distributions

1. INTRODUCTION

This appendix describes in detail the analyses carried out with a view to identifying suitable probability distributions for various hydrological variables. Initially, it describes the methodology applied, including selection and characteristics of possible probability distribution, methods of parameter estimation and goodness-of-fit tests. Subsequently, the results of the analyses are detailed, providing documentation for the finally recommended distributions for annual maximum water level, annual maximum discharges, average seasonal discharges and total annual rainfall.

A summary of this appendix is provided in sections 6.1 - 6.2 of the Main Report.

2. SELECTION OF PROBABILITY DISTRIBUTIONS

2.1 Methodology

Prior to the systematic frequency analysis of water level, discharge and rainfall data, tests have been performed for the selection of the most appropriate probability distributions for use in Bangladesh.

For water levels and discharges focus has been on gauging stations along the main rivers. Even in these rivers particular statistical behaviour, induced by local hydraulic processes, may occur as observed for example for water levels at Hardinge Bridge, where the selected standard distribution is not applicable (Section 3.2). In such cases, specific distribution studies should be undertaken, following the methodology outlined in this section.

Rainfall probability distributions are generally not affected by particular local conditions and the distribution recommended by the FHS may be applied country wide.

The methodology used in this study for the selection of probability distributions is also recommended for application by other FAPs for feasibility studies and detailed design, at project specific locations. The methodology includes:

- Selection of possible probability distributions among the most widely used ones:

    * Gumbel (or GEV type I)
    * GEV type II
    * GEV type III
    * Log Normal
    * Pearson III
    * Log-Pearson III

- Selection of representative and reliable key-stations, well distributed over the study area (in the present study 5 stations);

- Fitting of the various probability distributions for the selected key-stations, using the Maximum Likelihood method or another method of similar quality, and plotting of the results for visual inspection. Special attention should be given to eventual outliers or the eventual need for left censoring;

- Application of goodness-of-fit tests, such as the Kolmogoroff-Smirnov and Chi-square tests;

- Comparison of the extrapolation properties of the tested probability distributions;

- Selection of (an) appropriate distribution(s) for application in the project area.

In carrying out the analyses the plotting position formula proposed by Benard and Bos-levenbach has been applied, i.e $p=(m-0.3)/(n+0.4)$, where p is the assigned exceedance probability, m is the rank of the event and n is the total number of observations.

The standard applied in Bangladesh by the BWDB is the generally acknowledged Weibull formula: $p = m/(n+1)$. The reason for using the Benard and Bos-Levenbach formula in the FHS is simply because this is the formula used in HYMOS.

The selection of plotting position formula is very much a matter of taste and to justify one in favour of the other is very difficult. In the actual case, where the period in question (1965-89) contains two major floods, 1987 and 1988, probably with higher return periods than 25 years, it may be argued that the use of the Weibull formula is conservative, while the Benard and Bos-Levenbach formula attach a return period, which is closer to the (unknown) true period of these events.

For comparison of the extrapolation properties of various distributions, extrapolated values have been plotted for the fitted distributions up to the 1,000 year return period. It is acknowledged that such an extrapolation is certainly not needed for the FAP, and has little value as such, considering the available short observation periods (only 24 years). However, probability distributions used to estimate 100-year design events or levels, should preferably produce also realistic 1,000-year events. If the latter appear not to be realistic (for example a 1,000-year maximum water level of more than 2 m above the 1988 maximum water level), there is no guarantee that extrapolations towards the 100 year events can be relied upon.

The above methodology has been applied for the following hydrological variables:

- annual maximum water levels;

- annual maximum discharges;

- average seasonal discharges;

- total annual rainfall.

The analyses have been carried out using HYMOS, a hydrological data management and processing package developed by DEFLT HYDRAULICS.

2.2 Characteristics of Selected Distributions

The Gumbel distribution implies the estimation of only 2 parameters, which is an advantage in the event of short data series. The function is generally useful for estimating extreme annual events. Its limitation is that its skewness is fixed, which reduces its flexibility.

The next four distributions mentioned in Section 2.1, require the estimation of 3 parameters, viz. a location (threshold), scale and shape parameter. This provides sufficient flexibility for practical purposes.

The Log-Pearson distribution has in fact 4 parameters (also in the way it is used in the National Water Plan (NWP)), which makes its use in the event of only short series of observations less attractive.

The first three distributions all belong to the GEV family. In HYMOS this family was split up into its three members on purpose. The Gumbel or GEV type I distribution has neither an upper limit, nor a lower one. The GEV type II has a lower threshold and is therefore useful for hydrological parameters exhibiting no clear upper limits, such as for example maximum hourly rainfall data or annual maximum discharges. The use of the GEV type III, with an upper threshold, for such parameters is questionable, which is the reason that a particular GEV type can be selected in HYMOS.

The range of annual maximum water levels in Bangladesh exhibits on the contrary a kind of upper limit. During extreme floods huge spills into the flood plains occur, the country is nearly totally flooded and at some stage water levels can hardly rise anymore. In such case the GEV type III may, but not necessarily, be an appropriate choice.

Mean values of hydrological parameters, such as mean annual or mean (sub)seasonal flows or rainfalls generally exhibit a low skewness. The log-normal or GEV type III distributions are appropriate in these cases.

The tests, discussed in the following sections, showed that the Pearson III distribution generally produced results very similar to those for the log-normal distribution. The latter is, however, much easier in its application and is therefore preferred.

For the preparation of the National Water Plan, MPO has used the Log-Pearson III distribution for annual maximum discharges, seemingly without providing any justification of that choice. A disadvantage of this distribution is that it requires the estimation of four instead of three parameters, viz. two location parameters (one for the normal variable and one for its log-transformed values), a scale and a shape parameter. The need to reduce the normal values with a threshold before the logarithms are taken, is obvious for water levels. Two water level stations may well exhibit the same statistical distribution, but be located at different altitudes. Levels first have to be reduced with a certain reference level before they are transformed in the logarithmic domain.

With respect to annual maximum discharges a zero 'reference discharge' (location parameter) could be taken, but this also means in fact the choice of a fourth parameter, while the result will generally be poor in that case. For example, annual maximum discharges at Bahadurabad nearly always exceed 40,000 m3/s and a non-zero location parameter for the discharges before taking the logarithms can be expected to produce better results in such case.

The estimation of four parameters on the basis of only 25 years data can hardly be expected to produce reliable results from a statistical point of view, even when the best parameter estimation method is used. Hence, the Log-Pearson III distribution faces a disadvantage in this respect compared to the other distributions, and should only be advocated if clear evidence for its appropriateness exists.

Recently, a study for the selection of a probability distribution applicable for annual maximum discharges in Bangladesh was carried out at the Institute of Flood Control and Drainage Research of the Bangladesh University of Engineering and Technology, see Ref.1. It concludes that both the GEV and the Log-Pearson III distributions are suitable for use in Bangladesh. No clear preference for one of the two distrubutions could be assessed.

It is noted that these studies are also based on short records of observations, viz. 20 to 30 years. Hence, likewise the Chi-square and other test, as well as visual inspection of goodness-of-fit, such studies based on short records of data can never properly assess the most adequate probability distribution for estimation of design events in the order of 100 years or more. Therefore, other considerations and physical evidence have to be used as an additional basis for selecting a distribution for application in the FAP.

In the FHS, therefore, the criterion was adopted that the recommended distribution should produce seemingly realistic design events for a 1,000 year return period. The tests, as discussed in the following sections, have shown that the fitted Log-Pearson III distributions generally exhibit rather poor extrapolation properties, in a sense that non realistic (or at least always on the high side) 1,000-year events are produced by this distribution. This, together with the need to estimate four parameters on the basis of only 25 years of data, prompted the FHS to ultimately not recommend this distribution. Nevertheless, it has been tested for all concerned hydrological parameters.

2.3 Methods of Parameter Estimation

It is stressed that parameter estimation methods based on the first two or three moments, although attractive from a computational point of view, should never be used under the prevailing conditions, given that generally only short records of observed or simulated events will be available, in the order of 25 years. In such cases these methods may induce a considerable bias in the derived design conditions. Instead, methods identical to or of

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similar quality as those used in the FHS are recommended, viz.:

- Maximum Likelihood methods (in some cases a slight modification is necessary);

- Probability Weighted Moment methods, or

- other methods of proven similar quality, if any.

Minor differences between the results of various equally good parameter estimation methods are of no significance, in particular in view of the errors embedded in observations and model results and due to the statistical uncertainty related to the generally short records of observations (as given by confidence intervals). Moreover, strong statistical tests to recommend on one distribution in favour of another on the basis of only minor differences are not available.

For the FHS (modified) Maximum Likelihood method has been used, as embedded in the HYMOS system. This method of parameter estimation is, generally, considered to be solid and accurate. Full information is available in the FAP 25 office.

2.4 Goodness-of-fit Tests

Reference is made to standard text books for a description of the Chi-square test for testing the goodness-of-fit of theoretical probability distributions. One particular aspect related to the number of class intervals should, however, be pointed out here. The minimum number of observations in each class should, generally, not be less than 5. Hence, with 24 observations available, the number of classes NCL should be at maximum 4. However, the number of degrees of freedom NDF of the test statistic should also at least be 1. NDF is calculated from:

$$NDF = NCL - NPAR - 1$$

where NPAR denotes the number of parameters to be estimated. This yields for the tested probability distribution functions the following minimum number of classes and number of observations (n = 24/NCL) in each interval, given NDF = 1:

Distribution	NPAR	min. NCL	n
Gumbel	2	4	6
Log-Pearson III	4	6	4
Other 4 distrib.	3	5	5

The Chi-square test only provides useful results when the number of classes is similar for each of the tested distributions, where NDF may vary with the number of estimated parameters. Consequently, the probabilities of exceedance of the test statistics, obtained in the present analyses for the Gumbel and the Log-Pearson distributions, can not be compared with those for the other four distributions.

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The Kolmogoroff-Smirnov considers only the largest difference between observed and theoretical cumulative probabilities. It does not suffer similar limitations as the Chi-square test for small samples. However, this test has limited value since its ability to discriminate between various distributions is extremely weak. This is confirmed by the results in the subsequent sections and its use is not recommended.

3. RECOMMENDED PROBABILITY DISTRIBUTIONS

3.1 Summary

This section summarizes the results of the systematic analysis of suitable probability distributions for frequency analysis of hydrological variables in Bangladesh. The recommendations, in particular valid for the main river system, are as follows:

- the 3-parameter log-normal distribution is appropriate for the statistical analysis of annual maximum water levels and average annual, seasonal and sub-seasonal discharges (flood volumes);

- the 3-parameter GEV-2 and the 2-parameter Gumbel distribution are appropriate for the analysis of annual extreme discharges. The GEV-3 distribution may be considered, but it should be noted that this member of the GEV-family has an upper threshold, which may not be very realistic for the considered variable;

- the 3-parameter log-normal distribution is appropriate for the analysis of annual, seasonal and sub-seasonal rainfall data. It has been outside the scope of the FHS to determine the most appropriate distribution for short term maximum rainfall data (hourly or daily).

The Log-Pearson III distribution, as applied for maximum discharges in the NWP, gives simular results as the GEV for low to medium return periods. For higher return periods (more than 100 years) the distribution gives higher peak discharges than any other tested distributaries and is thus probably somewhat conservative. It has the additional disadvantage that it has four parameters, the estimation of which is doubtful based on such short records as are available in Bangladesh.

The Pearson III, as applied for annual maximum water level in the NWP, usually yields the same results as the log-normal distribution. The latter is preferred for its easiness in application.

It is stressed that the above recommendations should not be applied rigidly, without precaution. Probability analysis is too much a matter of judgement to justify application of such recommendations as if they would represent the only truth. They may be considered no more and no less than guidelines.

Nevertheless, it is recommended that all FAPs choose their design criteria in the same manner. For example, design levels for the Right and Left Embankments of the Jamuna should be established in the same way.

It is noted that the choice of a particular distribution function is hardly relevant for a design period of say less than 50 years. Most theoretical distributions produce more or less the same design values. However, the actual choice of a distribution may substantially affect the 100-years design events.

In some cases, in particular when local conditions induce a particular statistical behaviour other than the one(s) observed in the main river system of Bangladesh, it may be necessary to repeat the full analysis for the complete set of potentially appropriate distributions for some key-stations in an area, along the lines indicated in Section 2.1. Hence, it is recommended that other FAPs, who are not working along the major rivers and require design levels for higher return periods (75-100 years), perform a similar analysis for their project area in feasibility and detailed design stage, to confirm the validity of the above results for each particular region and secondary river system.

The above precautions are valid for each of the considered hydrological variables, and are therefore not repeated in the subsequent sections.

3.2 Distribution of Annual Maximum Water Levels

All distributions mentioned in Section 2.1 were tested on annual maximum water levels at five stations along the main river system in Bangladesh:

- Bahadurabad on the Jamuna;

- Serajganj on the Jamuna;

- Baruria on the Padma;

- Mawa on the Padma;

- Bhairab Bazar on the Meghna.

Due to the necessity of a severe left censoring of maximum water levels at Hardinge Bridge, only the Gumbel distribution could be easily used in that case.

The results for each of the above five stations are plotted for comparison in Figures A.5.1 a) to A.5.1 e). All tested distributions fit fairly well and it is evident that a single visual inspection is not conclusive.

The results of the "goodness of fit" tests are summarized in Table A.5.1 and extrapolations of the tested distributions for the various stations are shown in Figure A.5.2. It is noted that Table A.5.1 shows the probability of exceedance of the test statistic. The highest value relates to the best fit.

Table A.5.1: Maximum Water Level Frequency Analysis;
Goodness-of-fit Tests.

Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Bahadur-abad	KS	0.980	0.991	k<.01	0.986	0.998	0.998
	CHI2	0.109	0.288		0.288	0.288	0.129
Sirajganj	KS	0.938	0.936	k<.01	0.979	0.991	0.944
	CHI2	0.056	0.234		0.445	0.445	0.317
Baruria	KS	0.992	0.976	k<.01	0.993	0.996	0.975
	CHI2	0.414	0.234		0.234	0.445	0.480
Mawa	KS	0.900	0.956	k<.01	0.985	0.997	0.964
	CHI2	0.079	0.277		0.394	0.277	0.340
Bhairab Bazar	KS	0.924	k>-.01	0.867	0.858	0.916	0.878
	CHI2	0.083		0.317	0.317	0.445	0.025

Notes :
1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

The following observations can be made:

- Log-Pearson III often yields unlikely high extrapolated values for high return periods; it is also not recommended for other reasons discussed in section 2.2.

- Pearson III produces usually the same results as the log-normal distribution, which is preferred for its easiness in application.

- GEV type II, due to possible large negative values of the shape parameter k may yield very high extrapolated values for high return periods.

- Gumbel and GEV type III often produce the same results and may lead to very low extrapolated values for high return periods.

Considering the above, the log-normal distribution is recommended for the statistical analysis of annual maximum water levels. It shows relatively good goodness- of-fit tests, seems to produce reasonable extrapolated values for very high return periods and is easy to use.

A separate analysis was made of annual maximum water levels at Hardinge Bridge, where the lower annual maxima obviously belong to another parent distribution than the highest maxima, cf Figure A.5.1 f). A substantial left censoring has to be applied in this case, discarding all levels below a certain threshold (chosen at 14.8 m). Only the Gumbel distribution was selected for this case, given the theoretical difficulties in applying a substantial censoring for other distributions.

3.3 Distribution of Annual Maximum Discharges

The distributions mentioned in section 2.1 were tested for annual maximum discharges at the following stations:

- Bahadurabad on Jamuna;
- Hardinge Bridge on Ganges;
- Bhairab Bazar on Upper Meghna;
- Baruria on Padma;
- Nilukhirchar on Old Brahmaputra.

Table A.5.2 : Maximum Discharge Frequency Analysis;
Goodness-of-fit tests.

Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Bahadur-abad	KS	0.810	k>-.01	0.936	0.919	0.842	0.832
	CHI2	0.197		0.234	0.234	0.234	0.176
Hardinge Bridge	KS	0.637	k>-.01	0.919	0.946	0.858	0.442
	CHI2	0.564		0.037	0.134	0.037	0.046
Bhairab Bazar	KS	0.991	0.991	k<.01	0.991	0.991	0.971
	CHI2	0.273	0.480		0.480	0.480	0.317
Baruria	KS	0.877	k>-.01	k<.01	0.883	0.789	0.710
	CHI2	0.124			0.028	0.028	0.022
Nilukhi-rchar	KS	0.988	k>-.01	0.988	0.988	0.980	0.955
	CHI2	0.157		0.111	0.111	0.111	0.057

Notes :
1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

The results are plotted in Figures A.5.3 a) to A.5.3 e) for visual inspection. A fairly good fit is obtained for all distributions and stations. The results of the goodness-of-fit tests are summarized in Table A.5.2 and extrapolations of all distributions for all stations are shown in Figure A.5.4.

No clear preference for either the GEV or the log-normal distributions can be assessed on the basis of the probability graphs and the Chi-square statistics.

Although the Log-Pearson III distribution shows as such a satisfactory fit, it generally yields lower goodness-of-fit results (Kolmogoroff-Smirnov) and produces less likely extrapolated values for high return periods. Its use appears to be more conservative.

Given the considerations elaborated in section 2.2, and the results of studies contained in Ref. 1, the FHS recommends the use of the GEV distribution for the statistical analysis of annual extreme discharges in the FAPs, in particular types I and II (note that the Gumbel distribution is to be taken if the shape parameter k approaches zero). The GEV type III may also be taken, but it should be recalled that this member of the GEV family has an upper limit, which may be less likely for the distribution of annual extreme discharges (see also its extrapolations for very high return periods, as contained in Figure A.5.4).

3.4 Distribution of Seasonal Discharges

A similar analysis was made for the 6 months (May to October) average discharge. Results are plotted on Figures A.5.5 a) to A.5.5 e), results of goodness-of-fit tests are summarized in Table A.5.3 and extrapolations are shown in Figure A.5.6.

Table A.5.3: Average seasonal (May-Oct) Discharge Frequency Analysis; Goodness-of-fit Tests.

Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Bahadur-	KS	0.912	k>-.01	0.905	0.866	0.913	0.916
abad	CHI2	0.083		0.445	0.079	0.445	0.445
Hardinge	KS	0.408	k>-.01	0.982	0.886	0.783	0.328
Bridge	CHI2	0.157		0.445	0.317	0.079	0.025
Bhairab	KS	0.756	0.745	k<.01	0.764	0.773	0.745
Bazar	CHI2	0.248	0.050		0.050	0.050	0.005
Baruria	KS	0.471	k>-.01	0.730	0.729	0.617	0.454
	CHI2	0.079		0.022	0.022	0.022	0.057
Nilukhi-	KS	0.454	k>-.01	0.673	0.714	0.578	0.344
rchar	CHI2	0.527		0.025	0.008	0.025	0.046

Notes :
1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

The skewness of the Log-Pearson III, the GEV type II and the Gumbel distributions is generally to pronounced for fitting probability distributions of variables representing average hydrological conditions (see also the extrapolations for very high return periods as depicted in Figure A.5.6).

A visual inspection of the probability plots, Figure A.5.5, nor the results of the goodness-of-fit tests point to a particular preference for either one of the other distributions, viz. the GEV III, the log-normal and the Pearson-III distributions. However, the GEV type III distribution may tend to underestimate extremes for rather high return periods, Figure A.5.6, while the log-normal distribution is easy to use compared to the Pearson-III distribution. It is therefore recommended to use the log-normal distribution for the statistical analysis of average seasonal or sub-seasonal discharges.

3.5 Distribution of Total Annual Rainfall

Tests were carried out on total annual rainfall data for five stations distributed over Bangladesh, viz Dhaka (R009), Sylhet (R128), Khulna (R510), Bogra (R006) and Chittagong (R306).

The results are displayed in Figures A.5.7 a) to A.5.7 e) and A.5.8 and Table A.5.4. Visual inspection suggests that the best fit is obtained with the log-normal distribution. This is confirmed by the goodness-of-fit tests, as presented in Table A.5.4. The log-normal distribution tends to produce 'reasonable' extrapolated values. This distribution is recommended for all annual or sub-seasonal rainfall frequency analysis in Bangladesh

Table A.5.4: Annual Rainfall Frequency Analysis; Goodness-of-fit Tests.

Station	Test	Gumbel	GEV2	GEV3	Log-Norm	Pearson III	L-Pearson III
Dhaka	KS	0.626	k>-.01	0.805	0.919	0.916	0.722
	CHI2	0.122		0.258	0.484	0.418	0.115
Sylhet	KS	0.692	k>-.01	0.611	0.575	0.644	0.624
	CHI2	0.596		0.187	0.247	0.294	0.155
Khulna	KS	0.648	k>-.01	0.787	0.809	0.780	0.645
	CHI2	0.046		0.109	0.109	0.109	0.057
Bogra	KS	0.280	k>-.01	0.615	0.689	0.606	0.327
	CHI2	0.017		0.009	0.009	0.009	0.007
Chittagong	KS	0.531	k>-.01	0.874	0.714		0.426
	CHI2	0.192		0.106	0.166		0.139

Notes :
1. k>-.01 or <.01 means that either GEV2 or GEV3 do not provide a good fit
2. Chi-square test for the Gumbel and Log-Pearson distribution cannot be compared with the results for the other distributions (see section 2.4)

4. REFERENCES

1. Karim, Md.A. and Chowdhury, J.U.:

Selection of Frequency Distribution Function for Annual Maximum Discharges in Bangladesh. 36th Annual Convention of the Institute of Engineers Bangladesh, Dhaka, January 1992.

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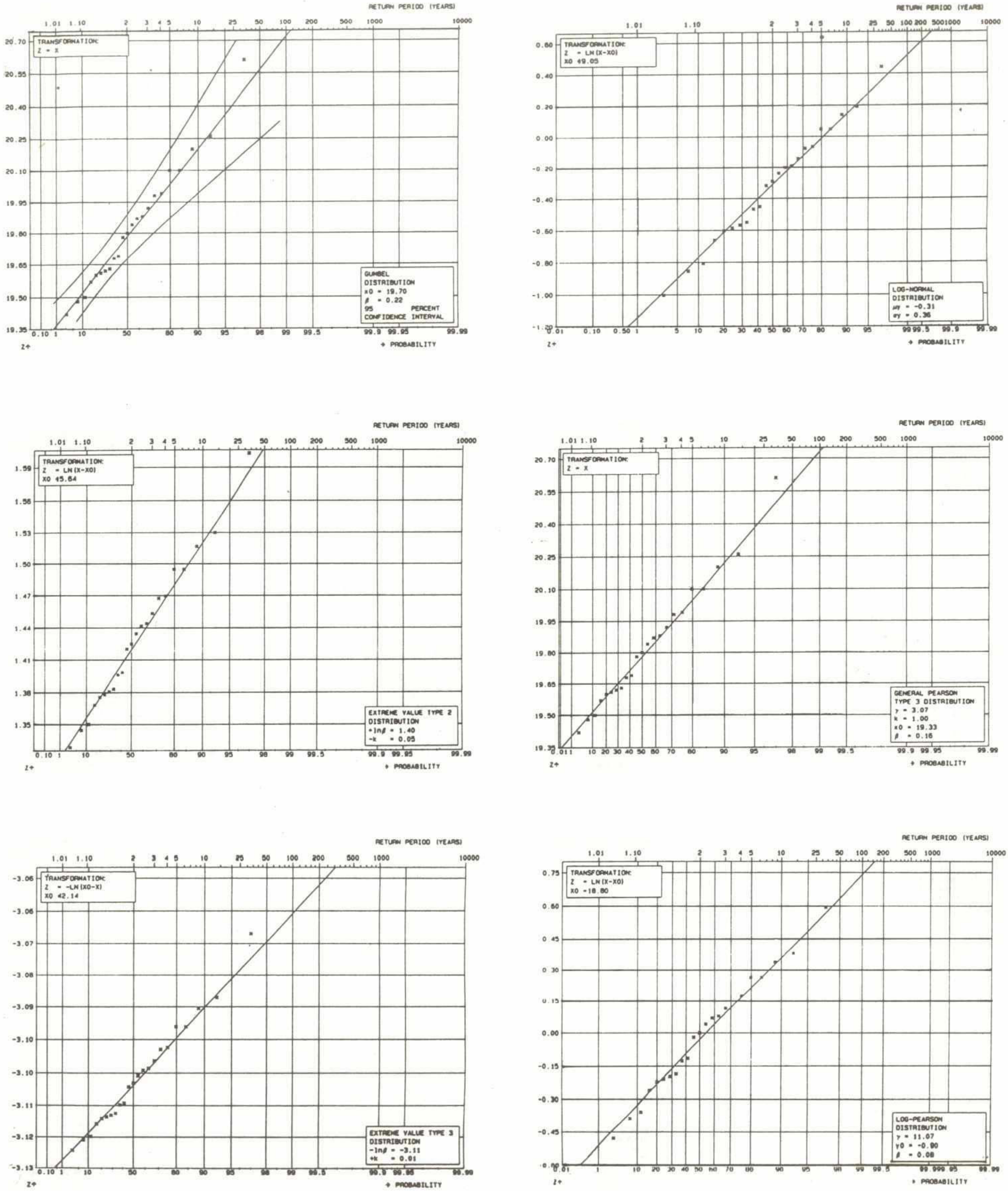
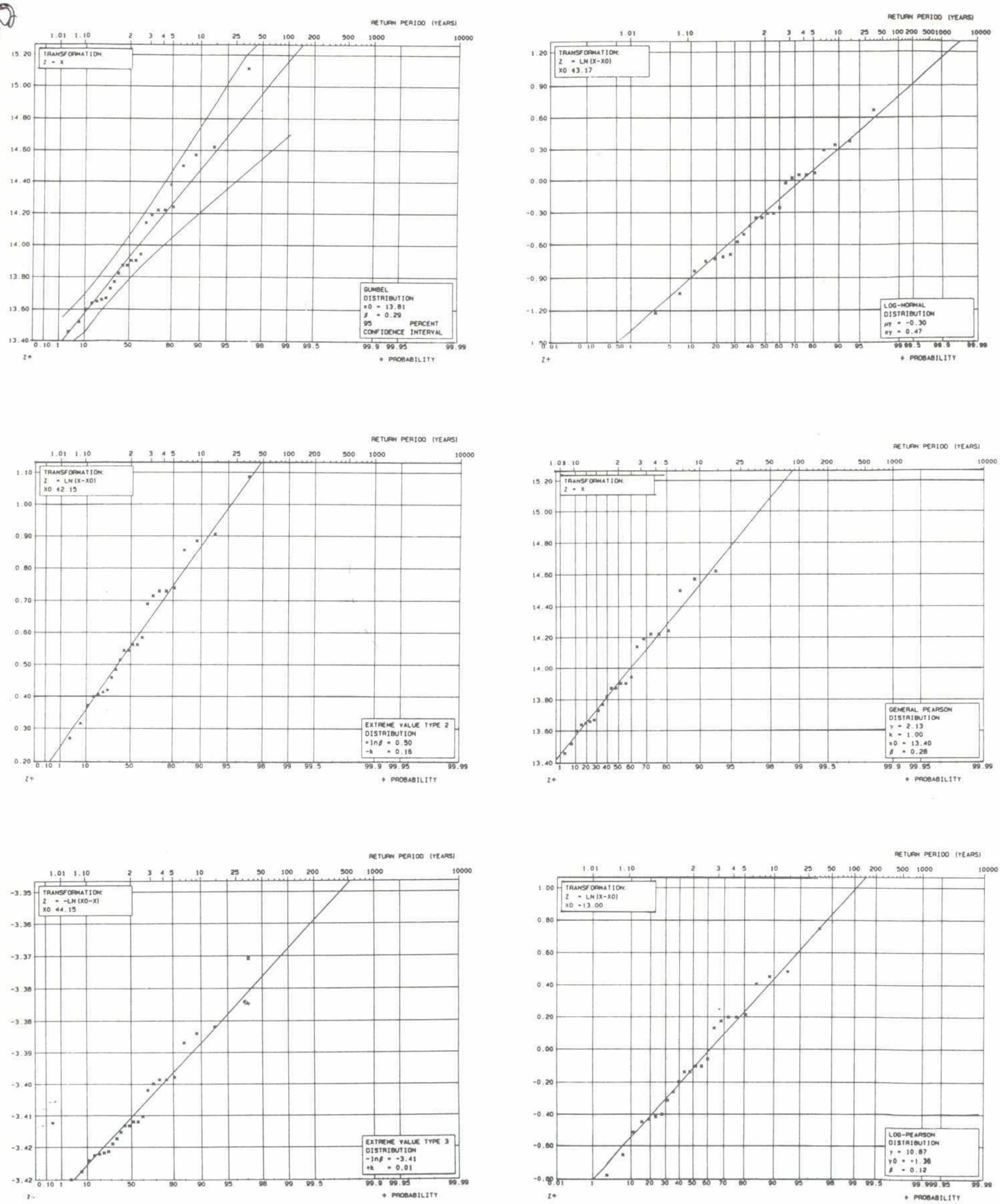


FAP25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Fitting of 6 Different Probability Distributions for Peak Water Level at Bahadurabad
JUNE 1992	FIGURE A.5.1 a)



FAP25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY**	
	Fitting of 6 Different Probability Distributions for Peak Water Level at Serajganj	
	JUNE 1992	**FIGURE A.5.1 b)**

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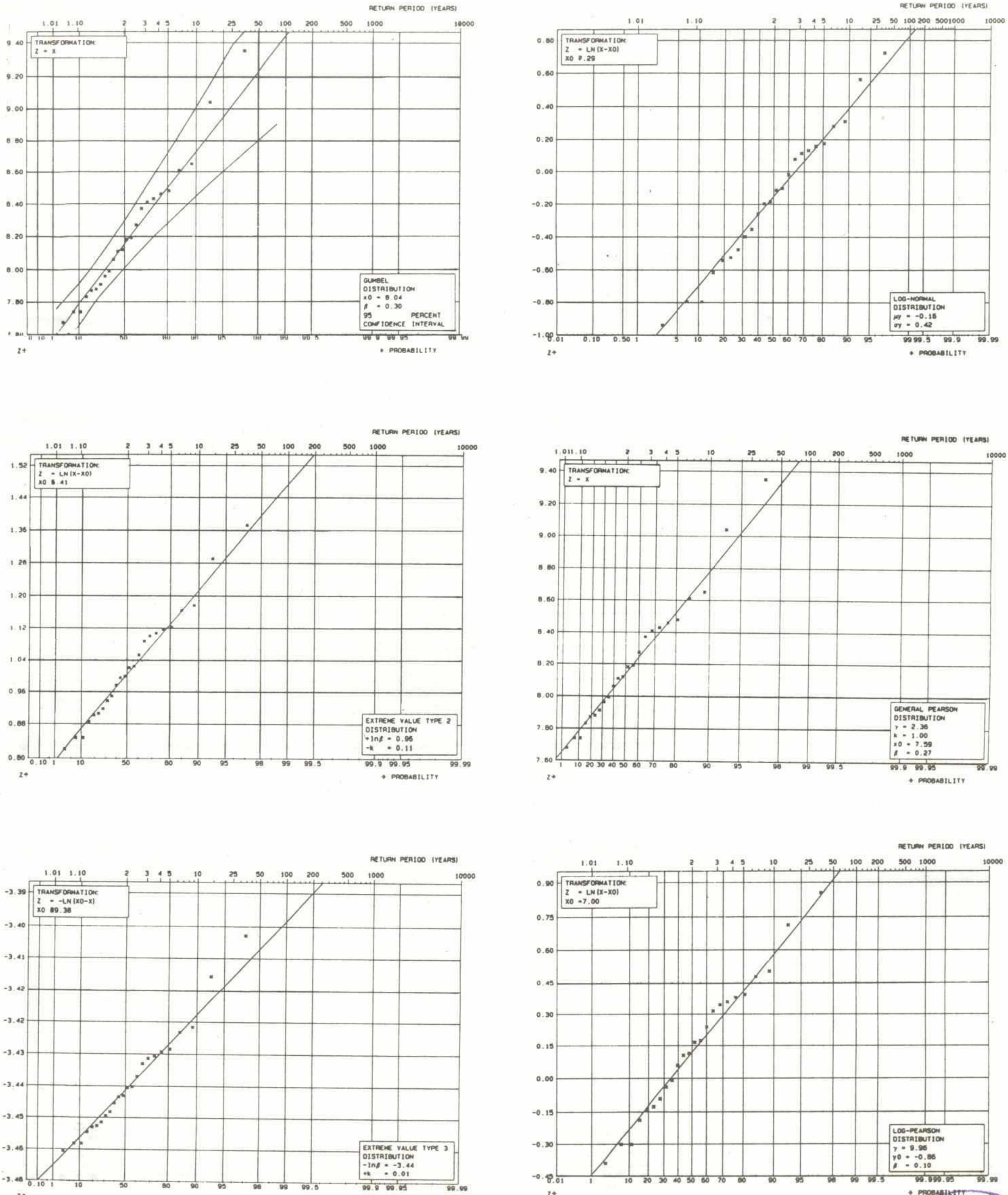
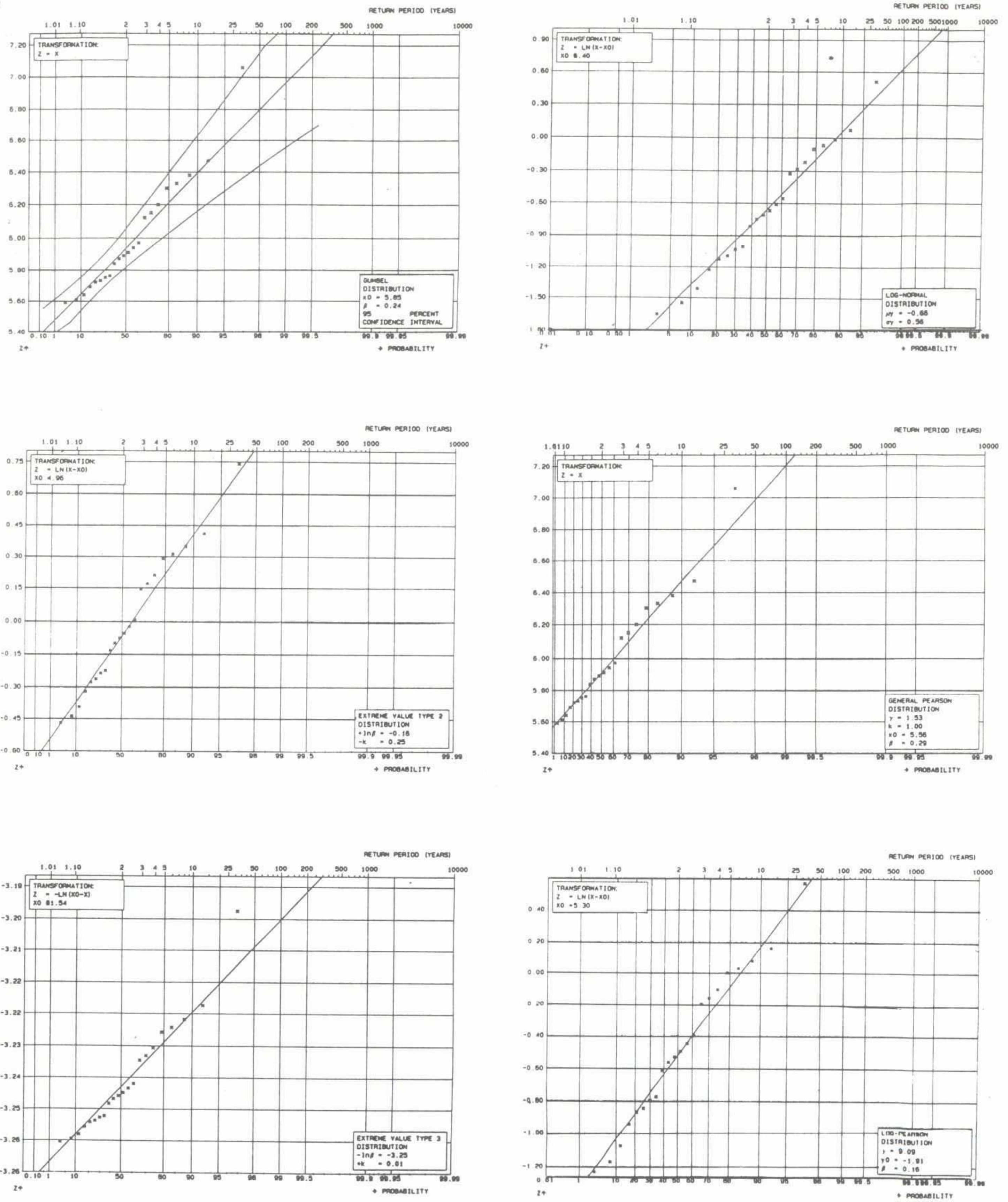
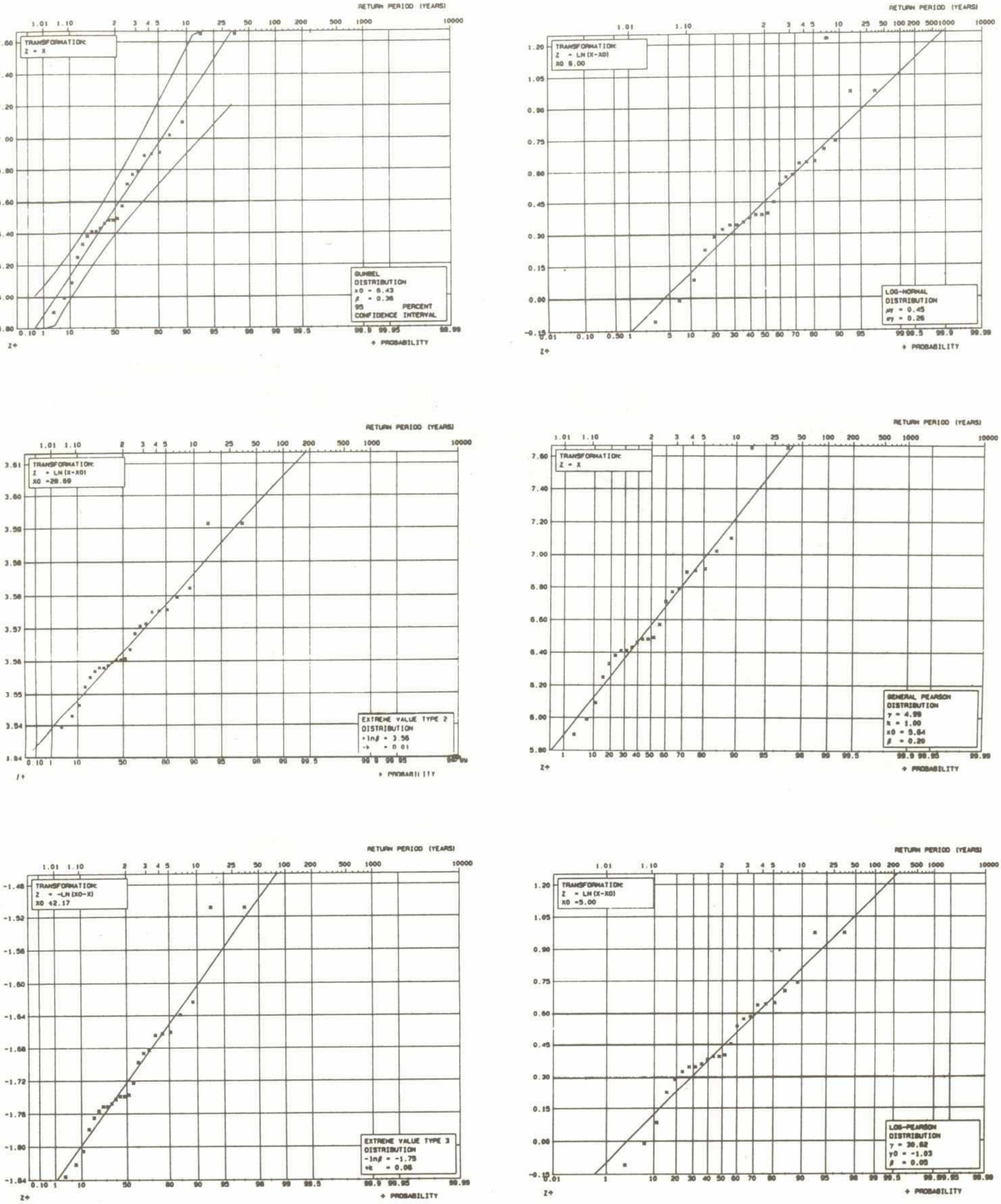


FAP 25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Water Level at Baruria	
	JUNE 1992	FIGURE A.5.1 c)



FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Water Level at Mawa	
	JUNE 1992	FIGURE A.5.1 d)



FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Water Level at Bhairab Bazar	
	JUNE 1992	FIGURE A.5.1 e)

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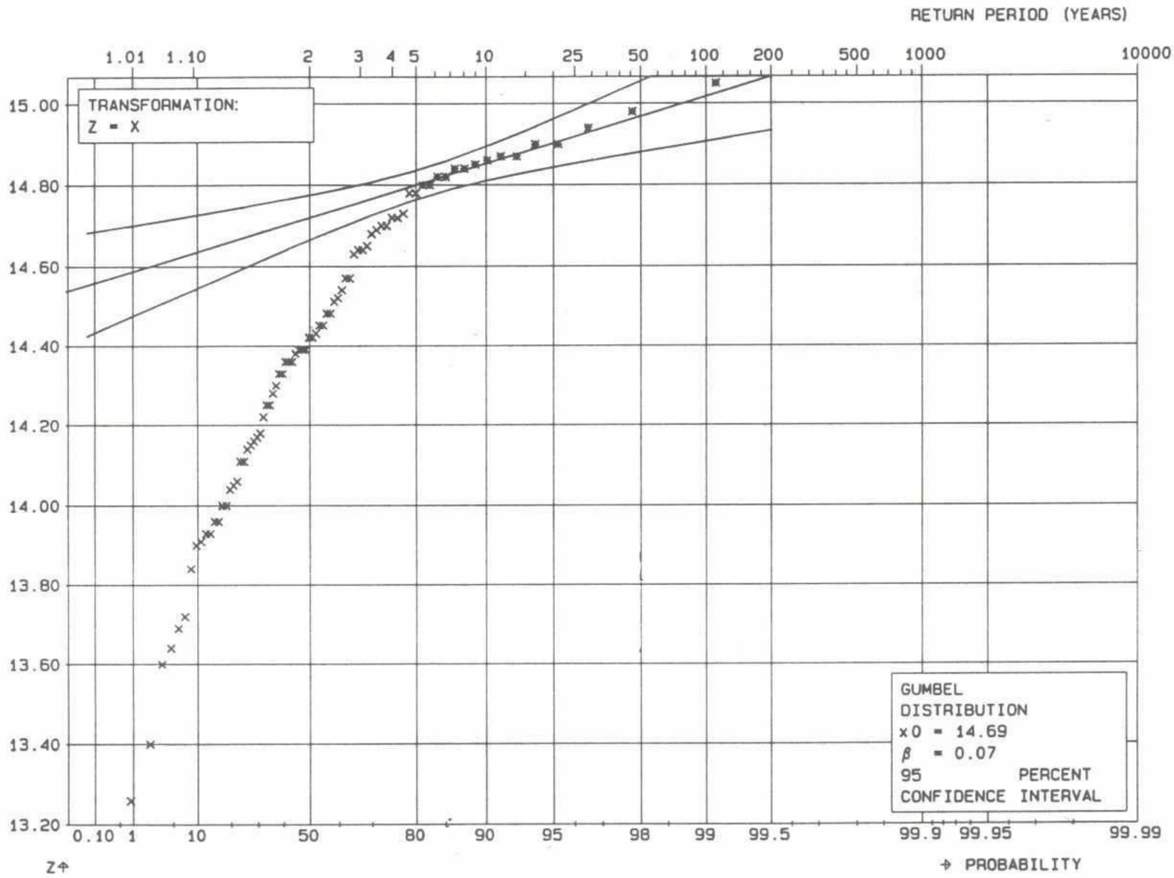


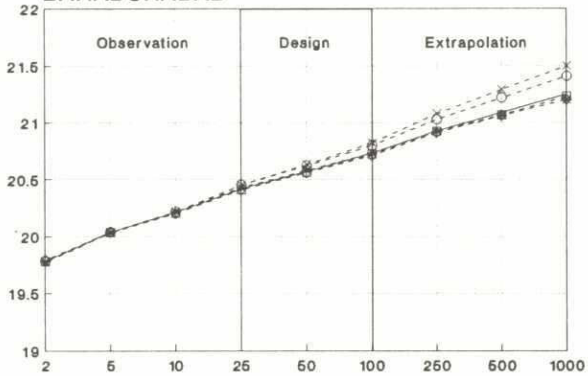
FAP 25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY**	
	Fitting of Gumble Probability Distribution With Left Censoring for Peak Water Level at Hardinge Bridge	
	JUNE 1992	FIGURE A.5.1 f)

COMPARISON OF 6 DIFFERENT DISTRIBUTIONS FOR PEAK WATER LEVEL

Legend :

X-axis = Return Period in Years
Y-axis = Peak Water Level in Meter
— = Log-Normal (3-Parameters)
-⊖- = Log-Pearson Type-III
-✳- = General Pearson-3 (3-Parameters)
-⊟- = Extreme Value Type-1 (Gumble)
-X- = Extreme Value Type-2 (3-Parameters)
-◇- = Extreme Value Type-3 (3-Parameters)

BAHADURABAD



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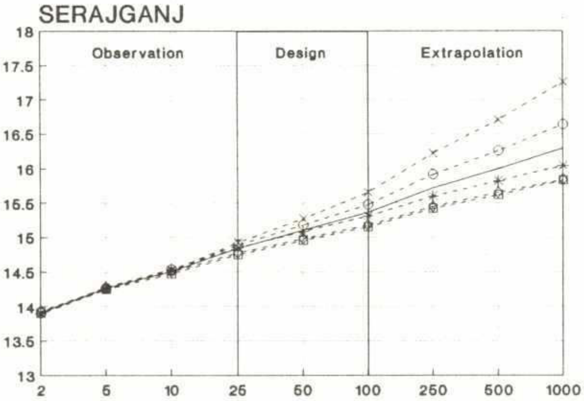

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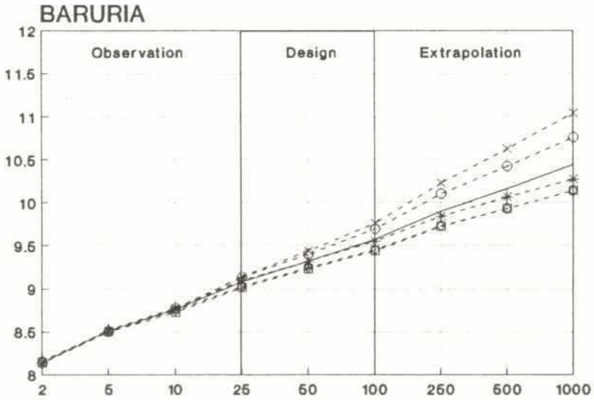

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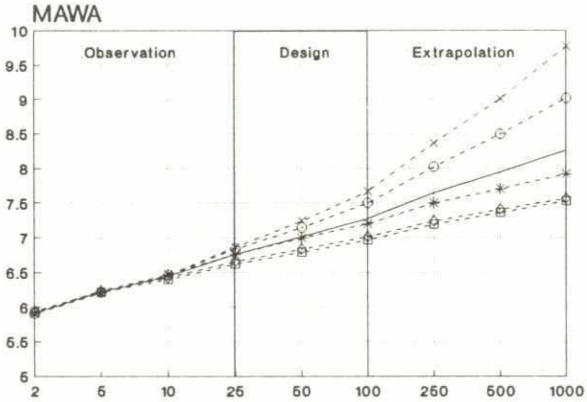
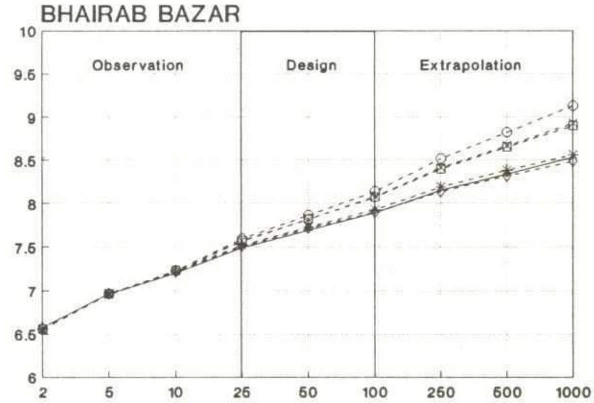
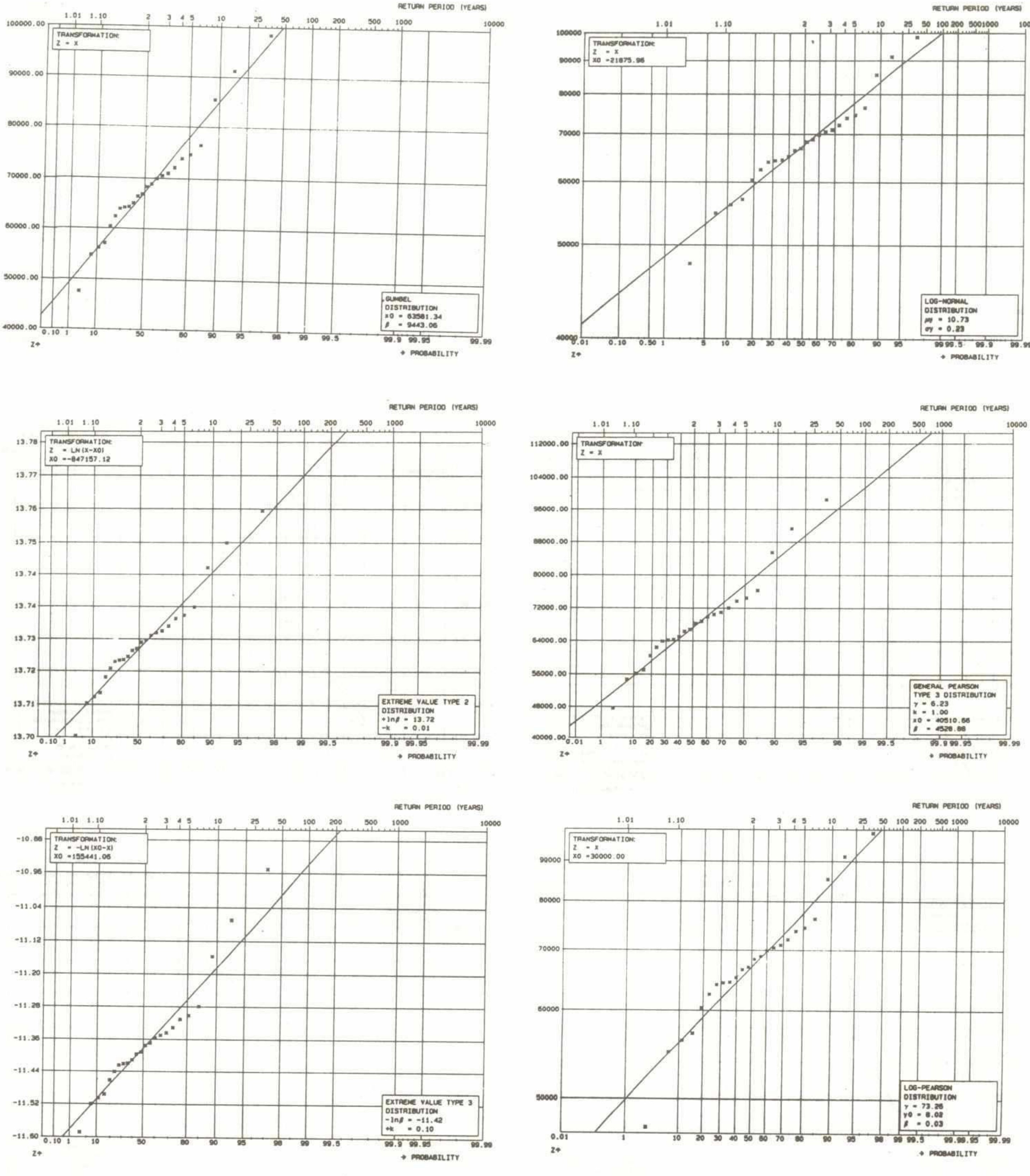


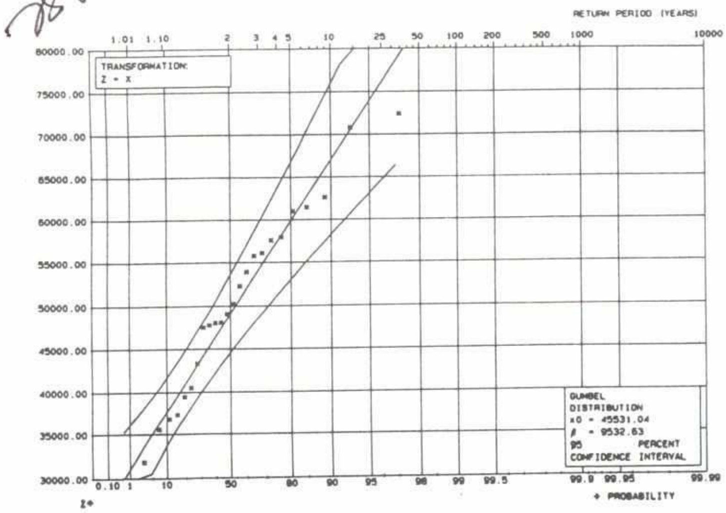
BHAIRAB BAZAR

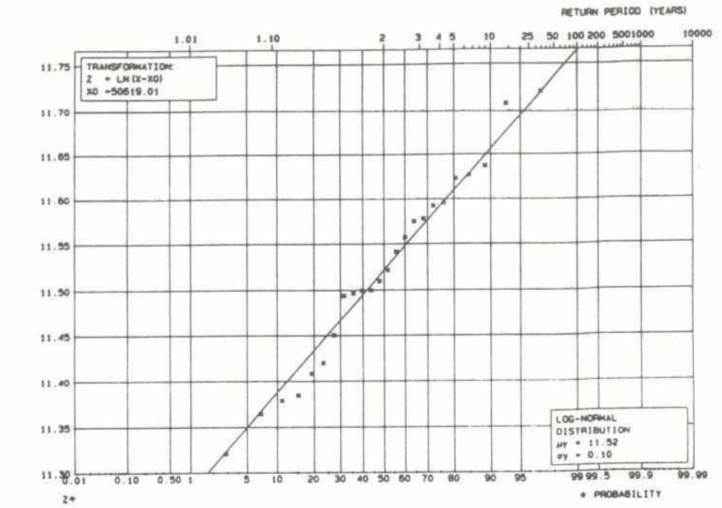


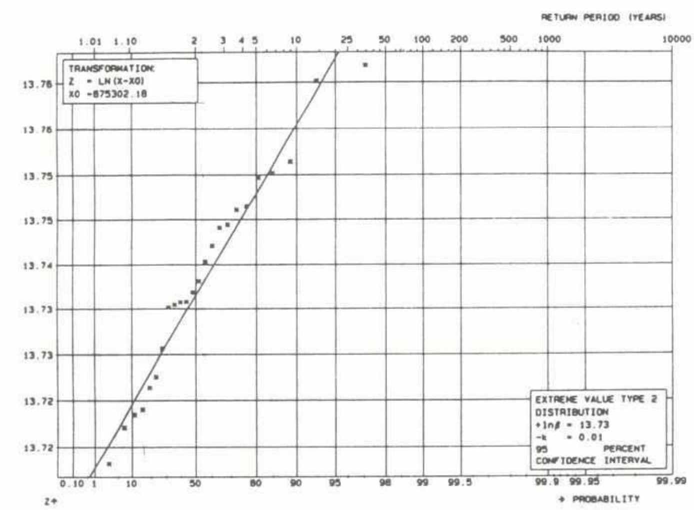
FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Extrapolation Properties of 6 Different Distributions for Peak Water Level	
	JUNE 1992	FIGURE A.5.2

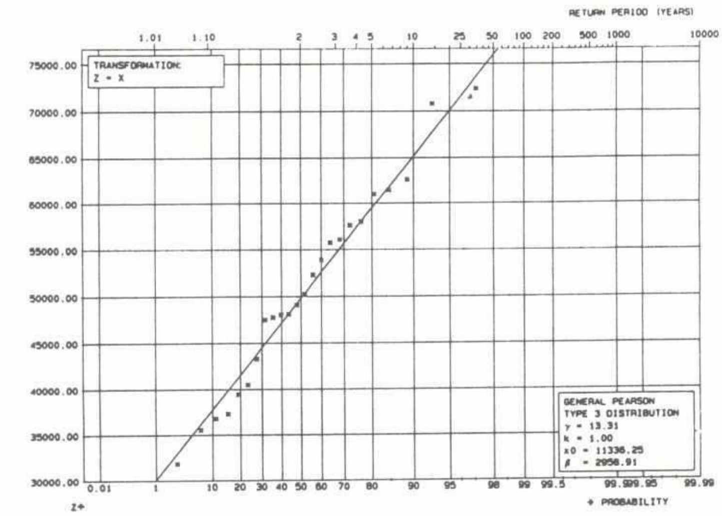


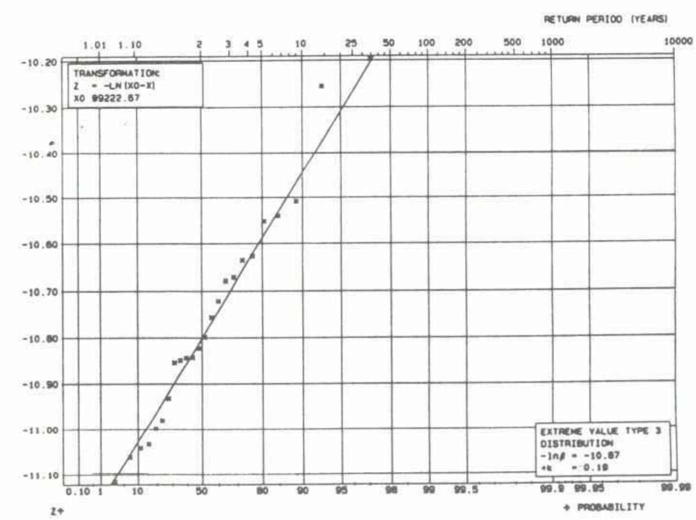
FAP25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY**	
	Fitting of 6 Different Probability Distributions for Peak Discharges at Bahadurabad	
	JUNE 1992	**FIGURE A.5.3 a)**

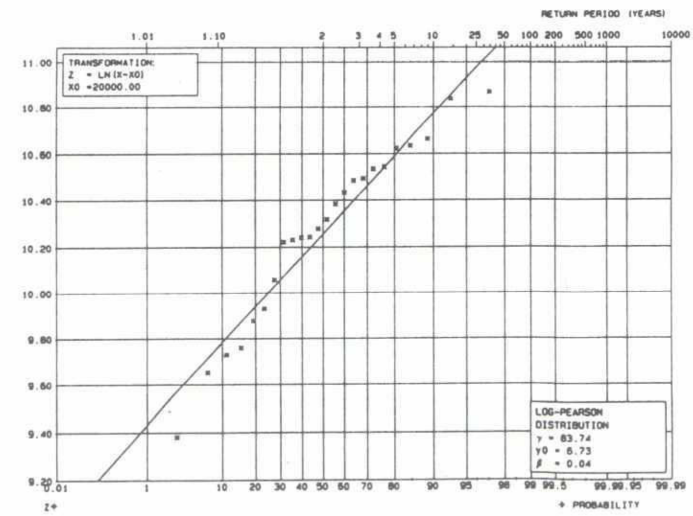




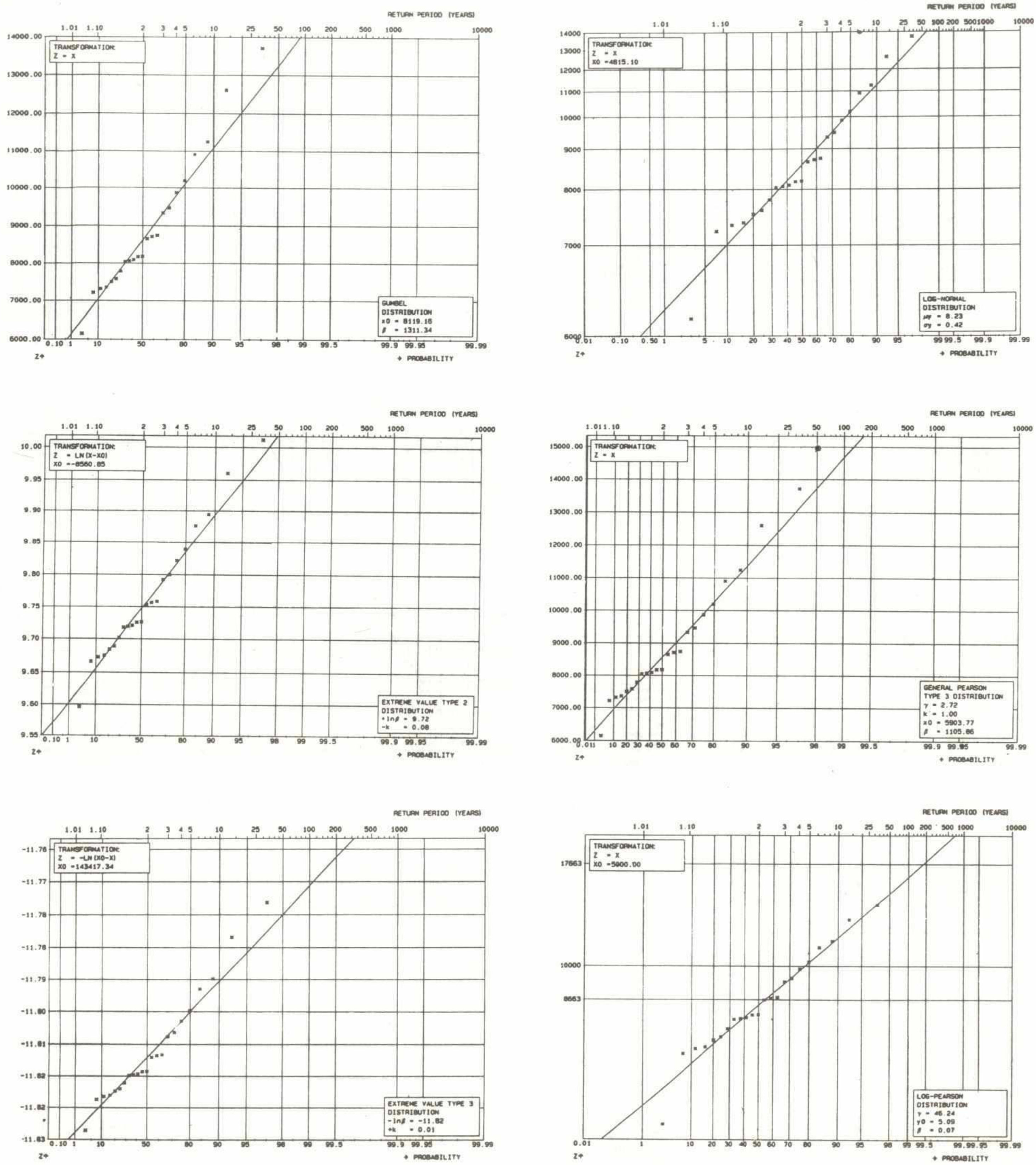




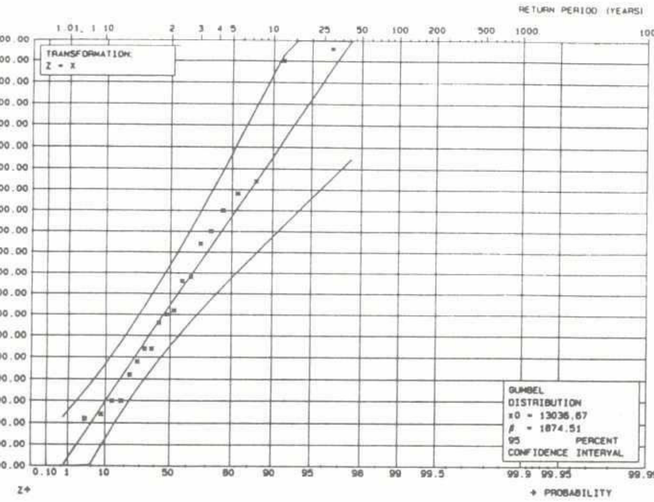


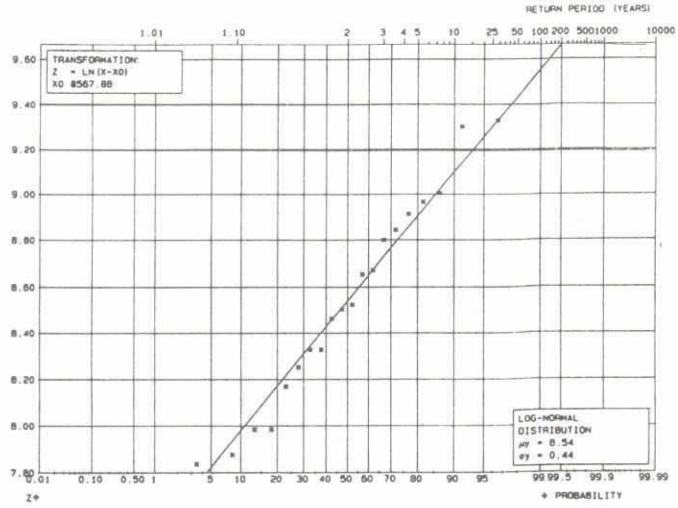


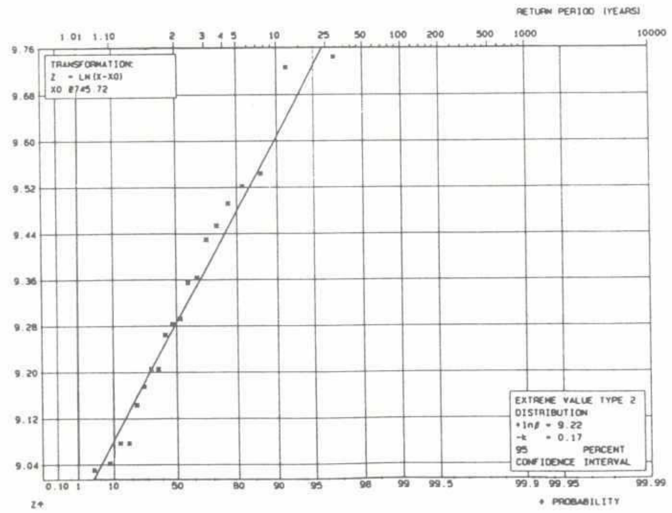
FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Peak Discharges at Hardinge Bridge	
	JUNE 1992	FIGURE A.5.3 b)

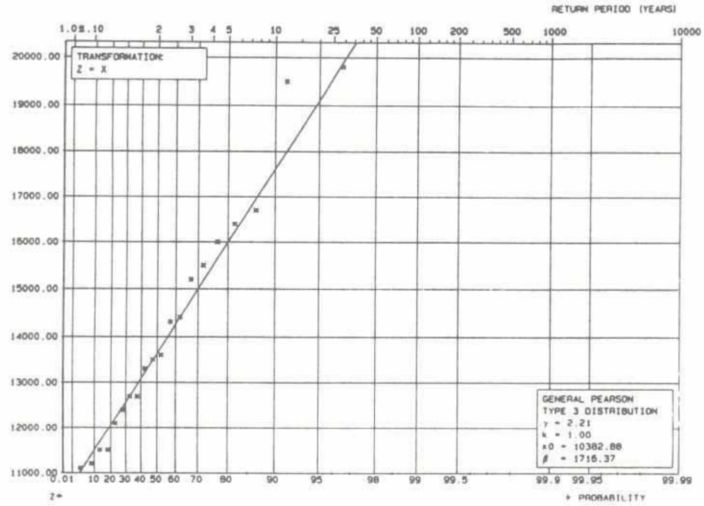


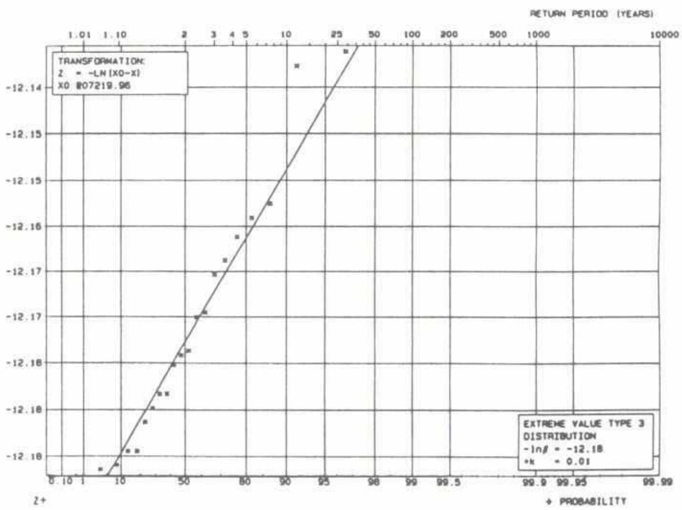
FAP 25 **FLOOD MODELLING & MANAGEMENT**	**FLOOD HYDROLOGY STUDY**	
	Fitting of 6 Different Probability Distributions for Peak Discharges at Baruria	
	JUNE 1992	**FIGURE A.5.3 c)**

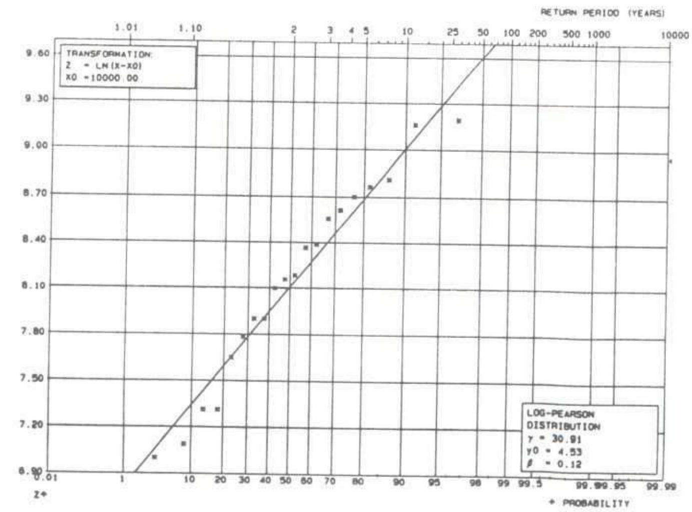




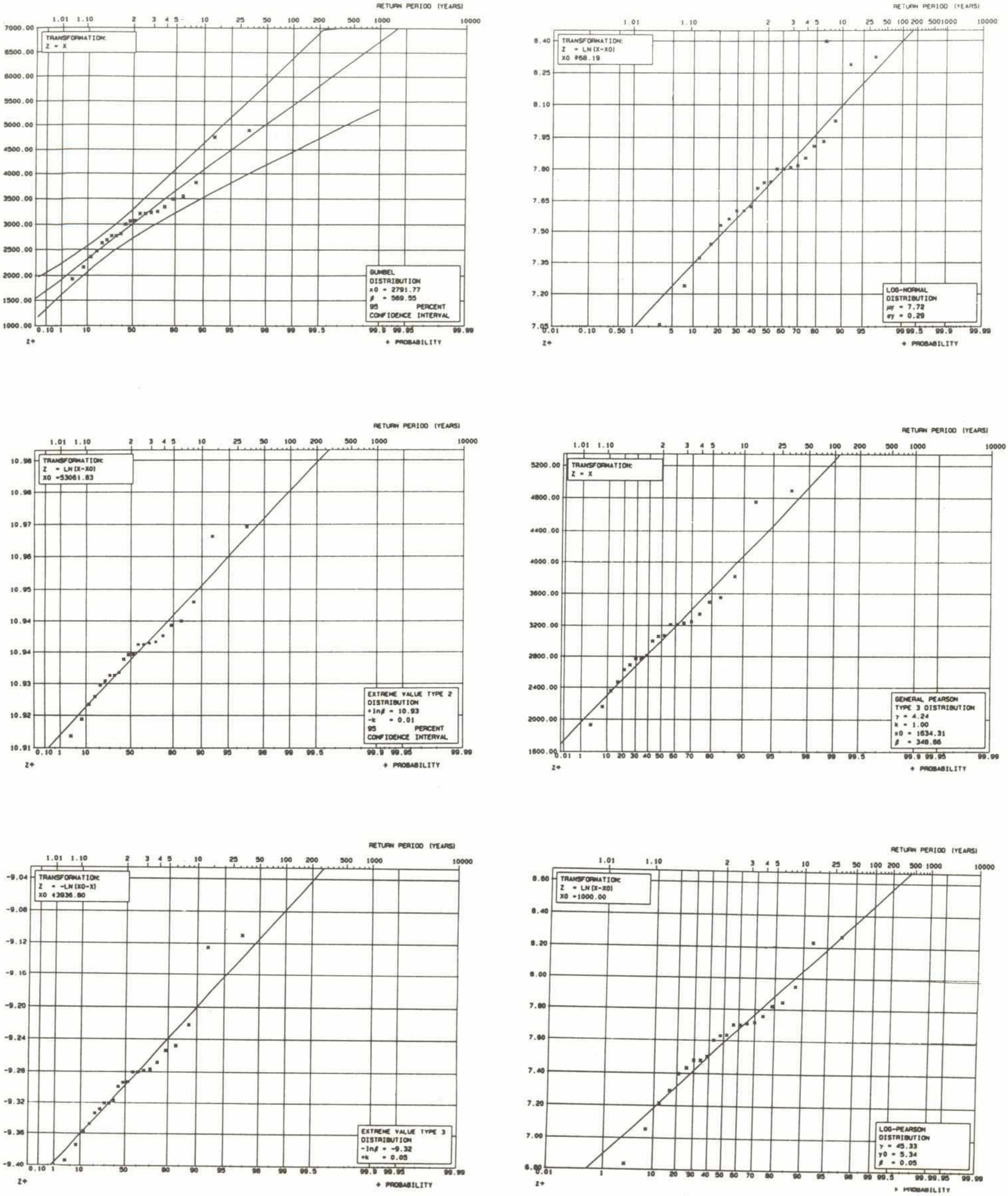




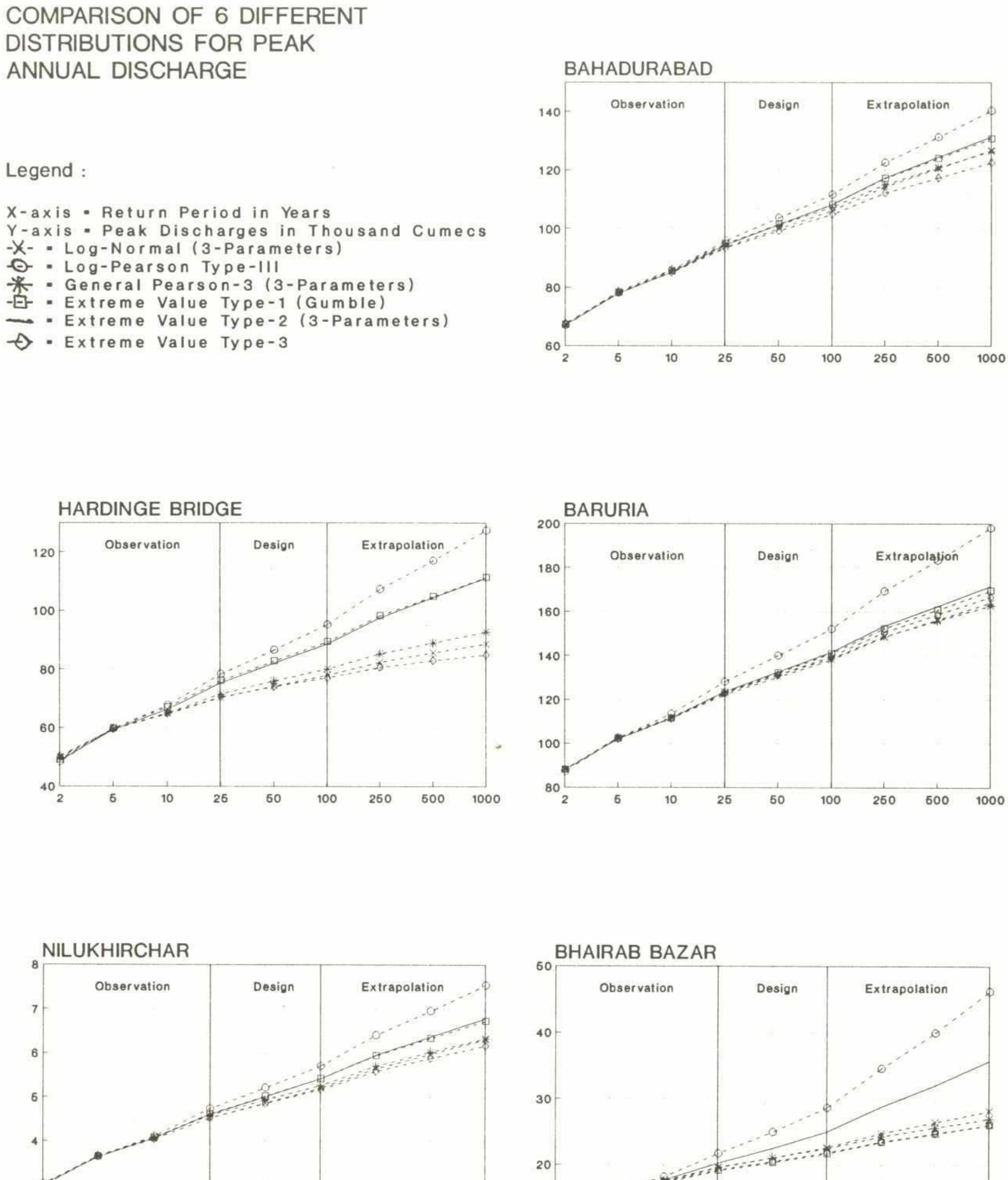




FAP 25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** **Fitting of 6 Different Probability Distributions for Peak Discharges at Bhairab Bazar** **JUNE 1992** — **FIGURE A.5.3 d)**



FAP25 **FLOOD MODELLING & MANAGEMENT**	**FLOOD HYDROLOGY STUDY** **Fitting of 6 Different Probability Distributions for Peak Discharges at Nilukhirchar**
	JUNE 1992 — **FIGURE A.5.3 e)**



FAP25

FLOOD MODELLING & MANAGEMENT

FLOOD HYDROLOGY STUDY

Extrapolation Properties of 6 Different Distributions for Peak Discharges

JUNE 1992

FIGURE A.5.4

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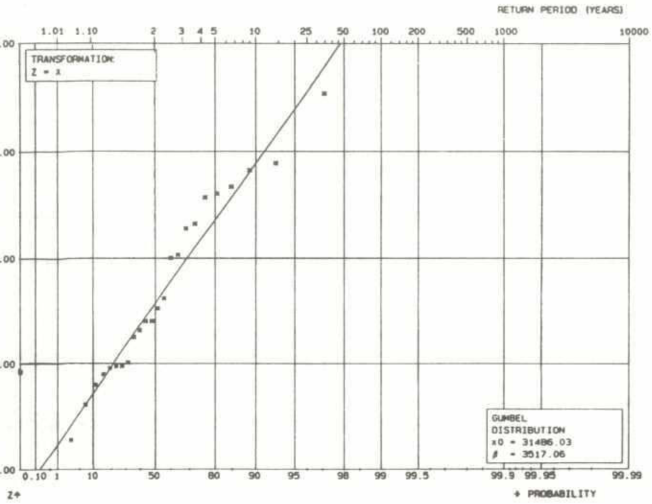
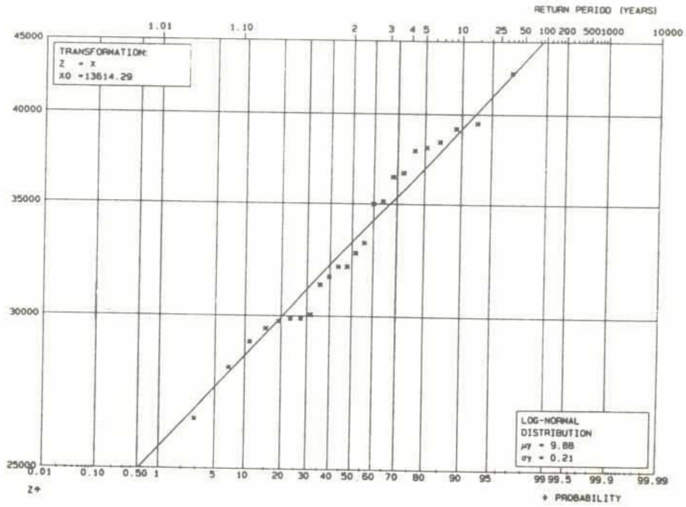
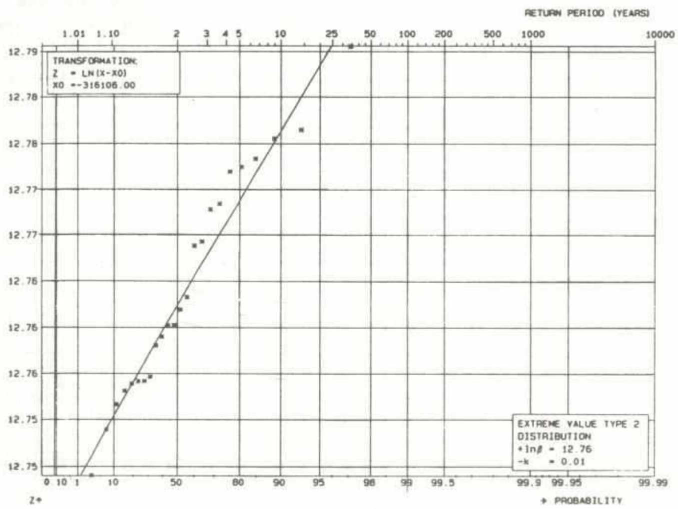
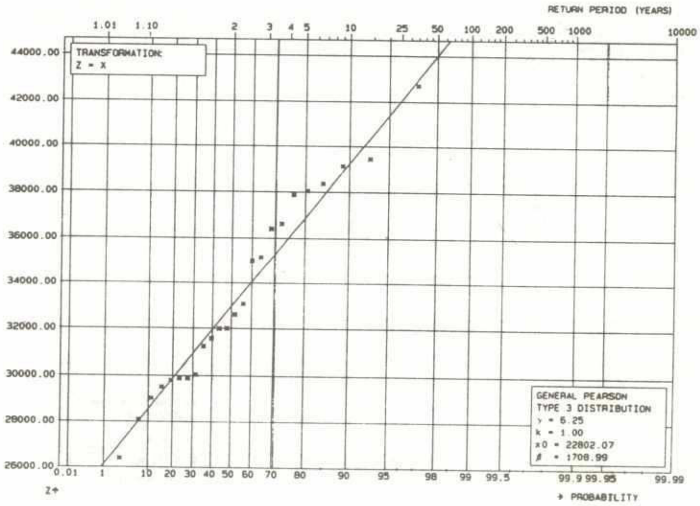
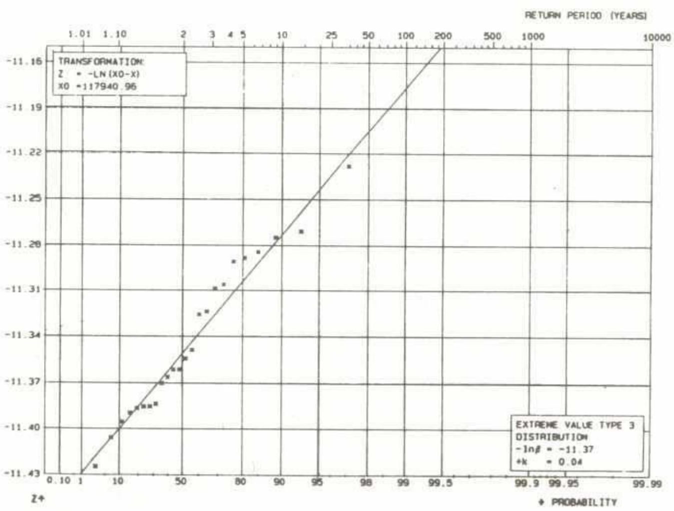
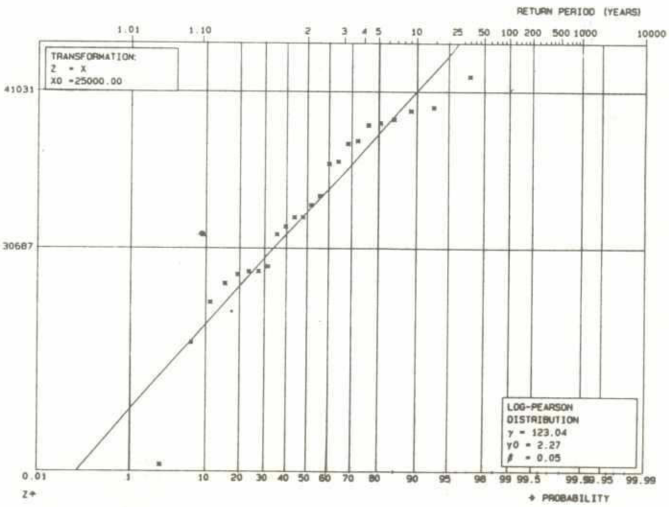




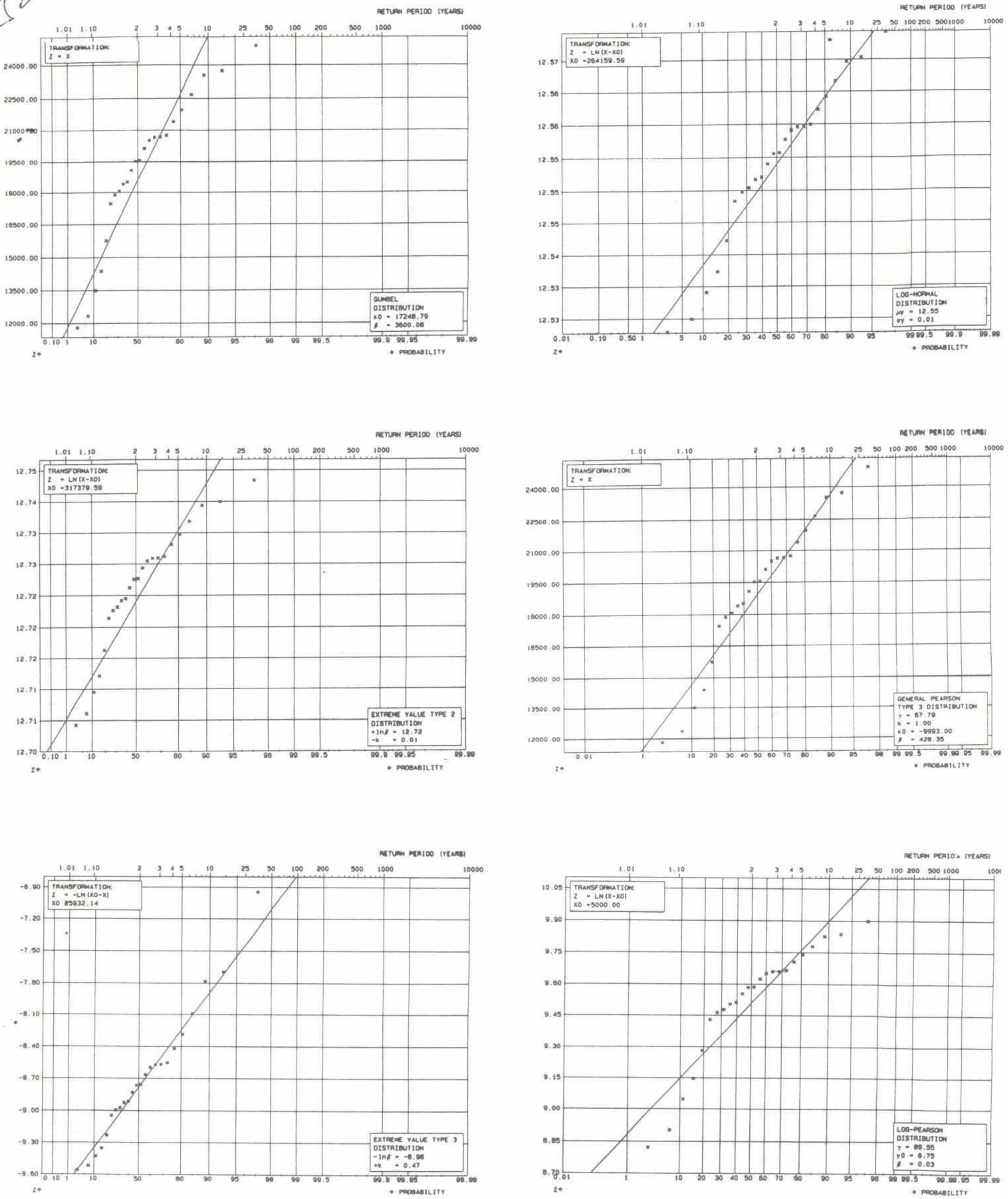








FAP 25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Fitting of 6 Different Probability Distributions for Mean Seasonal Discharges at Bahadurabad	
	JUNE 1992	FIGURE A.5.5 a)



FAP25

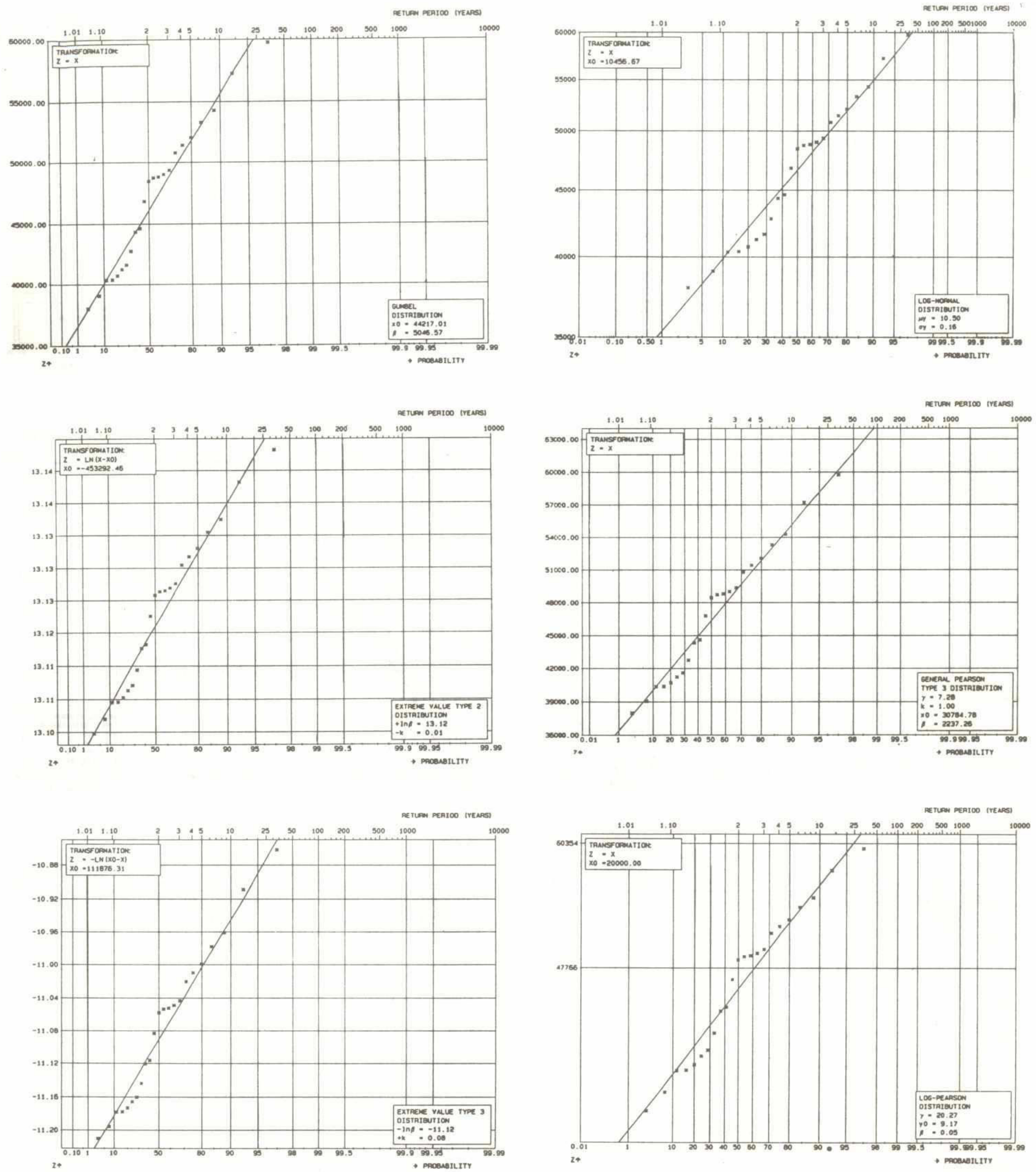
FLOOD MODELLING & MANAGEMENT

FLOOD HYDROLOGY STUDY

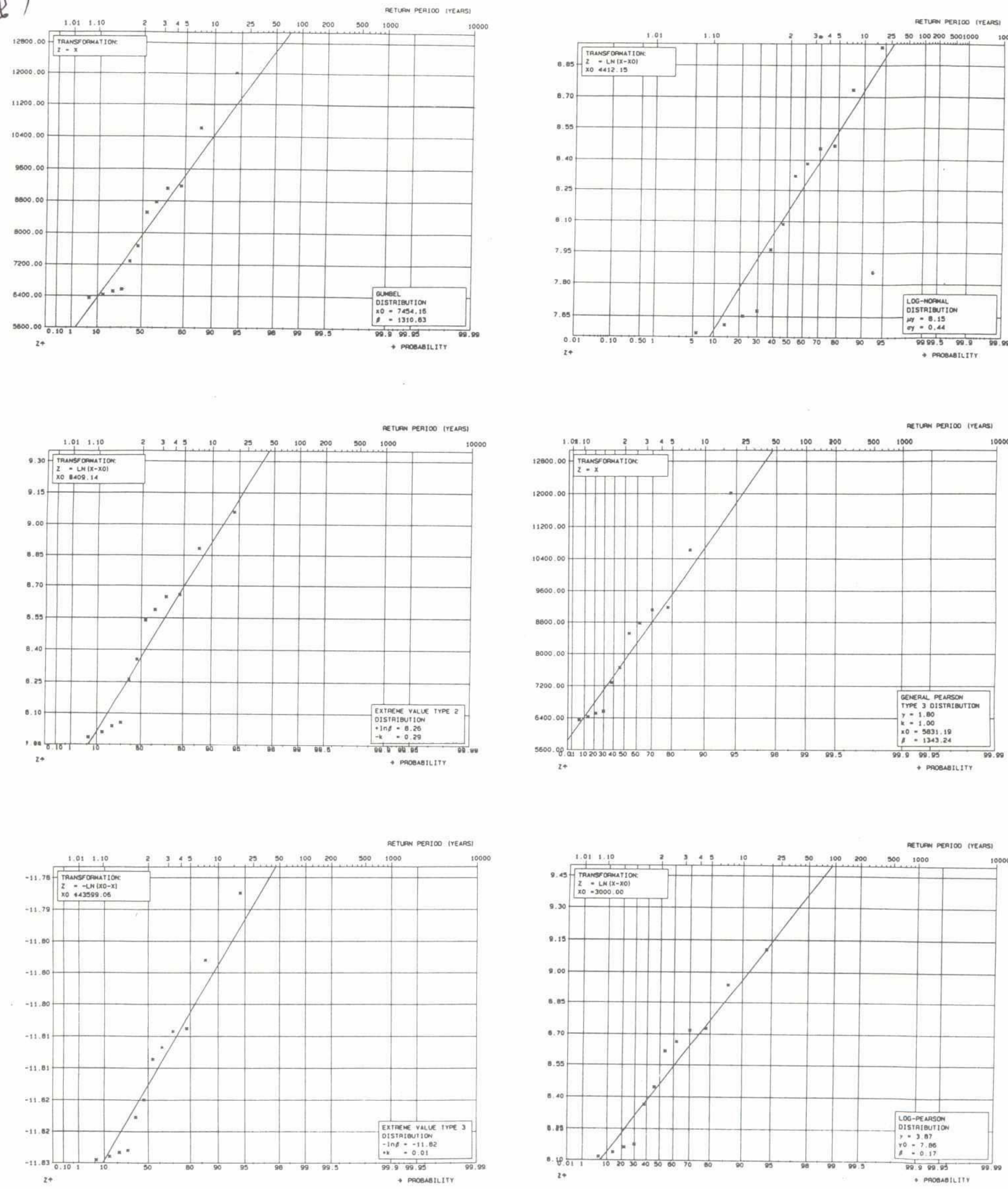
Fitting of 6 Different Probability Distributions for Mean Seasonal Discharges at Hardinge Bridge

JUNE 1992

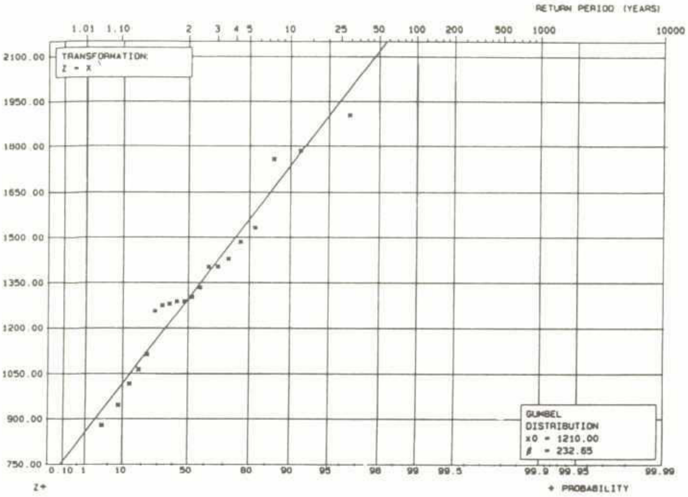
FIGURE A.5.5 b)

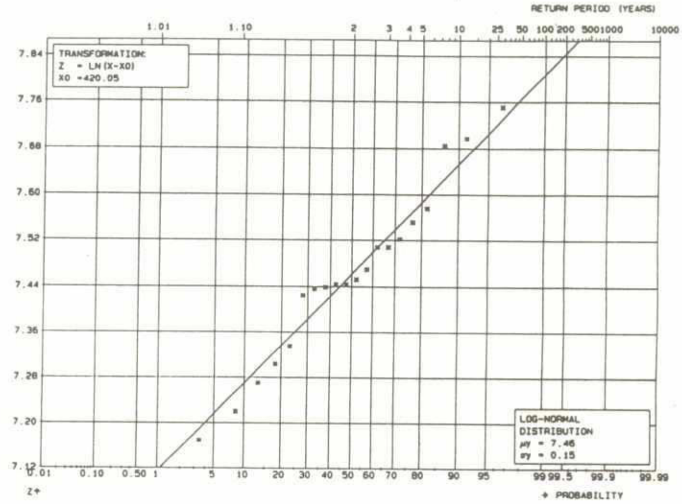


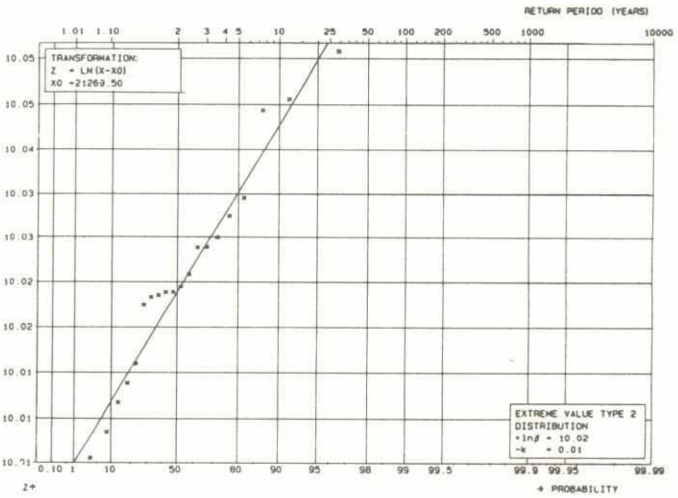
FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Mean Seasonal Discharges at Baruria	
	JUNE 1992	FIGURE A.5.5 c)

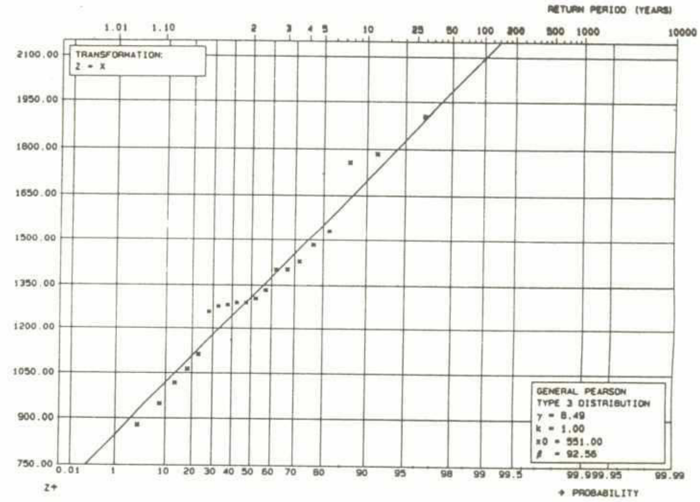


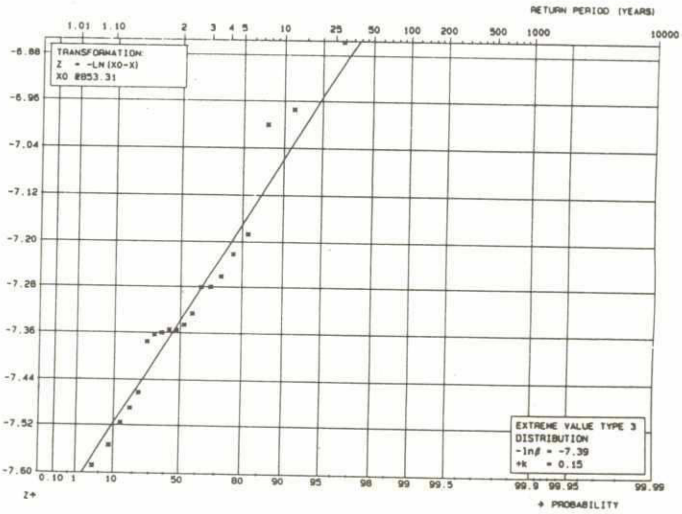
FAP 25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Fitting of 6 Different Probability Distributions for Mean Seasonal Discharges at Bhairab Bazar JUNE 1992 — FIGURE A.5.5 d)

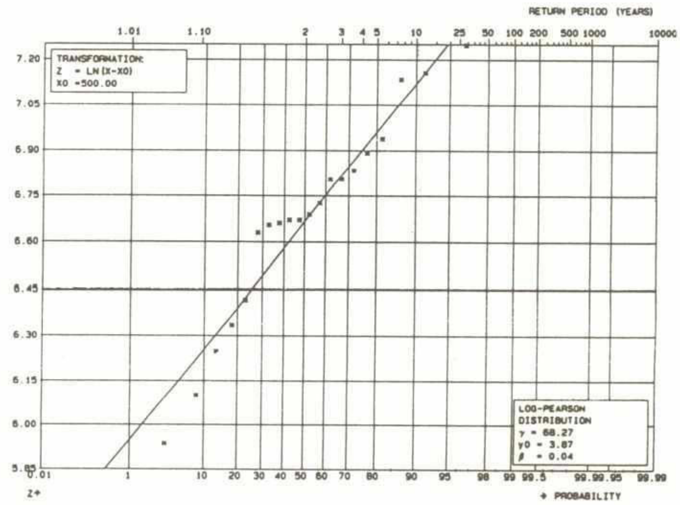












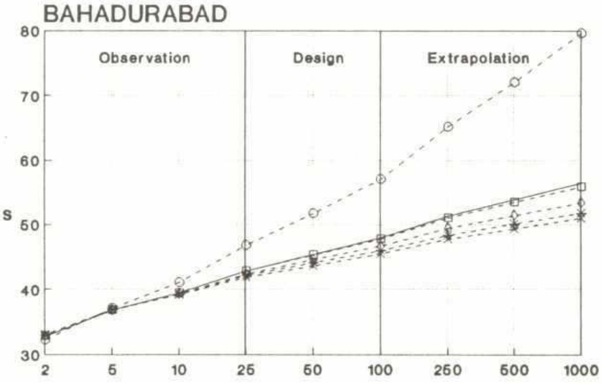
FAP25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Fitting of 6 Different Probability Distributions for Mean Seasonal Discharges at Nilukhirchar JUNE 1992 — FIGURE A.5.5 e)

COMPARISON OF 6 PROBABILITY DENSITY FUNCTIONS FOR 5 STATIONS (MEAN SEASONAL (MAY-OCT) DISCHARGE)

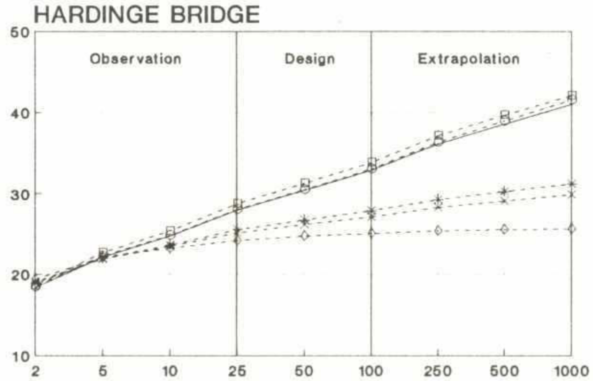
Legend :

X-axis = Return Period in Years
Y-axis = Seasonal Discharges in Thousand Cumecs
-X- = Log-Normal (3-Parameters)
-⊙- = Log-Pearson Type-III
-✳- = General Pearson-3 (3-Parameters)
-⊡- = Extreme Value Type-1 (Gumble)
—— = Extreme Value Type-2 (3-Parameters)
-◇- = Extreme Value Type-3 (3-Parameters)

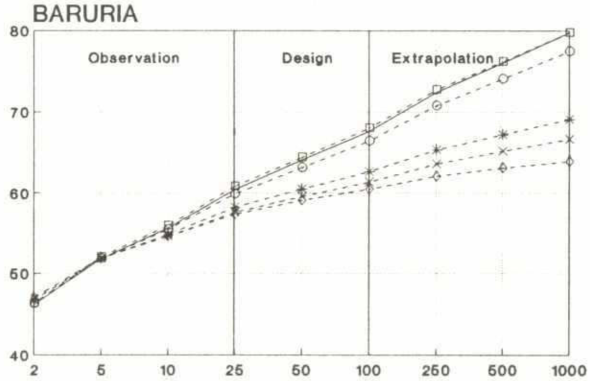
BAHADURABAD



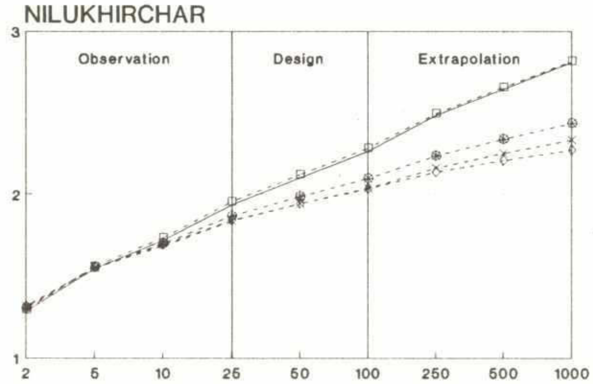
HARDINGE BRIDGE



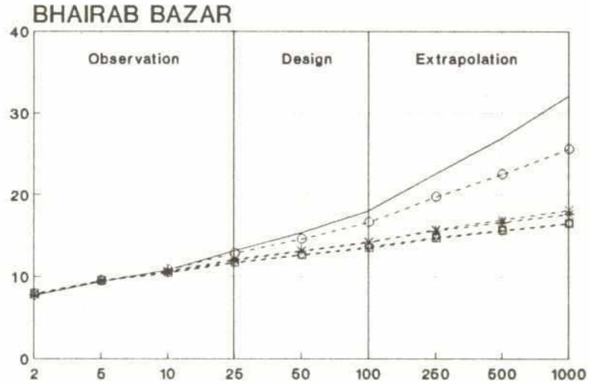
BARURIA



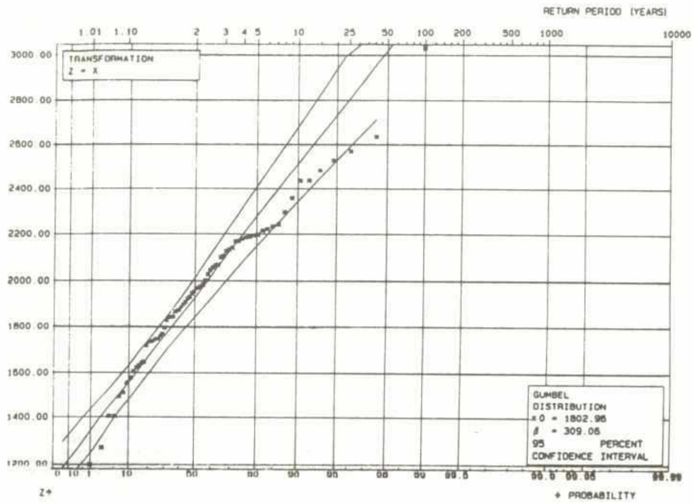
NILUKHIRCHAR

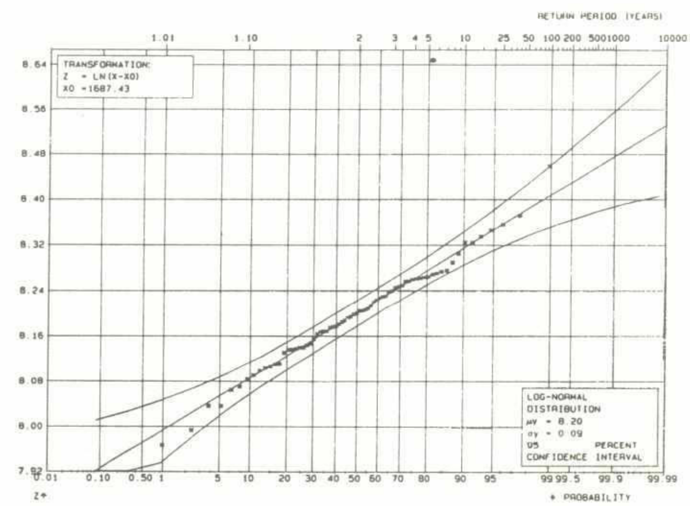


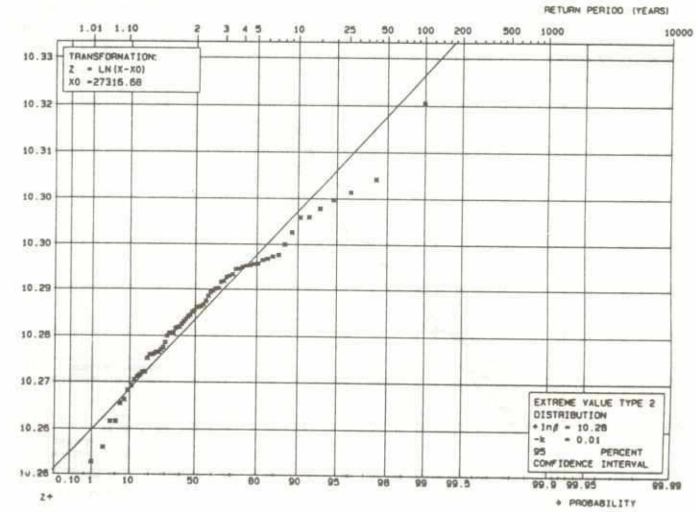
BHAIRAB BAZAR

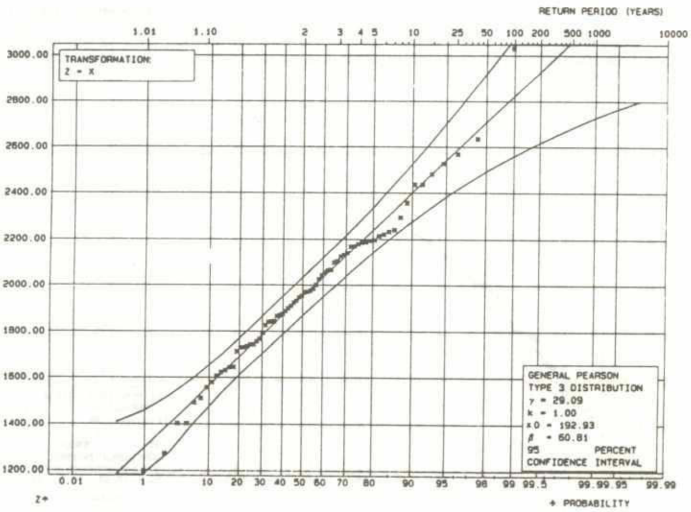


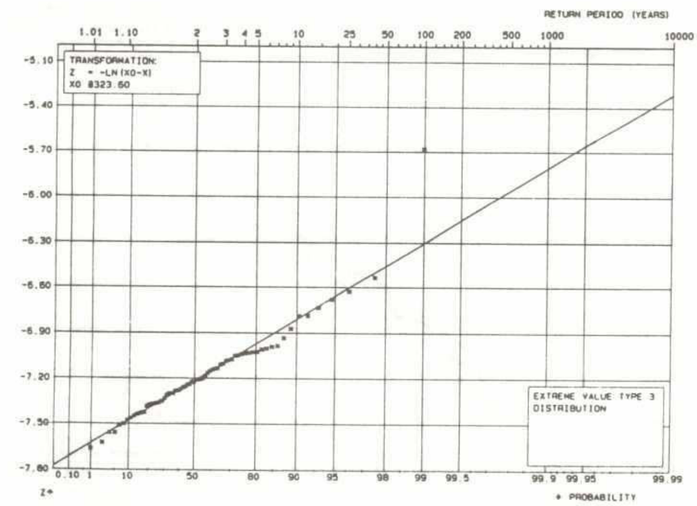
FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Extrapolation Properties of 6 Different Distributions for Mean Seasonal Discharges	
	JUNE 1992	FIGURE A.5.6

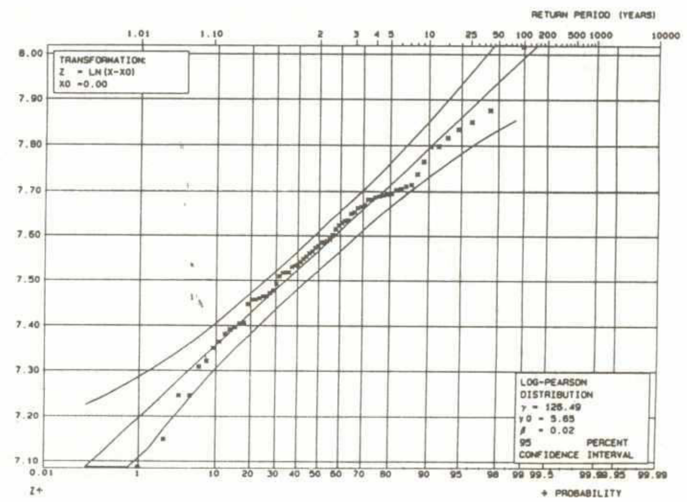




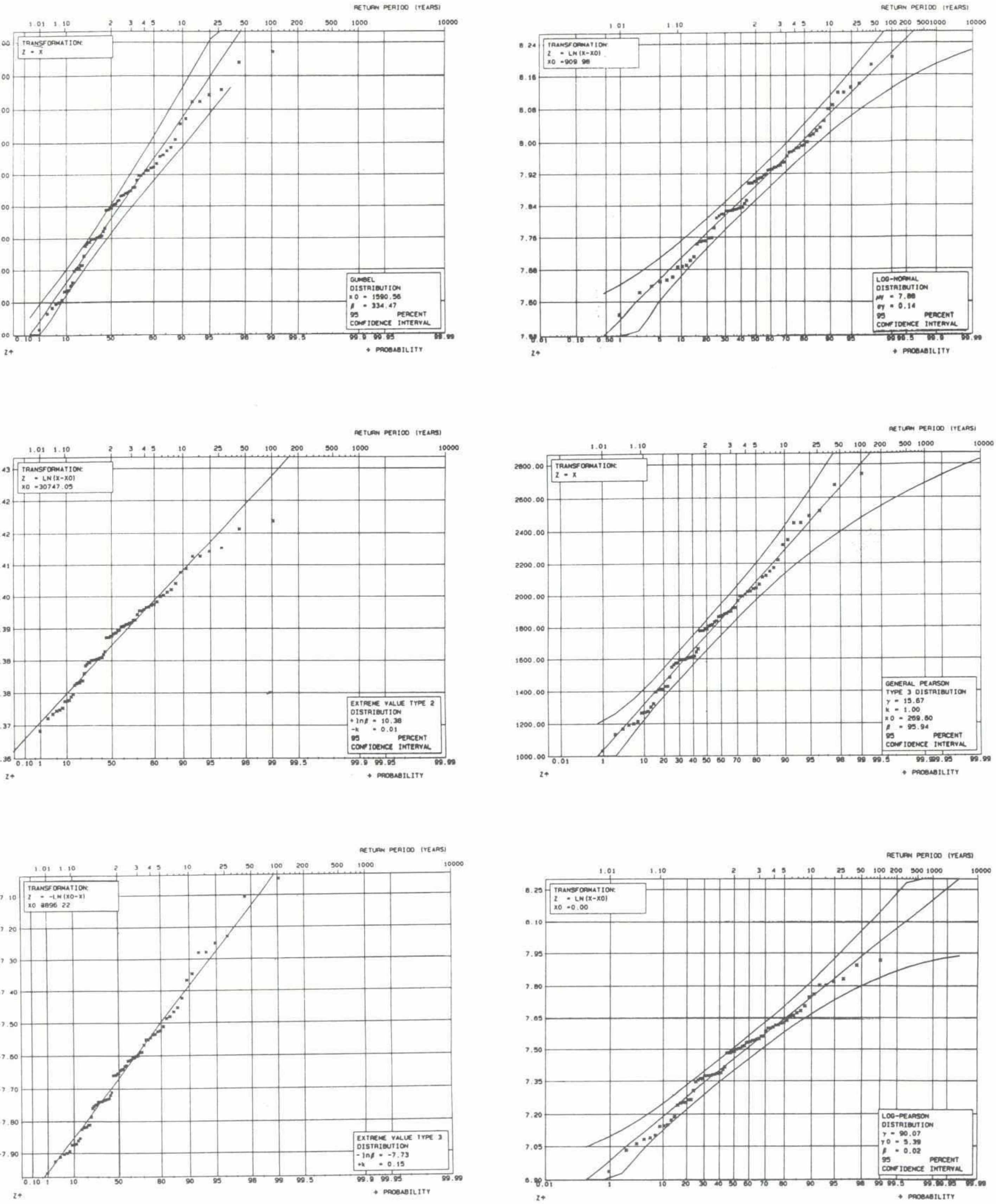




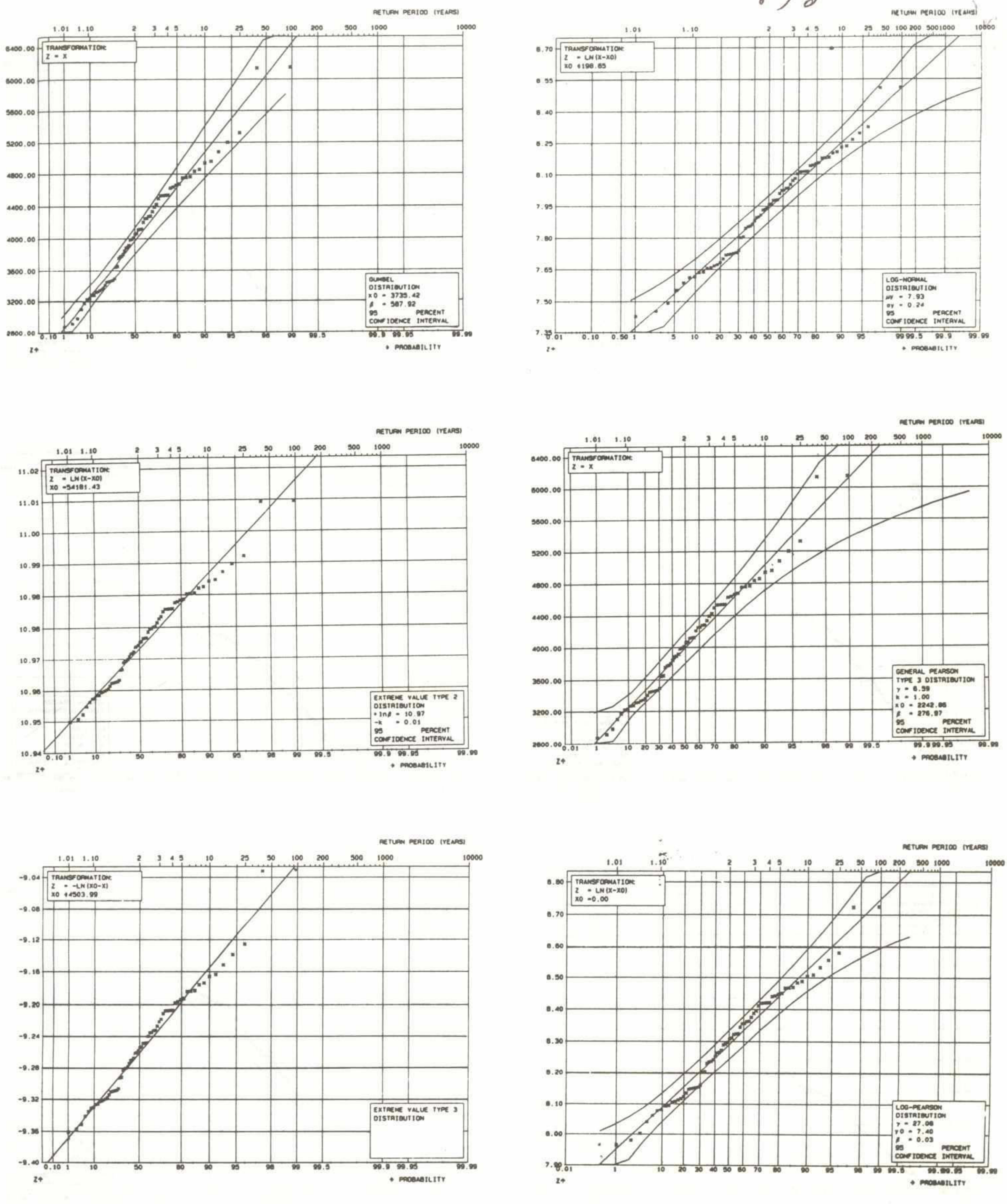




FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Annual Rainfall at Bogra	
	JUNE 1992	FIGURE A.5.7 a)



FAP 25 FLOOD MODELLING & MANAGEMENT	**FLOOD HYDROLOGY STUDY** Fitting of 6 Different Probability Distributions for Annual Rainfall at Dhaka
JUNE 1992	FIGURE A.5.7 b)



FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY Fitting of 6 Different Probability Distributions for Annual Rainfall at Sylhet JUNE 1992 — FIGURE A.5.7 c)

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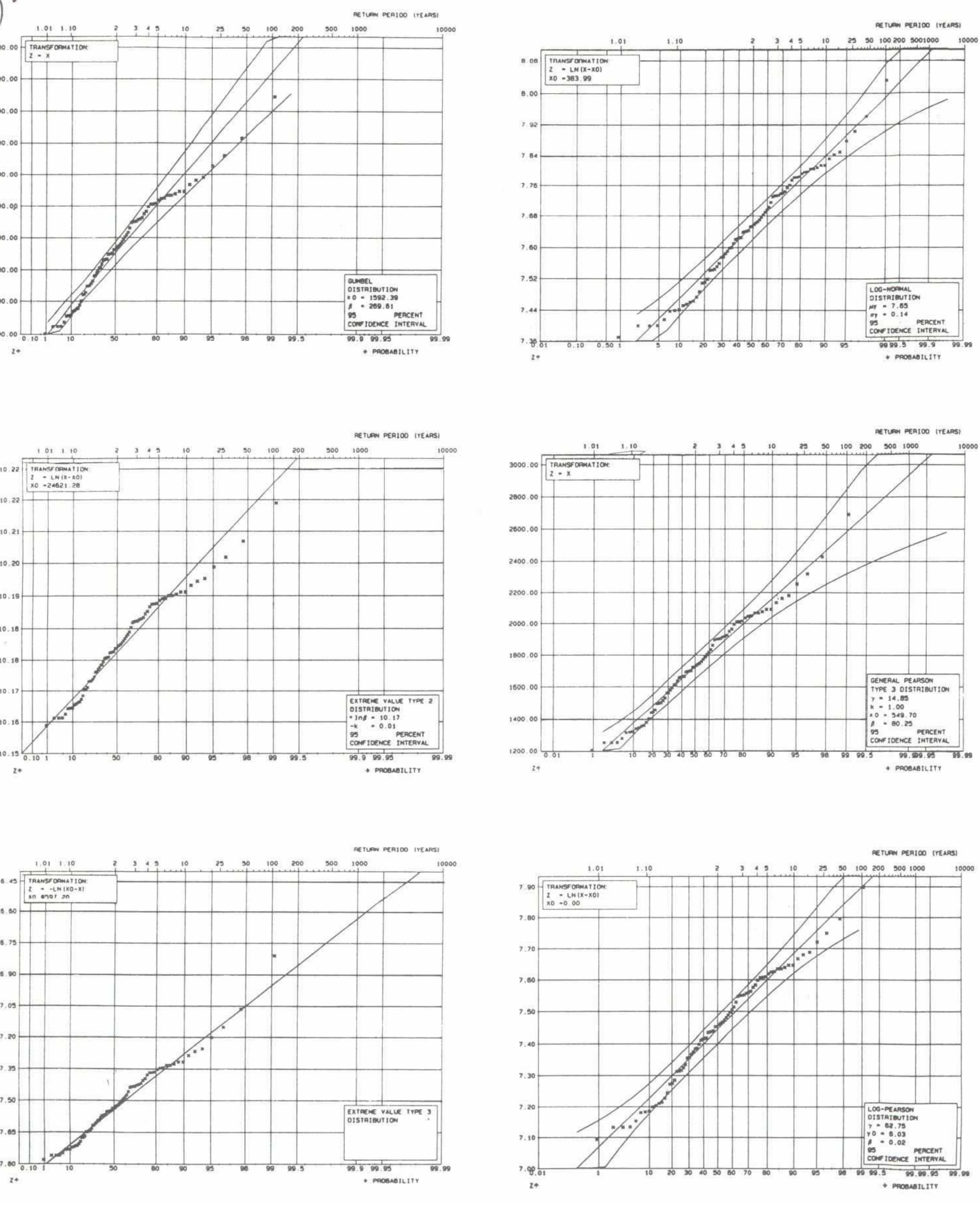
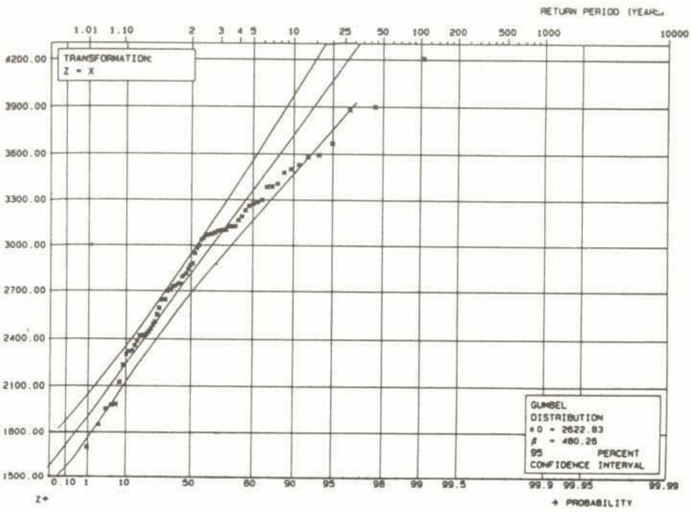
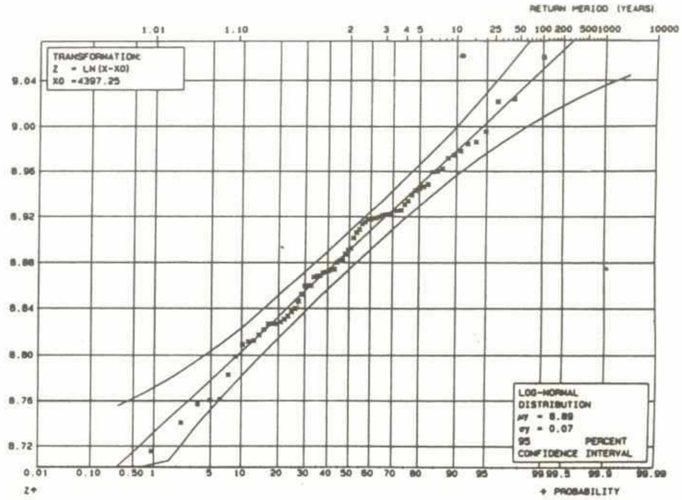
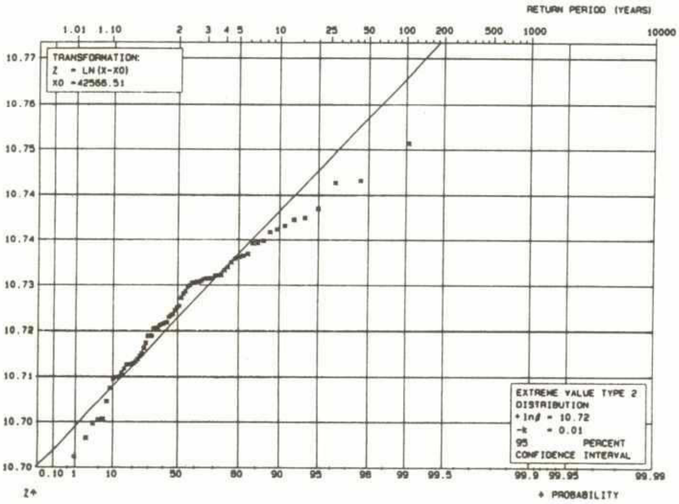


FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY	
	Fitting of 6 Different Probability Distributions for Annual Rainfall at Khulna	
	JUNE 1992	FIGURE A.5.7 d)







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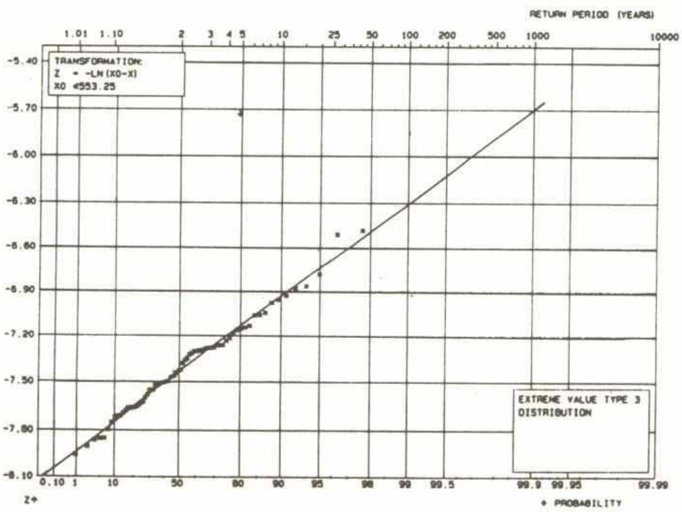
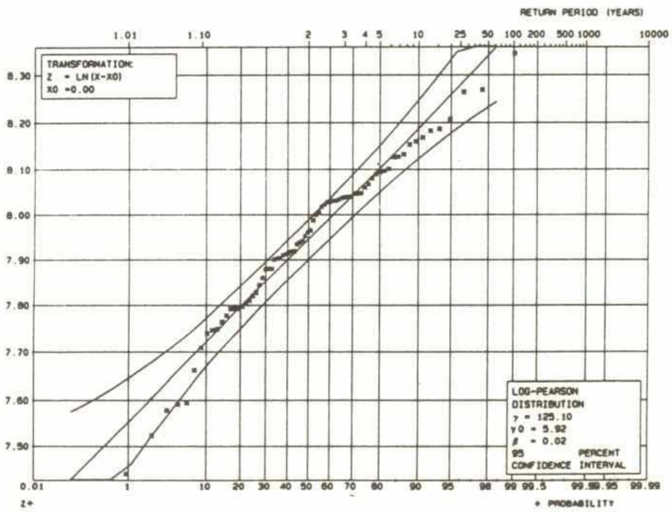
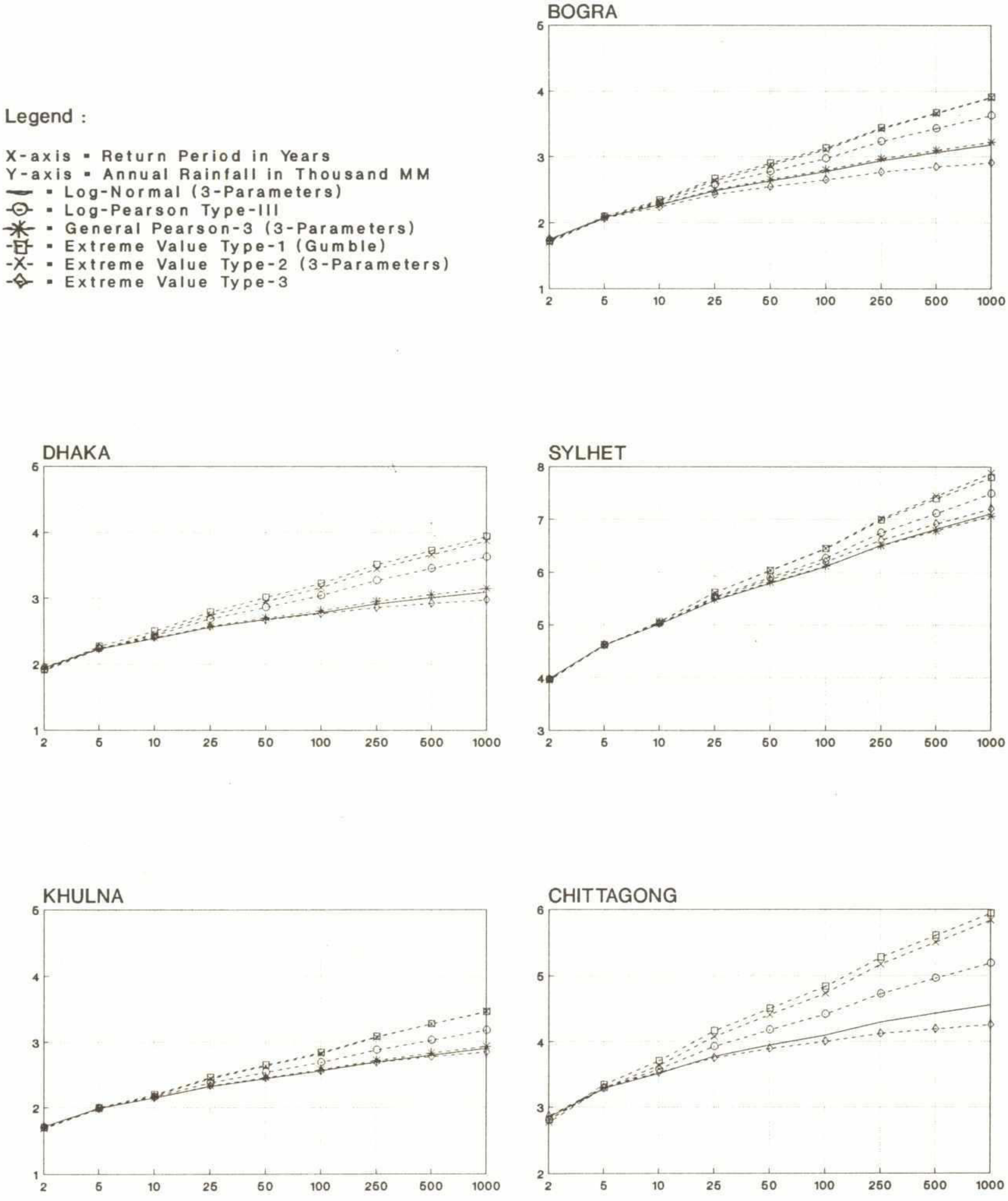




FAP25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY Fitting of 6 Different Probability Distributions for Annual Rainfall at Chittagong	
	JUNE 1992	FIGURE A.5.7 e)

COMPARISON OF 6 PROBABILTY DENSITY FUNCTIONS FOR 5 RAINFALL STATIONS



FAP 25 FLOOD MODELLING & MANAGEMENT	FLOOD HYDROLOGY STUDY
	Extrapolation Properties of 6 Different Distributions for Annual Rainfall
JUNE 1992	FIGURE A.5.8

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APPENDIX 6

Frequency Analysis of Observed Data

Appendix 6 contains tables of return periods for peak water level of important stations along the major rivers and important distributiaries. Observed annual peak water levels and related return periods are shown in pages A.6-2 to A.6-4. Graphical plots of the best fit probability distribution i.e. the log normal distribution for the stations are shown in pages A.6-5 to A.6-15. A Gumbel distribution has been used in case of Hardinge Bridge. One table showing return period for the peak discharges of the observation stations along the major river is seen in page A.6-16. Gumbel distribution is used for all the stations other than Bhairab Bazar, where GEV II distribution is used. Graphical plots of these stations are available at page A.6-17 to A.6-19. Seasonal distribution of discharge for the above stations are presented both in tabular and graphical form in pages A.6-20 and from A.6-21 to A.6-23 respectively.

PEAK WATER LEVEL

OBSERVED PEAK WATER LEVELS AND RELATED RETURN PERIODS

RIVERS	MEGHNA						ARIAL KHAN		PADMA			
STATIONS	BHAIRAB BAZAR		MEGHNA F. G.		CHANDPUR		MADARIPUR		BARURIA		MAWA	
YEAR	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.
1965	6.49	1.72	(-)	(-)	4.80	7.94	4.37	2.63	8.11	1.86	5.97	2.37
1966	6.91	4.37	(-)	(-)	4.85	10.65	4.74	6.15	8.46	4.41	6.38	8.24
1967	6.25	1.23	(-)	(-)	4.42	1.62	3.95	1.27	7.87	1.22	5.73	1.28
1968	6.77	3.07	5.67	2.57	4.64	3.40	4.66	5.08	8.43	4.07	6.20	4.75
1969	6.71	2.67	5.60	2.21	4.60	2.81	4.49	3.42	8.19	2.23	6.30	6.45
1970	7.10	7.43	5.84	3.90	4.71	4.75	4.69	5.46	8.41	3.86	(-)	(-)
1972	6.09	1.09	5.08	1.11	4.42	1.61	3.92	1.22	7.74	1.07	5.75	1.33
1973	6.48	1.69	5.40	1.56	4.73	5.14	4.41	2.87	8.27	2.70	6.12	3.71
1974	7.65	43.35	6.17	9.85	4.98	28.96	4.93	9.79	8.61	6.65	6.47	10.81
1975	6.48	1.69	5.23	1.26	4.50	2.02	3.91	1.21	8.18	2.18	5.87	1.79
1976	7.02	5.90	5.24	1.27	4.16	1.11	3.74	1.05	7.91	1.29	5.61	1.06
1977	6.57	1.99	(-)	(-)	4.39	1.52	4.01	1.37	8.12	1.90	5.89	1.89
1978	5.99	1.04	(-)	(-)	4.27	1.24	3.87	1.16	7.83	1.16	5.72	1.25
1979	6.33	1.35	(-)	(-)	4.35	1.39	3.86	1.15	7.68	1.03	5.59	1.04
1980	6.41	1.51	7.78	3.31	4.52	2.15	4.63	4.73	8.65	7.43	6.33	7.07
1981	6.46	1.63	(-)	(-)	4.38	1.47	4.10	1.57	7.96	1.40	5.84	1.65
1982	6.43	1.56	(-)	(-)	4.28	1.26	3.70	1.03	7.99	1.47	5.64	1.10
1983	6.79	3.22	(-)	(-)	4.46	1.80	4.14	1.68	8.48	4.65	5.91	2.00
1984	6.89	4.15	(-)	(-)	4.65	3.55	4.41	2.87	8.37	3.47	6.15	4.07
1985	6.38	1.45	(-)	(-)	4.27	1.24	4.27	2.14	8.06	1.68	5.94	2.17
1986	5.90	1.02	4.97	1.05	3.82	1.00	4.04	1.43	7.88	1.24	5.76	1.36
1987	6.90	4.26	5.98	5.61	4.50	2.02	5.17	17.79	9.04	22.55	(-)	(-)
1988	7.65	43.35	6.53	32.97	4.99	31.48	5.59	50.64	9.35	54.44	7.06	58.01
1989	6.41	1.51	5.14	1.16	4.29	1.28	4.20	1.87	7.74	1.07	5.69	1.19

Notes : A Log-Normal distribution is used for all the stations

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OBSERVED PEAK WATER LEVELS AND RELATED RETURN PERIODS

RIVERS	OLD BRAHMAPUTRA						KALIGANGA		LAKHYA		GORAI			
STATIONS	JAMALPUR		NILUKHIRCHAR		TOKE		TARAGHAT		DEMRA		KAMARKHALI		GORAI	
YEAR	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.
1965	17.07	2.16	(-)	(-)	(-)	(-)	9.05	2.89	5.80	2.04	8.63	1.27	12.79	1.67
1966	17.04	2.04	(-)	(-)	(-)	(-)	9.30	4.54	6.23	5.61	8.84	1.90	12.88	1.91
1967	16.83	1.46	12.06	1.37	(-)	(-)	8.73	1.82	5.42	1.19	9.02	3.52	13.13	3.15
1968	16.98	1.82	12.08	1.39	8.44	1.82	9.19	3.67	6.06	3.62	8.97	2.90	12.84	1.80
1969	17.09	2.26	12.04	1.34	8.23	1.48	8.82	2.04	5.83	2.17	9.12	5.41	13.28	4.68
1970	17.38	4.99	12.62	3.20	8.84	3.21	9.33	4.83	6.23	5.61	8.83	1.87	12.49	1.23
1972	17.28	3.65	12.42	2.20	(-)	(-)	8.56	1.51	5.38	1.15	8.19	1.01	12.04	1.03
1973	17.28	3.65	12.85	5.38	8.87	3.38	9.19	3.67	5.86	2.30	8.67	1.35	13.00	2.37
1974	17.56	9.84	13.29	18.44	9.68	21.22	9.47	6.58	6.57	15.05	8.72	1.46	13.09	2.87
1975	16.90	1.61	12.31	1.85	(-)	(-)	8.28	1.21	5.58	1.42	8.63	1.27	12.79	1.67
1976	17.22	3.08	12.49	2.49	(-)	(-)	(-)	(-)	5.45	1.22	8.78	1.66	13.13	3.15
1977	17.28	3.65	12.81	4.88	9.09	5.11	8.63	1.62	5.90	2.50	8.73	1.50	12.76	1.61
1978	16.81	1.42	12.19	1.58	8.35	1.65	7.96	1.06	5.48	1.26	9.05	4.05	13.27	4.55
1979	16.74	1.32	12.16	1.52	8.35	1.65	8.02	1.08	5.56	1.39	8.35	1.04	12.04	1.03
1980	17.40	5.34	12.80	4.77	8.83	3.16	9.40	5.65	6.21	5.32	9.21	9.01	13.43	7.52
1981	16.68	1.25	11.78	1.12	7.79	1.13	8.31	1.23	5.72	1.77	8.91	2.32	12.72	1.53
1982	16.62	1.19	12.00	1.29	8.01	1.26	8.16	1.14	5.47	1.25	9.18	7.60	13.13	3.15
1983	16.52	1.12	11.97	1.26	7.98	1.24	8.92	2.35	(-)	(-)	8.98	2.97	13.51	10.01
1984	17.30	3.87	12.82	5.00	8.96	3.97	9.22	3.92	6.30	6.80	8.81	1.76	(-)	(-)
1985	17.50	7.72	12.50	2.53	(-)	(-)	8.72	1.80	5.68	1.65	8.57	1.19	(-)	(-)
1986	15.96	1.01	11.36	1.01	7.38	1.03	8.38	1.29	5.12	1.02	8.82	1.84	12.71	1.51
1987	17.20	2.93	12.72	3.96	8.92	3.69	9.70	11.24	6.38	8.54	9.26	12.20	13.43	7.52
1988	17.81	32.71	13.70	72.93	9.81	30.74	10.37	74.09	6.92	45.96	9.47	56.39	13.65	17.46
1989	16.28	1.04	11.84	1.15	(-)	(-)	7.87	1.04	5.32	1.10	(-)	(-)	11.86	1.01

Notes : A Log-Normal distribution is used for all the stations

OBSERVED PEAK WATER LEVELS AND RELATED RETURN PERIODS

RIVERS	JAMUNA										GANGES			
STATIONS	CHILMARI		BAHADURABAD		KAZIPUR		SERAJGANJ		PORABARI		HARDINGE BDG.		SENGRAM	
YEAR	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.	PEAK	R. P.
1965	23.34	1.01	19.69	1.54	(-)	(-)	13.77	1.49	12.24	1.95	13.72	(-)	11.07	1.09
1966	23.81	1.46	19.62	1.31	(-)	(-)	13.87	1.84	12.49	3.50	14.28	(-)	11.63	1.91
1967	23.97	1.98	19.50	1.09	15.46	1.56	13.64	1.20	12.19	1.79	14.44	(-)	11.60	1.82
1968	24.04	2.32	19.80	2.10	15.62	2.14	13.94	2.16	12.40	2.76	14.04	(-)	11.37	1.35
1969	23.79	1.42	19.84	2.39	15.52	1.74	13.82	1.65	12.31	2.25	14.68	(-)	11.83	2.80
1970	24.19	3.45	20.20	9.73	16.20	11.49	14.22	4.45	12.61	5.05	13.92	(-)	11.32	1.29
1972	24.09	2.63	19.98	3.97	15.65	2.28	13.90	1.97	12.12	1.60	13.40	(-)	(-)	(-)
1973	23.88	1.65	19.88	2.74	15.77	3.06	14.22	4.45	12.30	2.20	14.18	(-)	11.93	3.53
1974	24.46	8.26	20.26	12.60	15.90	4.39	14.24	4.69	12.54	4.05	14.39	(-)	11.65	1.97
1975	23.78	1.40	19.60	1.26	15.07	1.05	13.60	1.14	12.06	1.47	14.31	(-)	11.65	1.97
1976	23.90	1.71	19.87	2.65	15.35	1.33	13.46	1.02	11.68	1.09	14.64	(-)	11.61	1.85
1977	24.11	2.77	19.99	4.12	15.42	1.47	13.90	1.97	12.28	2.11	14.11	(-)	11.51	1.59
1978	23.68	1.23	19.63	1.34	14.91	1.01	13.52	1.06	11.55	1.04	14.69	(-)	11.72	2.24
1979	(-)	(-)	19.78	1.98	15.25	1.19	13.67	1.26	11.74	1.12	13.64	(-)	10.91	1.04
1980	24.25	4.12	20.10	6.40	15.99	5.76	14.50	9.64	12.81	10.58	14.86	11.32	12.25	8.79
1981	(-)	(-)	19.48	1.07	15.41	1.44	13.87	1.84	11.83	1.18	14.19	(-)	11.47	1.51
1982	(-)	(-)	19.42	1.03	15.43	1.49	13.73	1.39	12.00	1.37	14.65	(-)	(-)	(-)
1983	24.04	2.32	19.92	3.17	15.61	2.09	14.19	4.10	12.41	2.83	14.81	6.63	12.02	4.44
1984	24.25	4.12	20.10	6.40	15.87	4.03	14.62	13.47	12.77	9.00	14.51	(-)	12.22	7.98
1985	23.92	1.78	19.61	1.29	15.69	2.51	14.14	3.59	12.44	3.06	14.16	(-)	11.49	1.55
1986	23.44	1.04	19.15	1.00	15.39	1.40	13.66	1.24	11.90	1.24	14.11	(-)	11.71	2.20
1987	24.69	19.67	19.68	1.50	16.18	10.73	14.57	11.72	12.88	14.24	14.79	3.98	12.50	21.30
1988	25.04	85.87	20.61	59.52	16.76	94.84	15.11	51.65	13.14	51.20	14.87	12.98	12.75	59.14
1989	23.58	1.12	19.57	1.20	15.54	1.81	13.65	1.22	11.53	1.04	13.26	(-)	10.79	1.02

Notes : A Log-Normal distribution is used for all the stations except Hardinge Bridge.
For Hardinge Bridge, Gumbel distribution with left censoring has been applied.
Therefore a return period can be defined only for peaks higher than 14,80 m.

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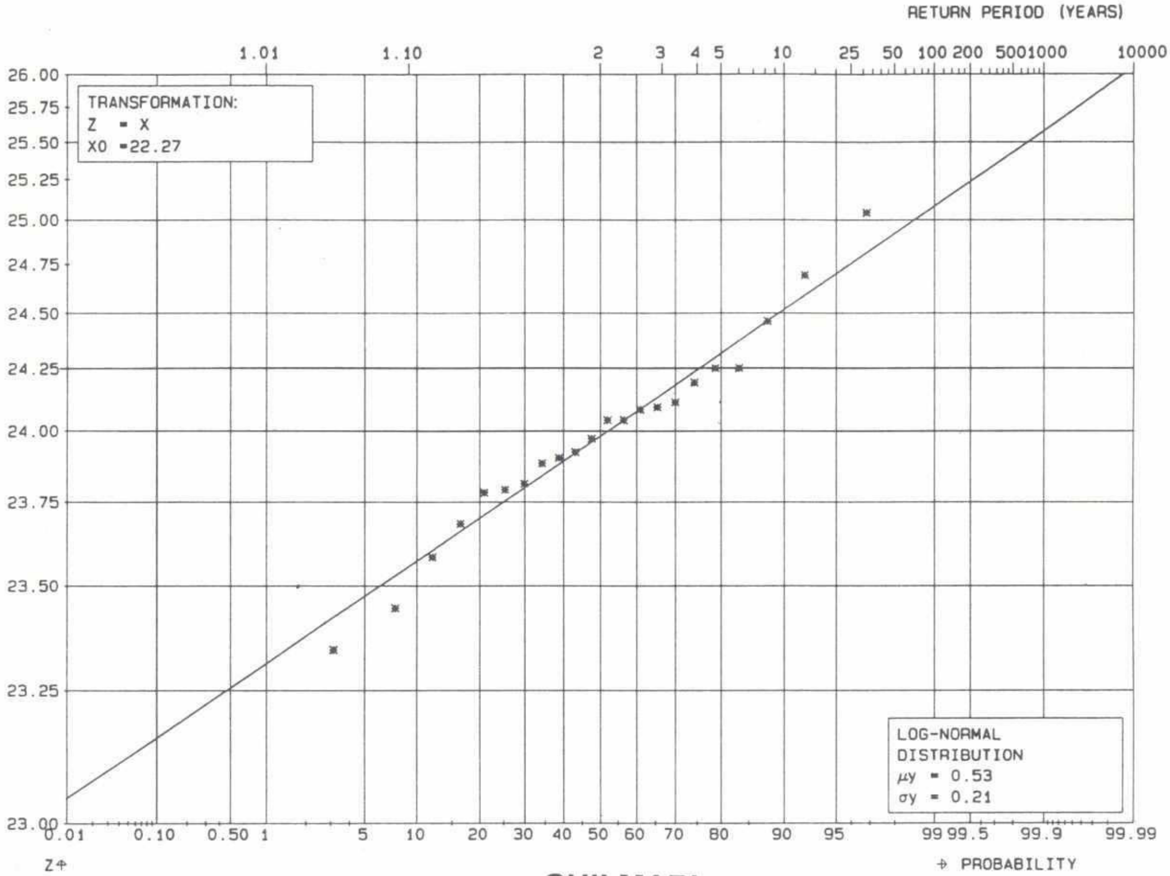

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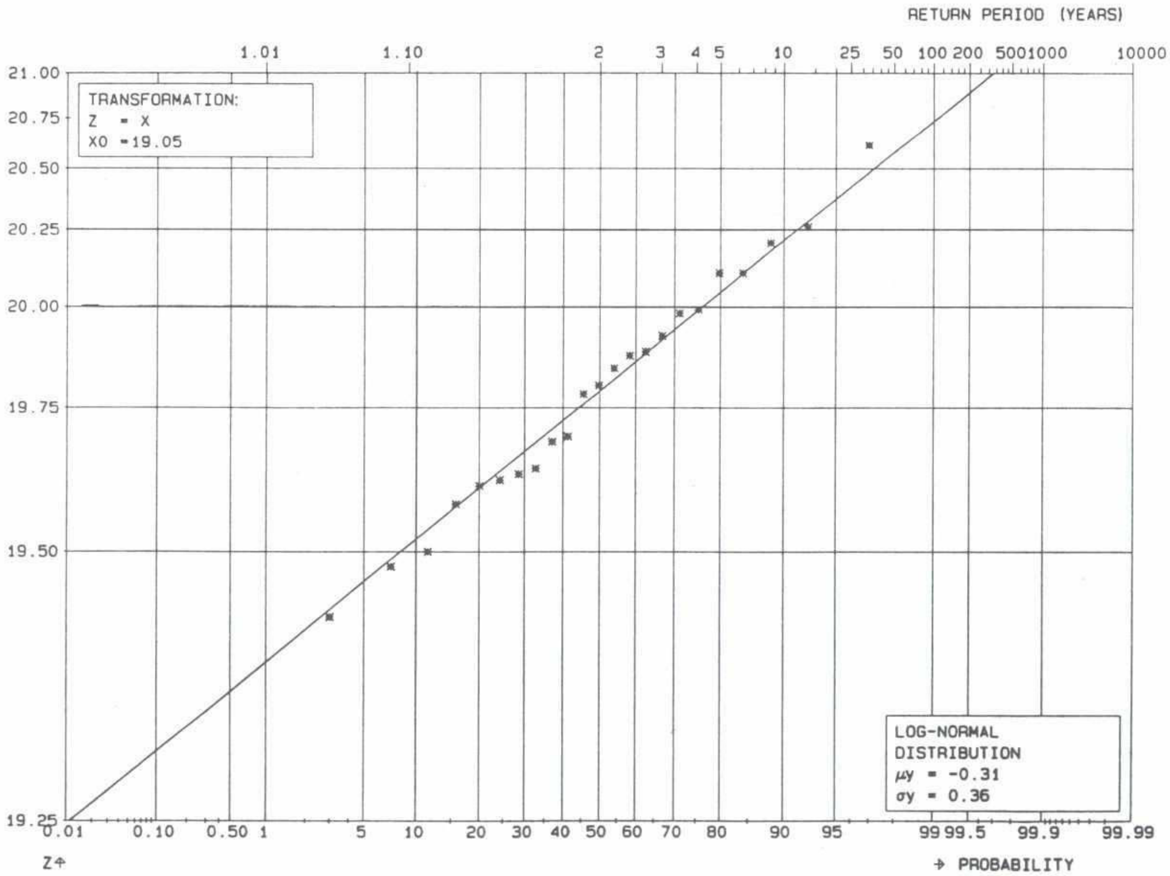

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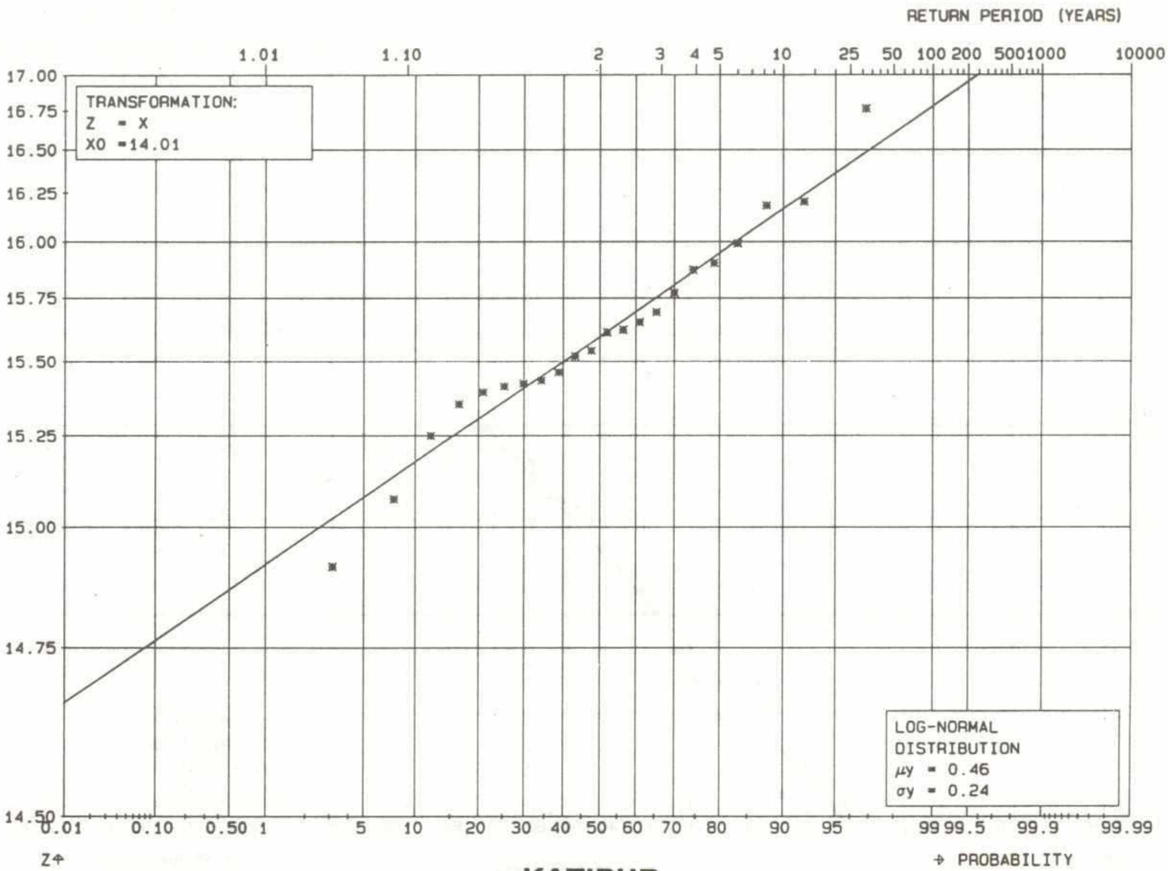

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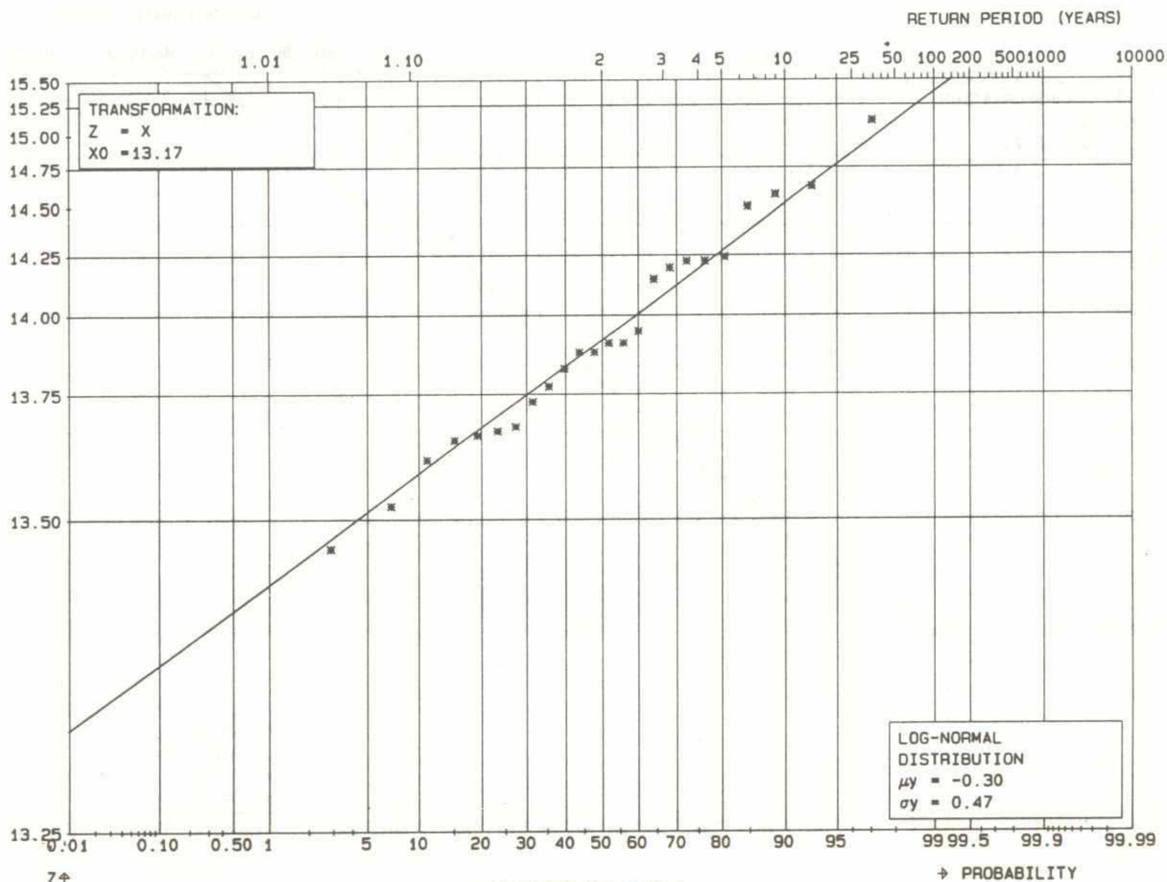

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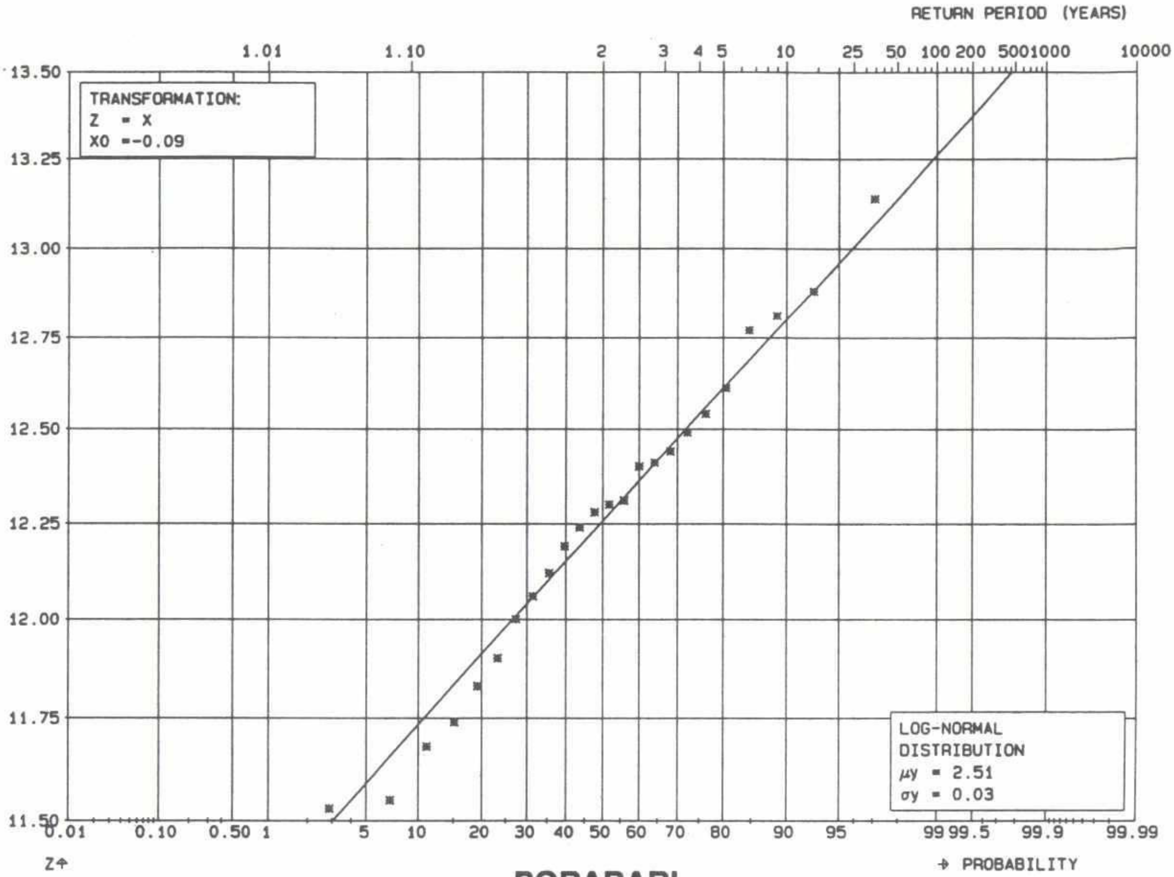

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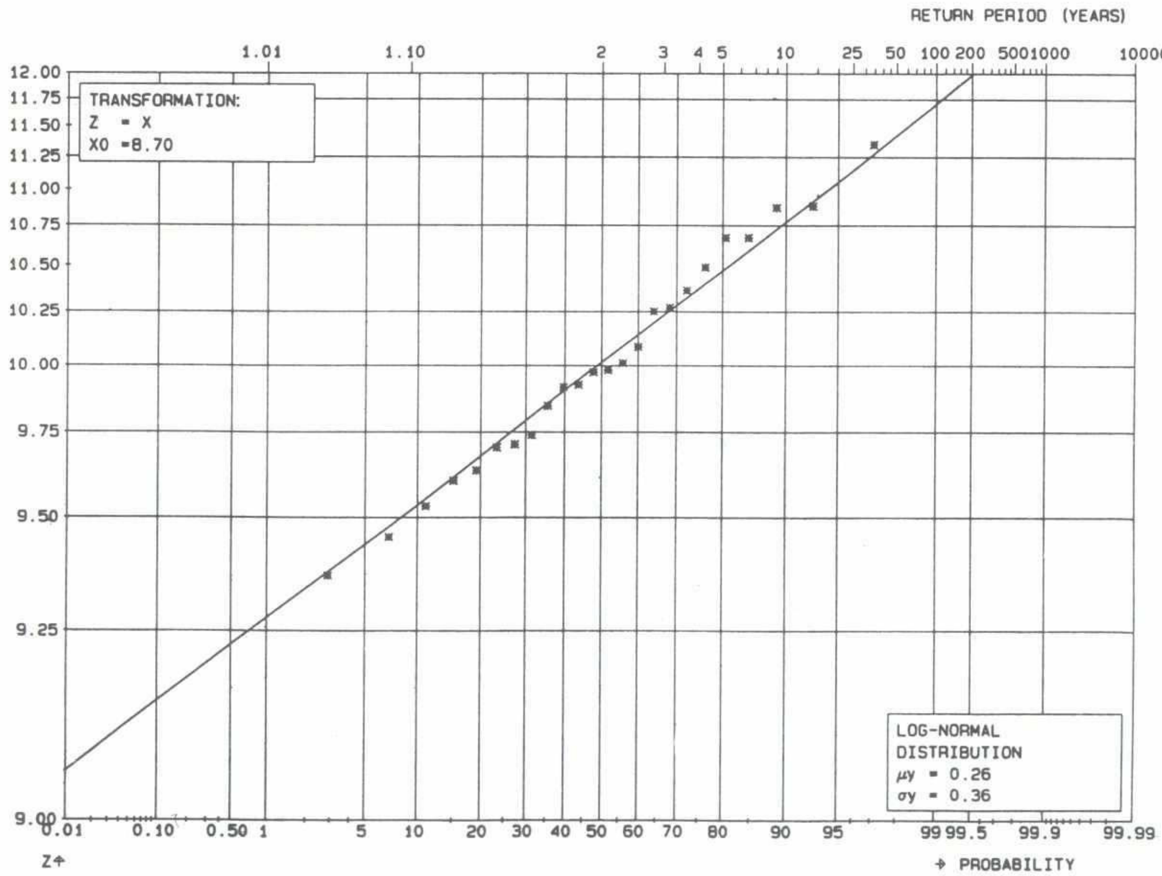

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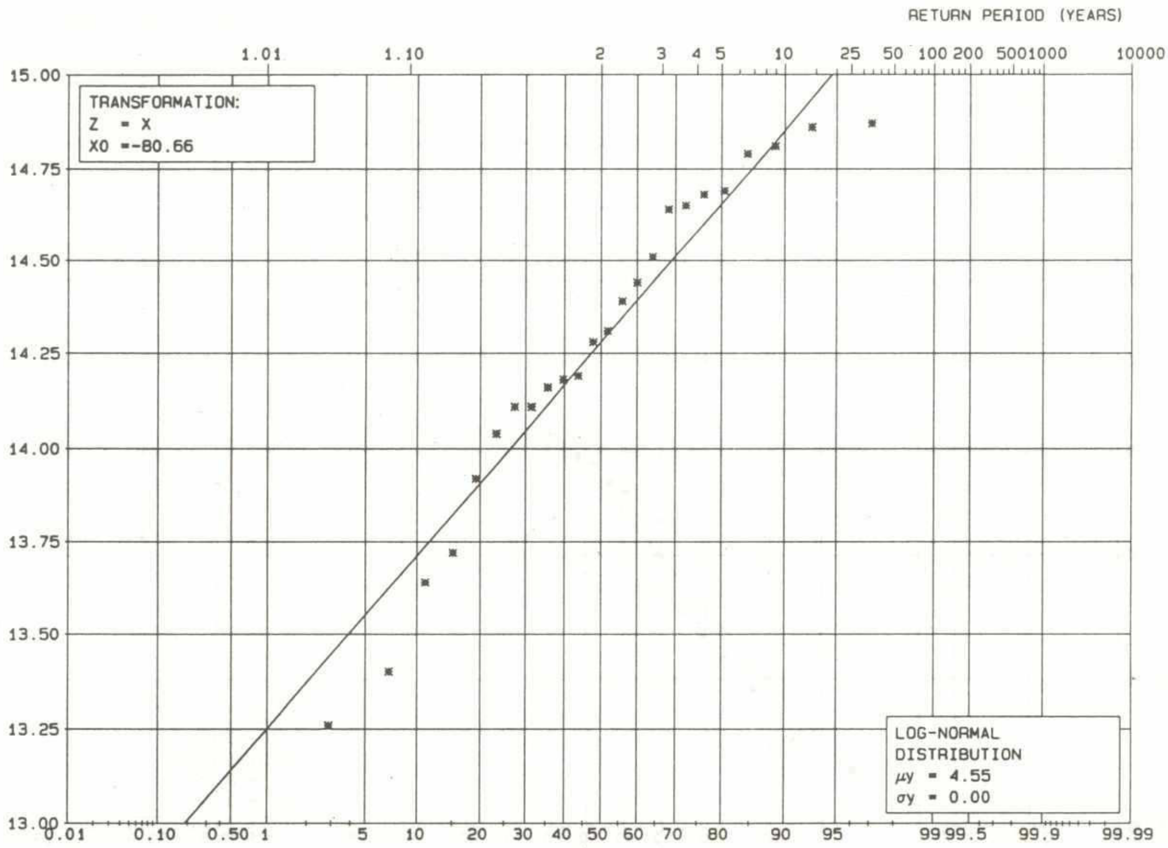

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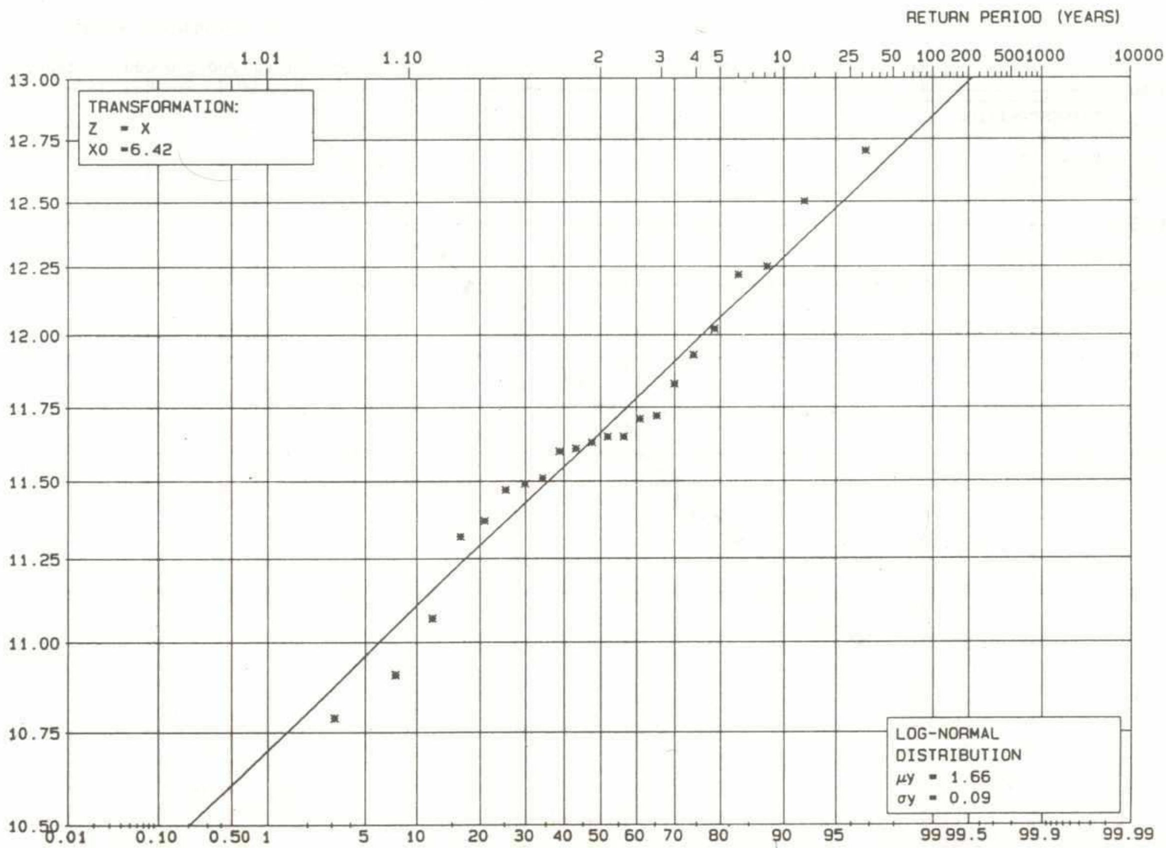

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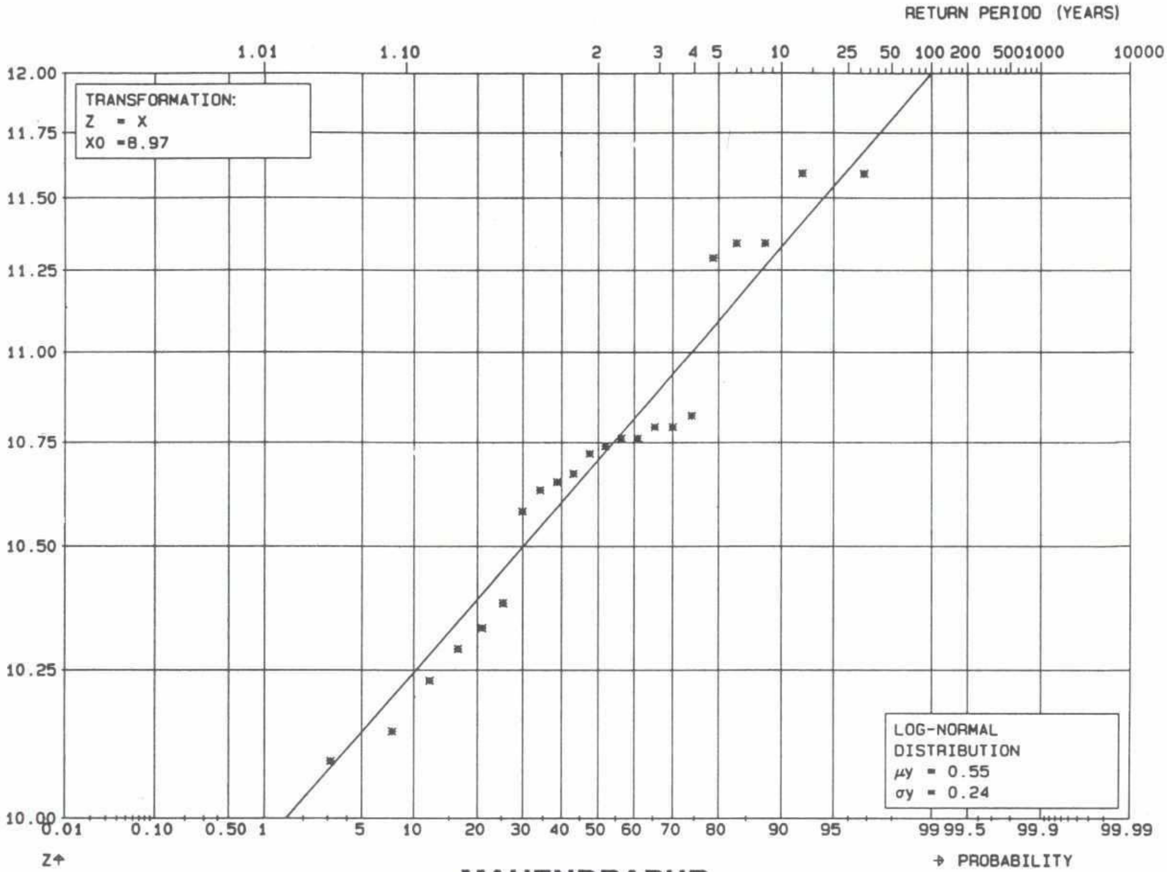

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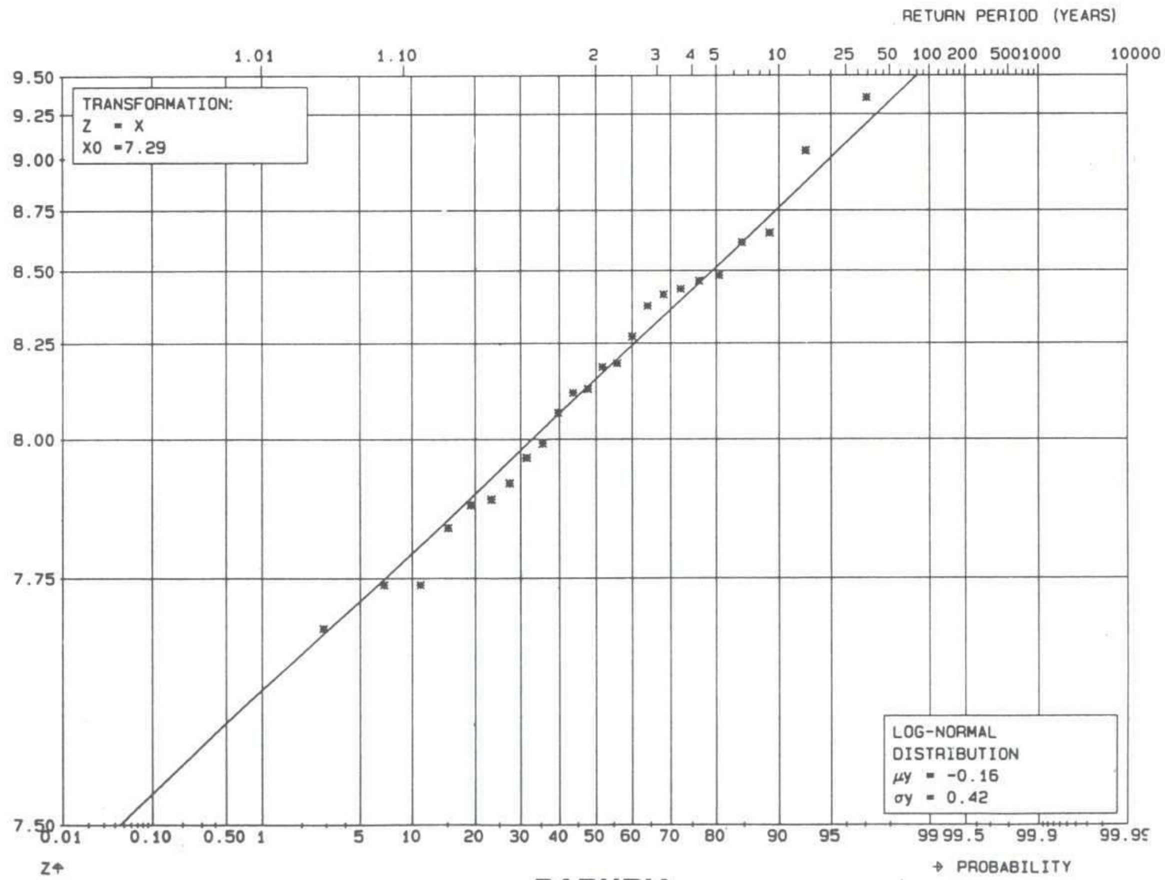

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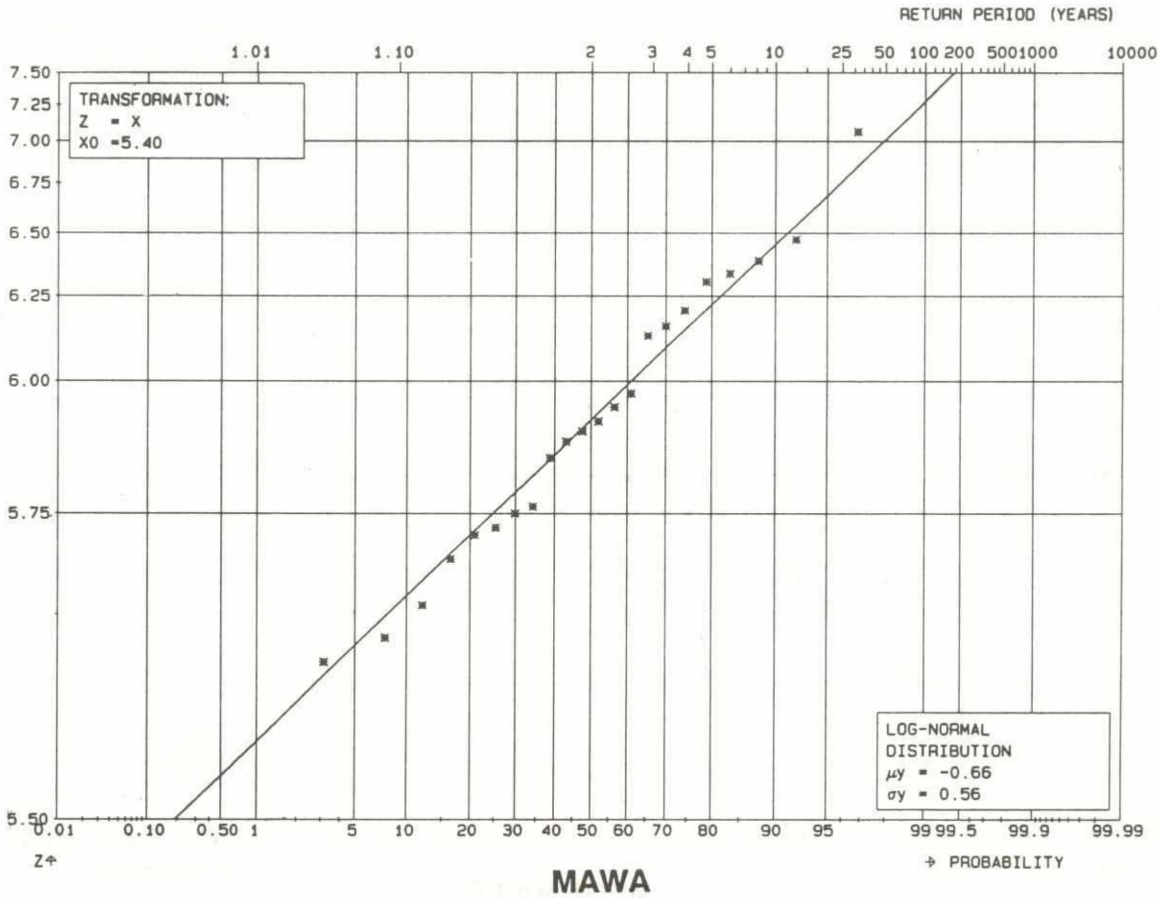

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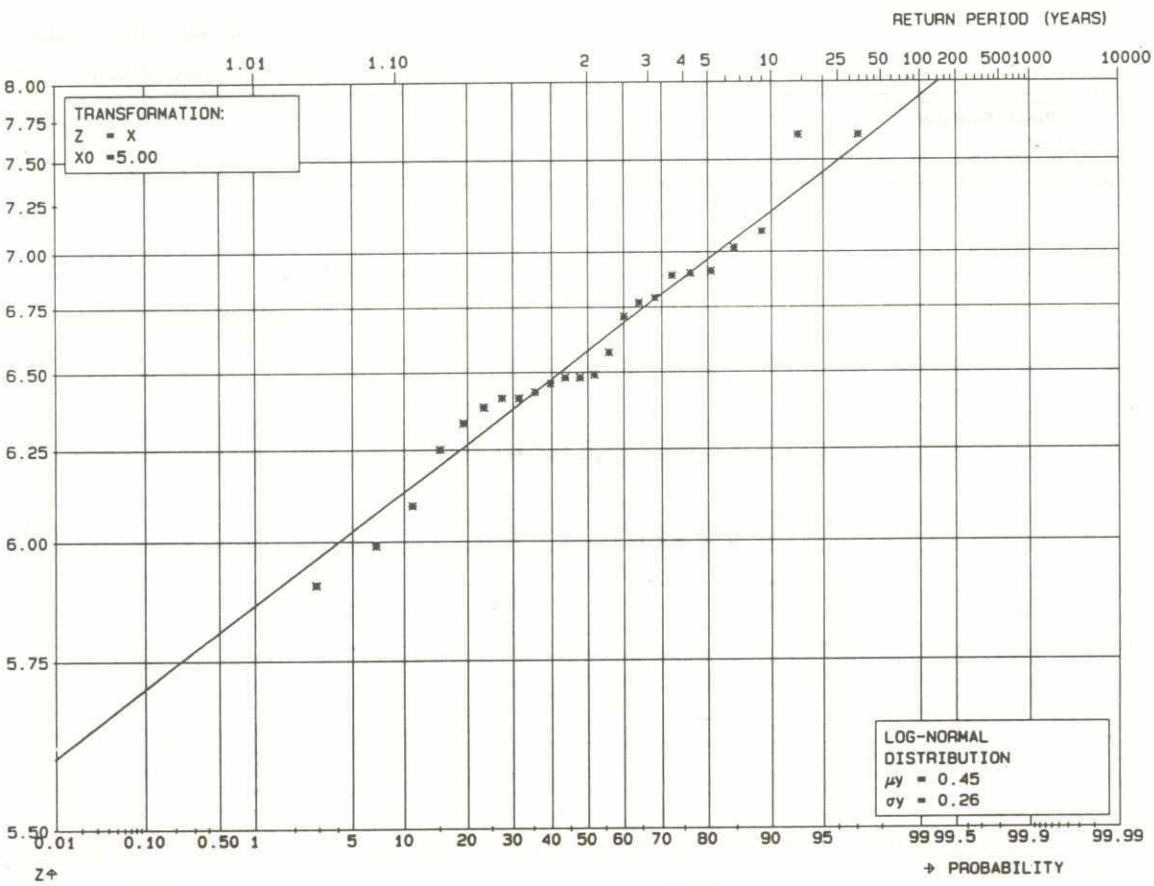

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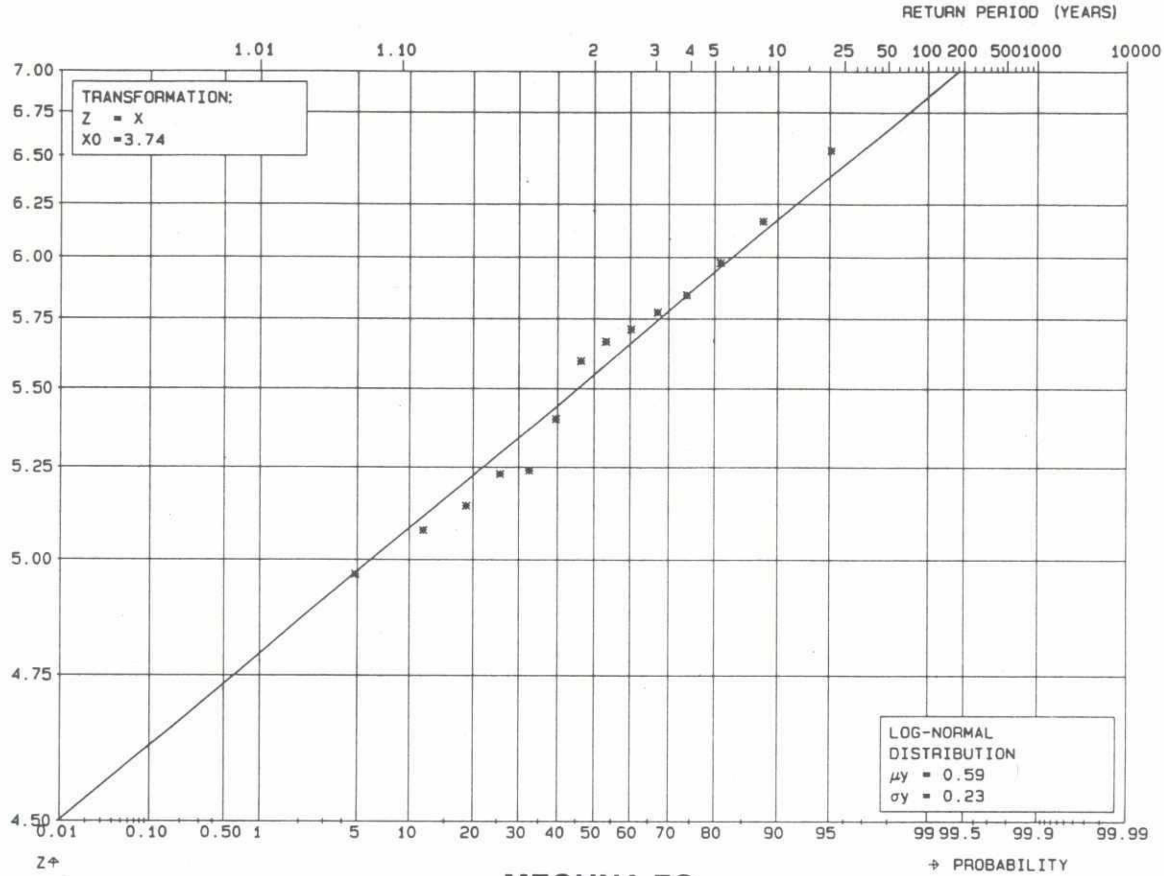

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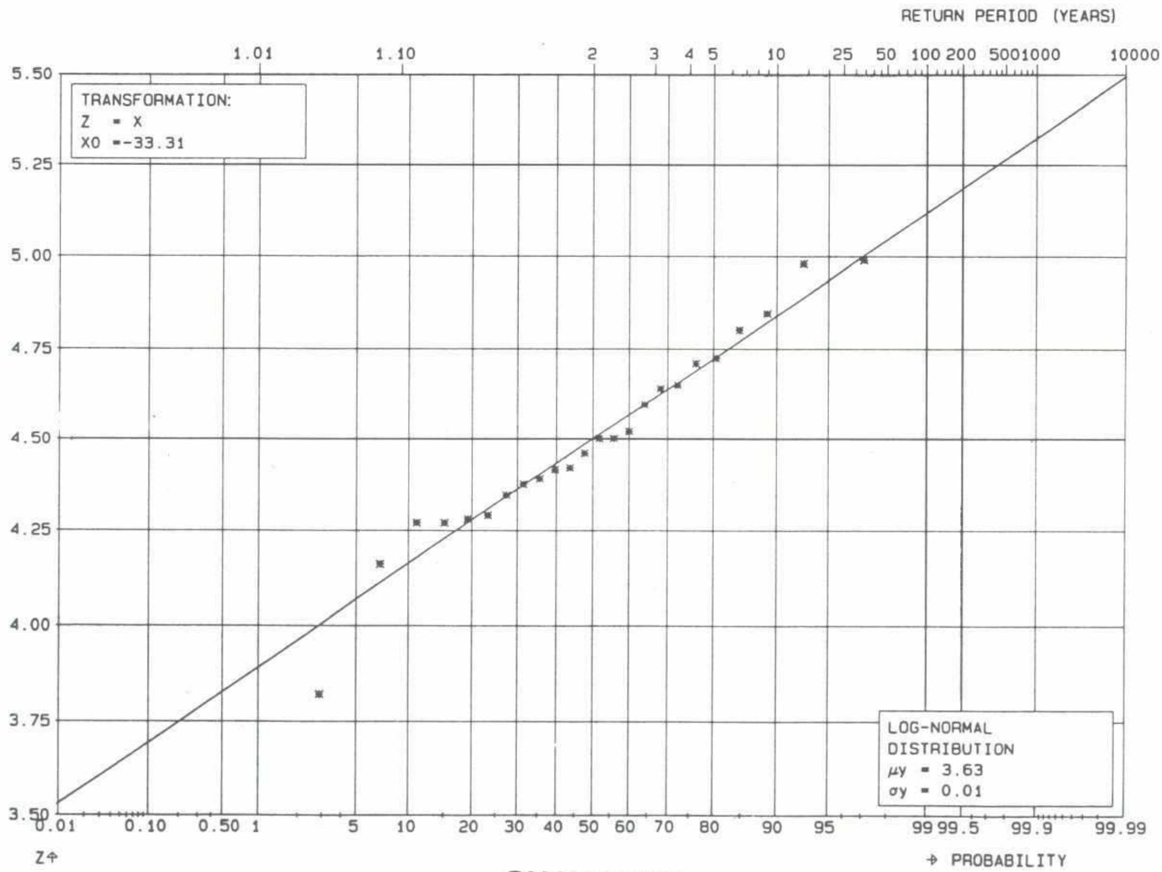

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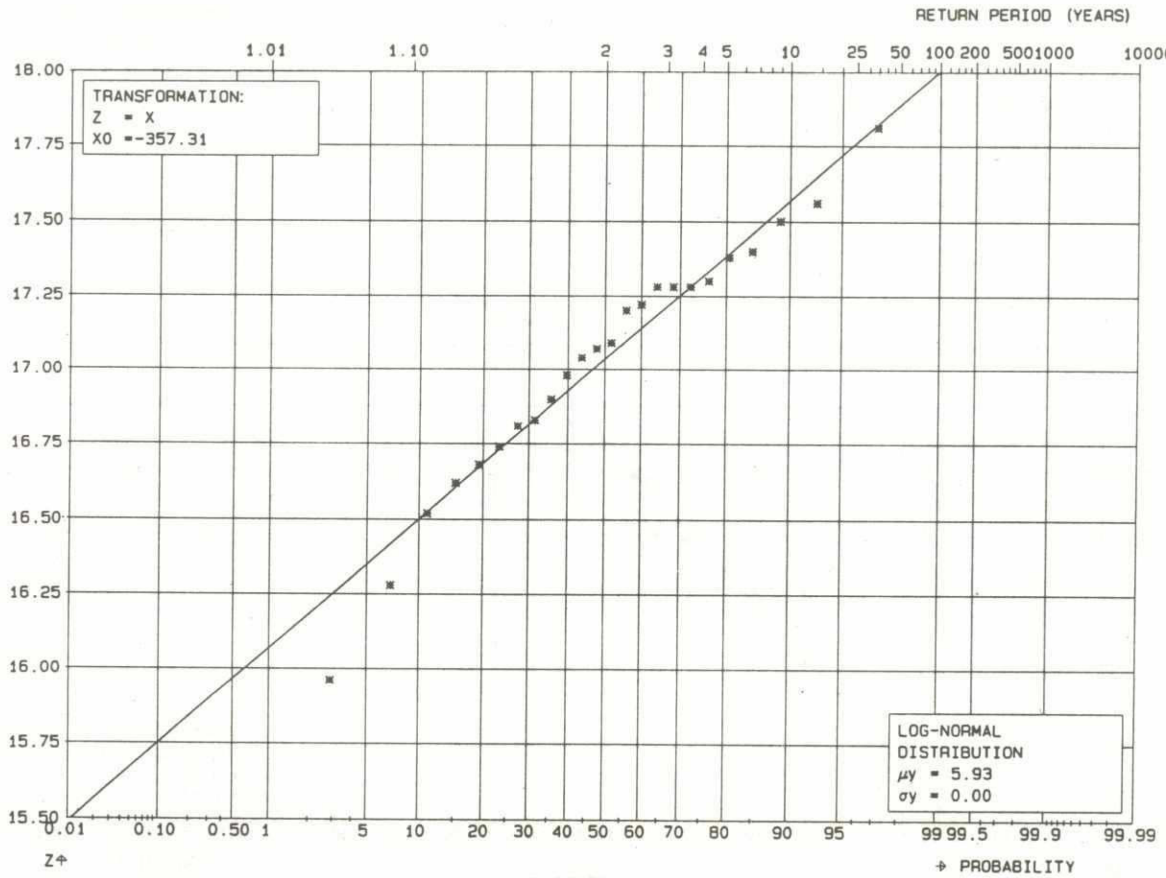

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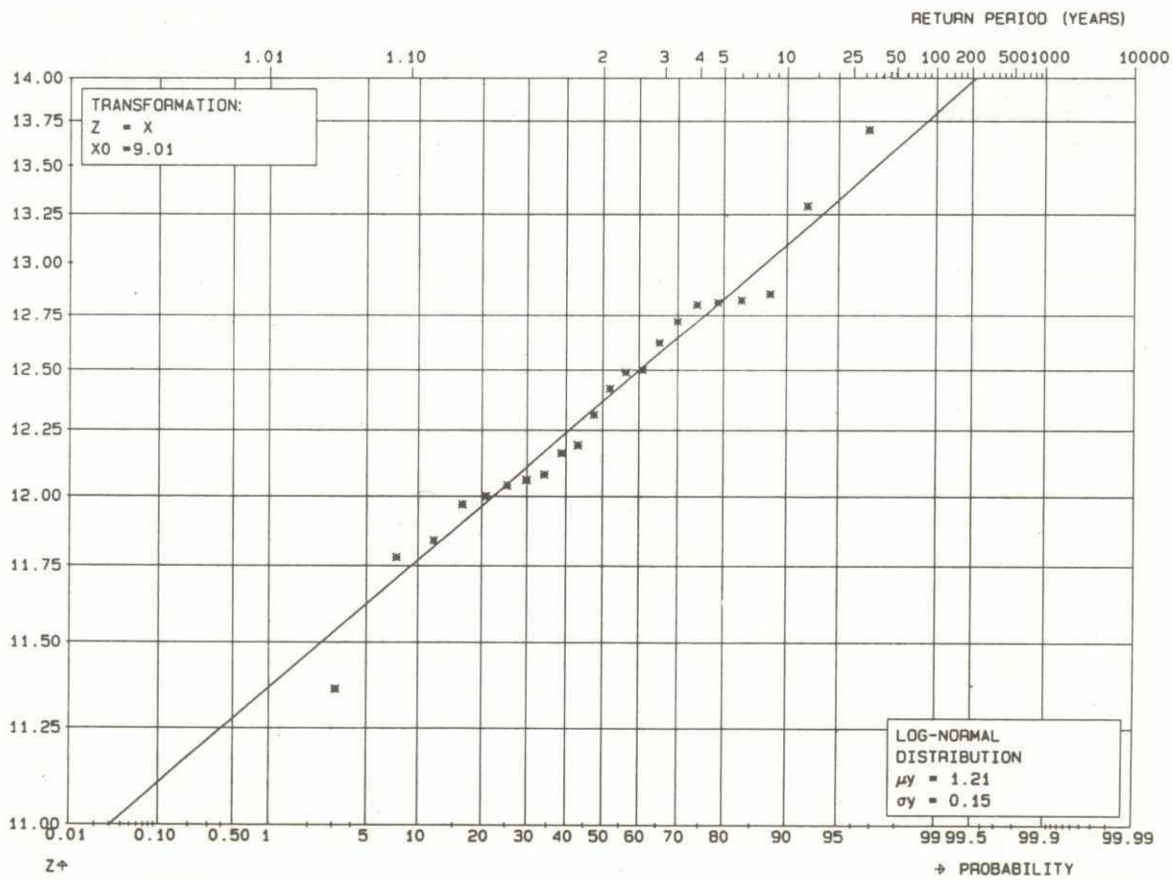

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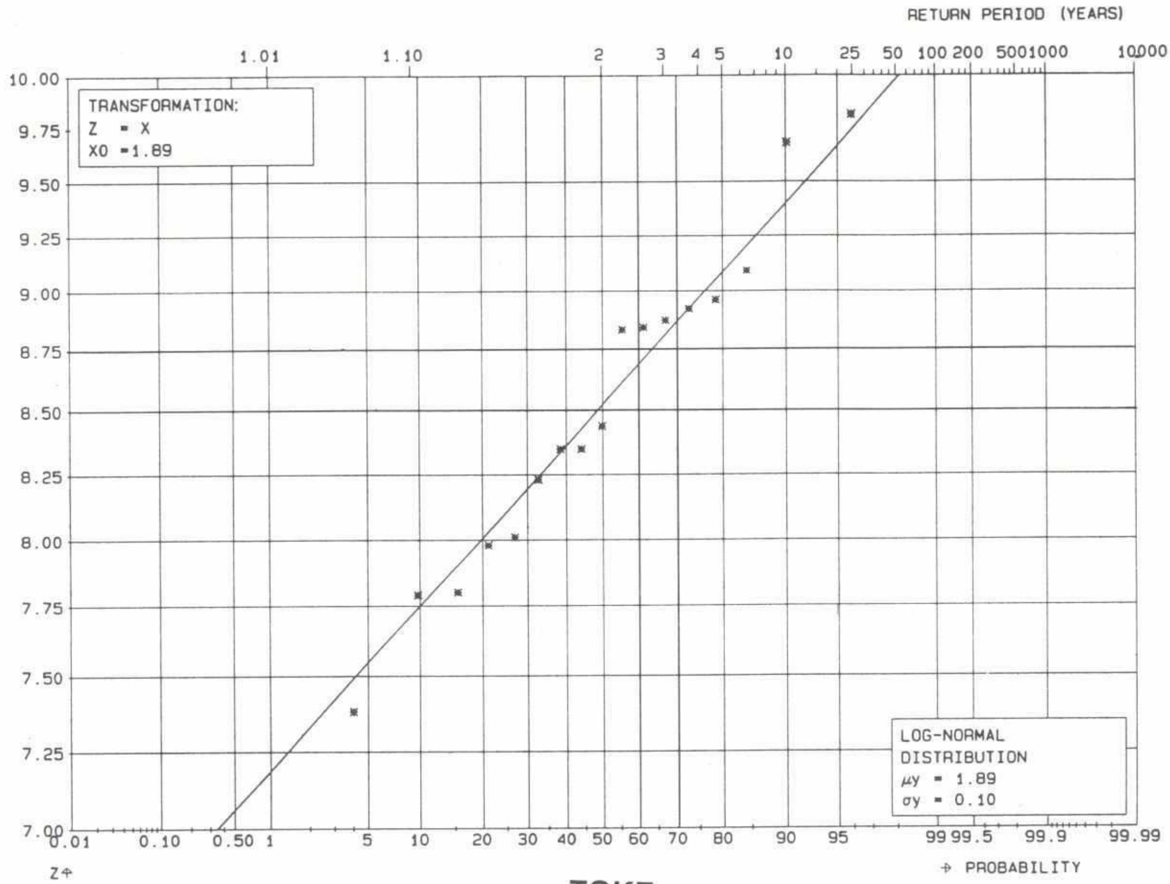

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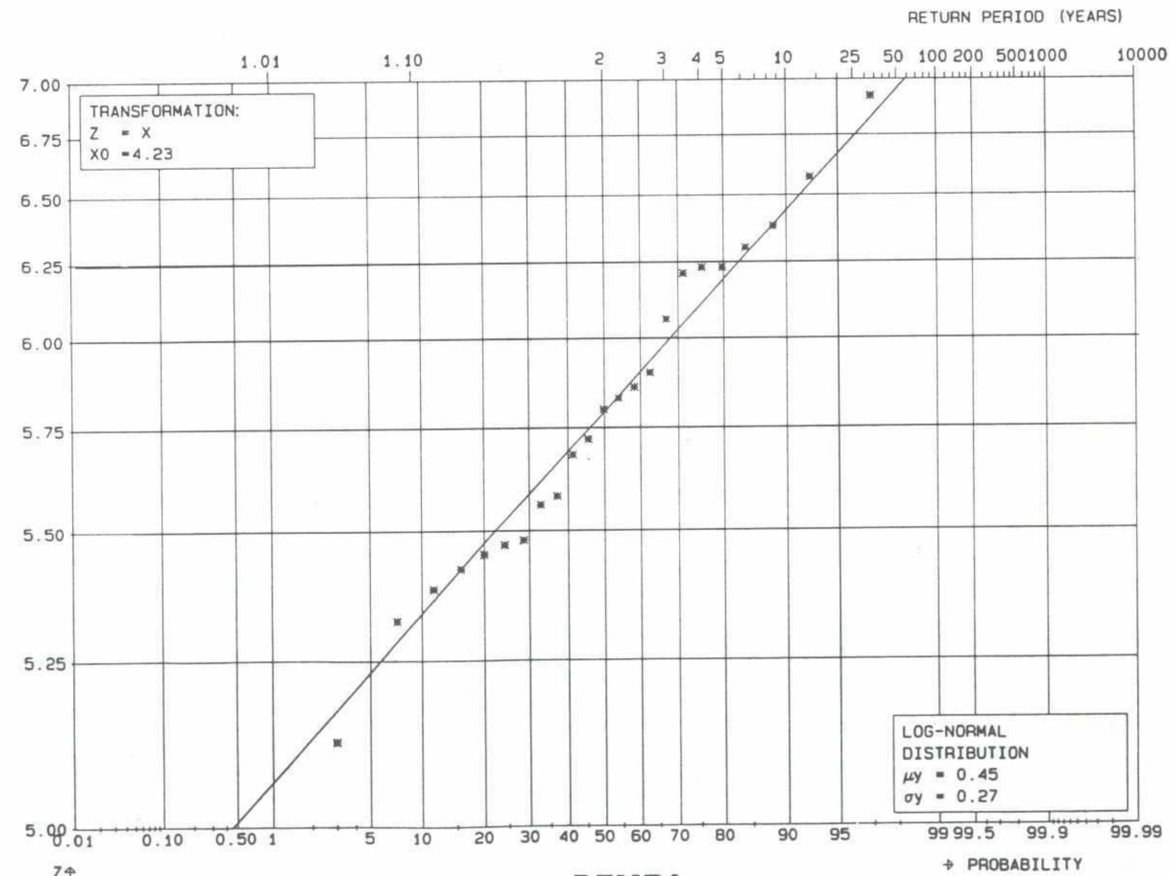

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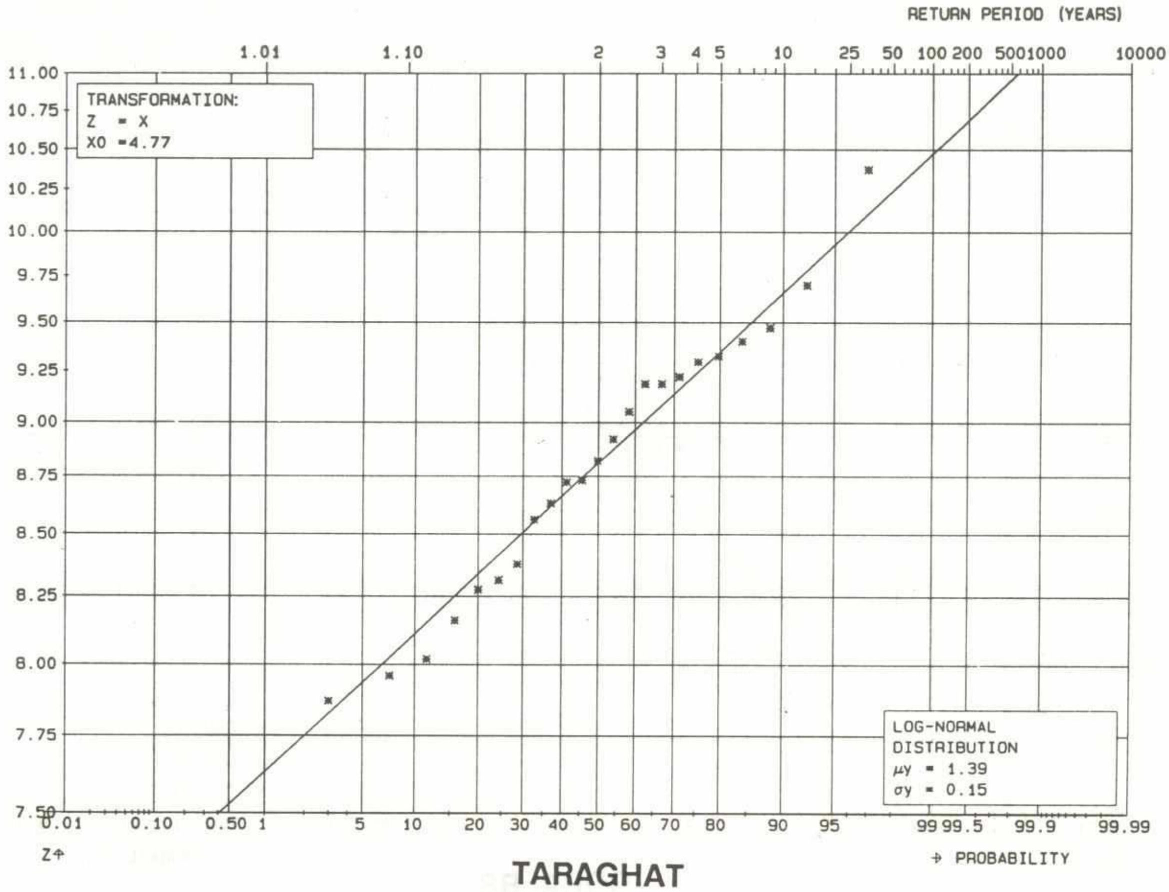

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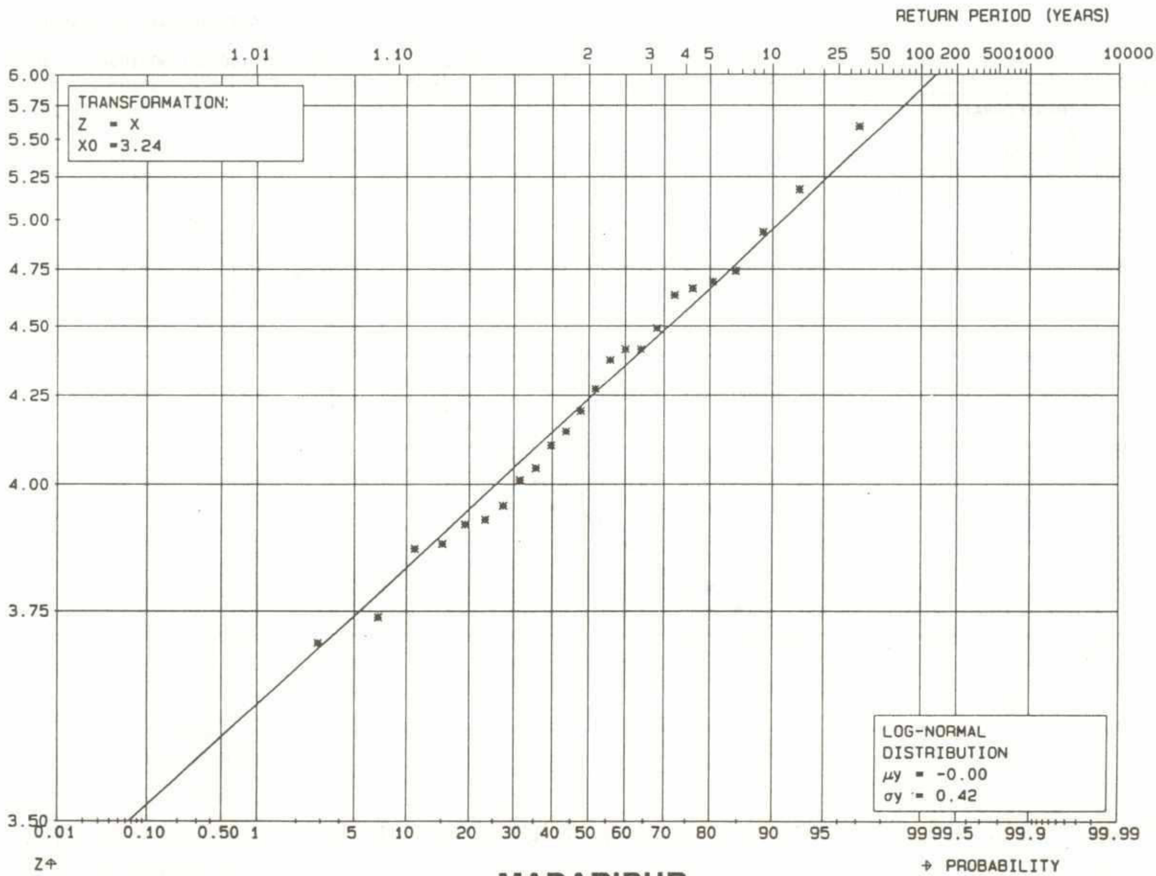

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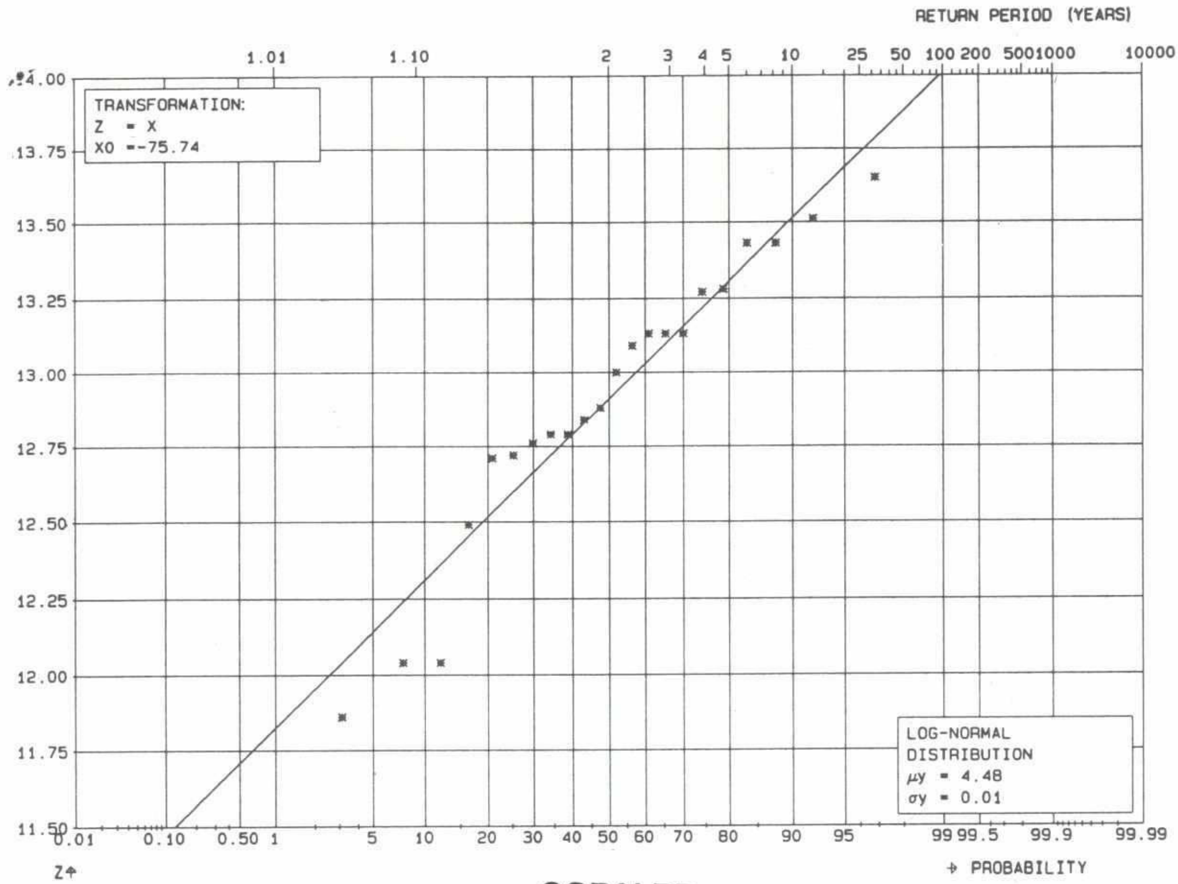

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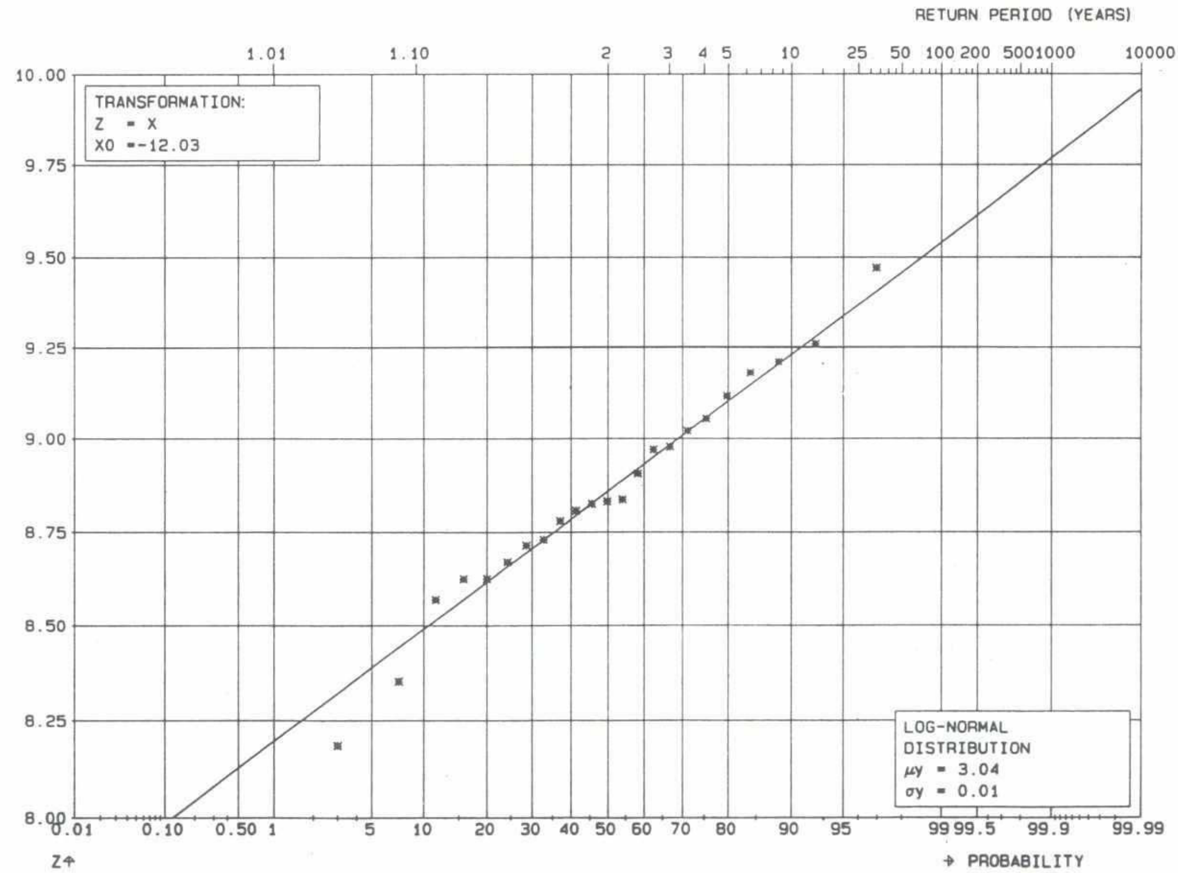


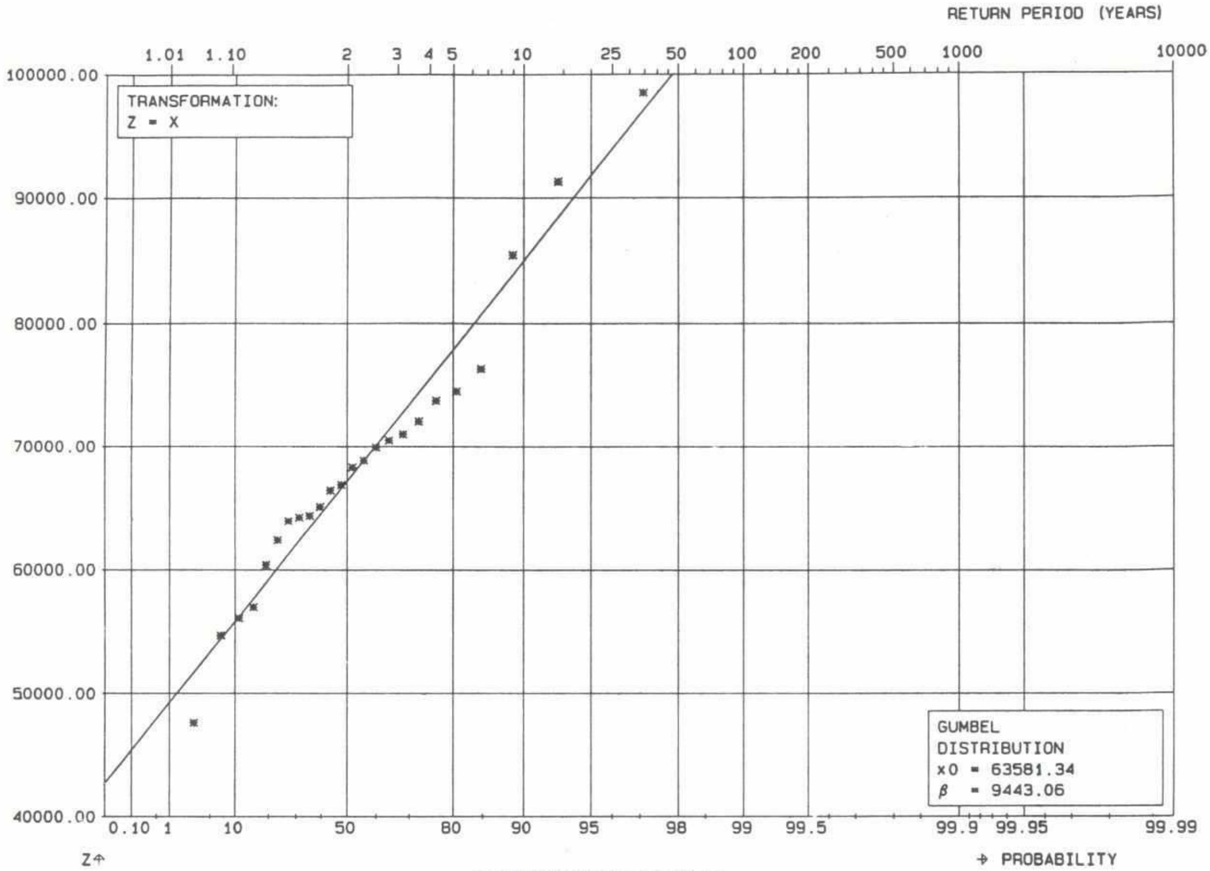
KAMARKHALI

PEAK DISCHARGE

ESTIMATED (BY RATING CURVE) PEAK DISCHARGES AND RELATED RETURN PERIODS

RIVERS	JAMUNA		GANGES		PADMA		UPPER MEGHNA		OLD BRAHMAPUTRA	
STATIONS	BAHADURABAD		HARDINGE BRIDGE		BARURIA		BHAIRAB BAZAR		NILUKHIRCHAR	
YEAR	PEAK	R.P	PEAK	R.P	PEAK	R.P	PEAK	R.P	PEAK	R.P
1965	64200	1.64	36800	1.09	(-)	(-)	12100	1.26	3200	2.70
1966	73700	3.45	40500	1.23	76800	1.28	14400	2.81	3400	3.93
1967	72000	2.99	49000	2.01	61500	1.01	12700	1.50	3000	2.00
1968	62300	1.47	43300	1.40	75000	1.25	13300	1.84	2800	1.61
1969	57000	1.16	56000	3.55	72000	1.16	11500	1.11	2700	1.55
1970	74400	3.70	39400	1.18	77800	1.38	16400	6.27	3200	2.77
1972	68800	2.29	35500	1.06	73500	1.20	11500	1.11	(-)	(-)
1973	68200	2.19	48000	1.87	86500	2.06	12400	1.36	(-)	(-)
1974	85400	10.60	53900	2.94	126000	31.10	19500	19.57	3800	6.60
1975	54700	1.08	50200	2.19	94700	3.33	12700	1.50	3000	2.15
1976	65000	1.74	60900	5.58	80600	1.54	16700	7.05	3200	2.62
1977	66800	1.97	48000	1.86	81800	1.63	(-)	(-)	3500	4.31
1978	56100	1.12	62500	6.50	80400	1.53	(-)	(-)	2700	1.55
1979	60300	1.33	37300	1.10	80900	1.56	(-)	(-)	2600	1.36
1980	91200	19.23	57600	4.07	109000	8.85	(-)	(-)	3300	3.15
1981	66400	1.91	47700	1.83	87400	2.16	11200	1.06	2600	1.43
1982	64300	1.66	61400	5.82	87000	2.12	13500	1.98	2400	1.21
1983	70900	2.73	57900	4.21	101900	5.36	16000	5.36	2300	1.13
1984	76300	4.37	55700	3.45	98700	4.32	13600	2.06	4700	31.63
1985	63900	1.61	47500	1.80	93300	3.06	14300	2.70	3000	2.18
1986	47600	1.00	52200	2.57	81700	1.62	11100	1.05	1900	1.01
1987	70400	2.61	70800	14.68	112500	11.36	15200	3.89	3200	2.62
1988	98400	40.52	72300	17.23	137000	71.61	19800	21.66	4800	40.31
1989	69800	2.49	31800	1.02	73000	1.19	15500	4.38	2100	1.05

Notes : A GEV II distribution is used for Bhairab Bazar.
Gumbel is used for all the others stations.



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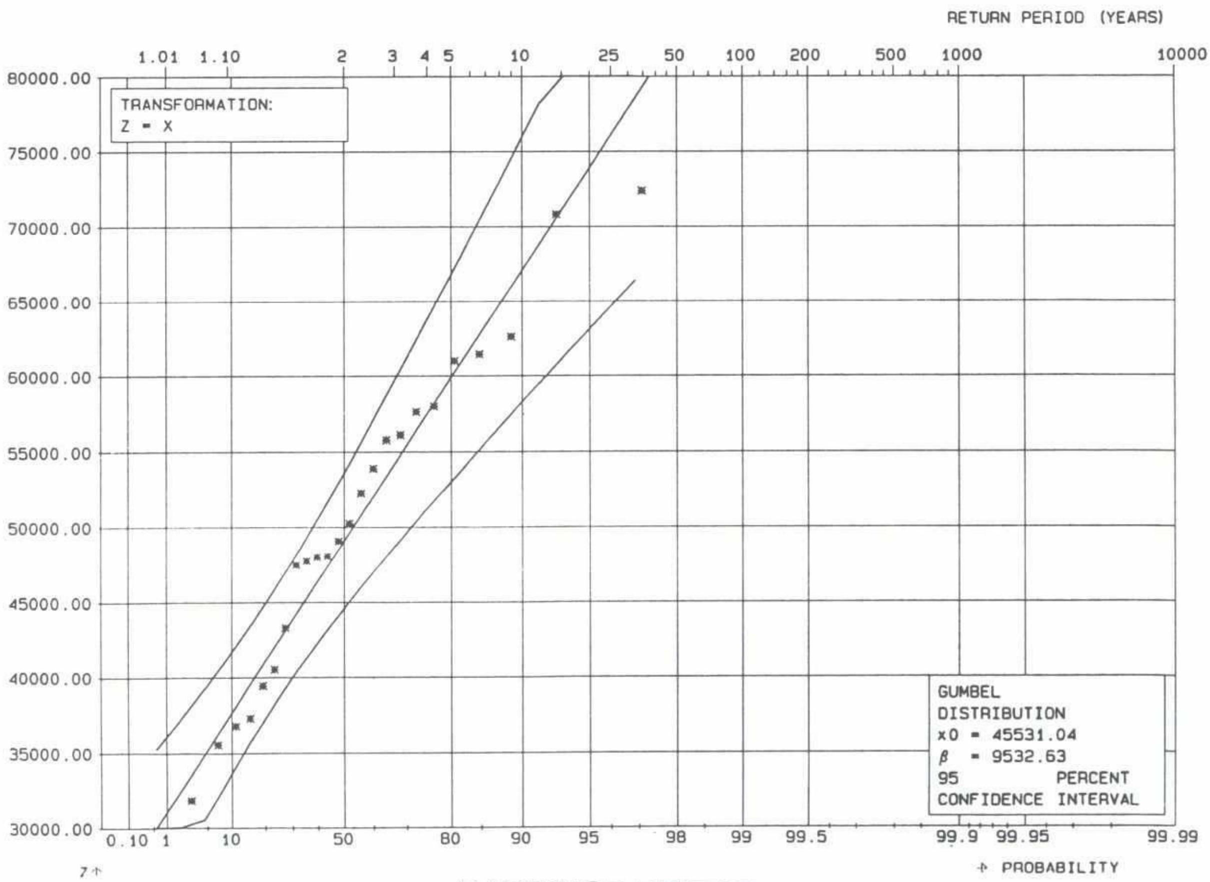
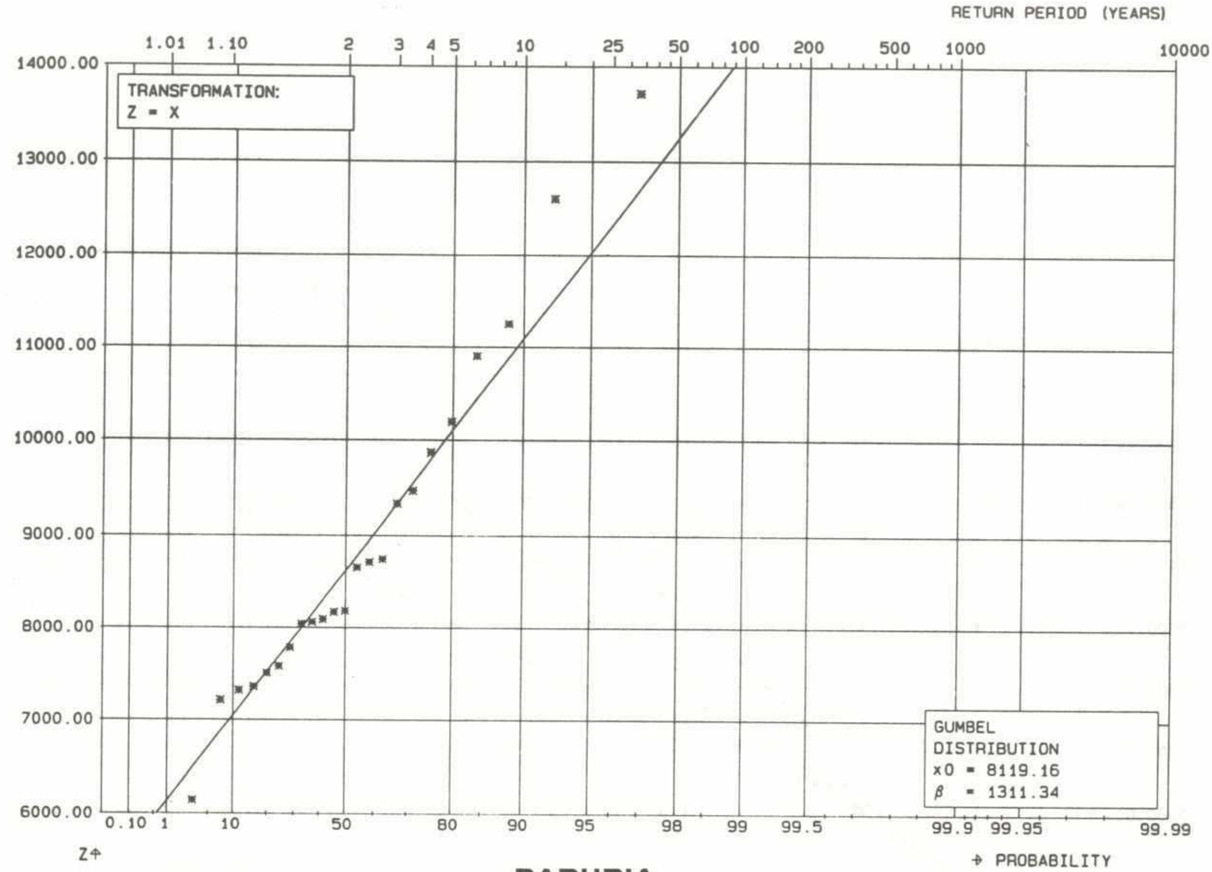


HARDINGE BRIDGE

PEAK DISCHARGE



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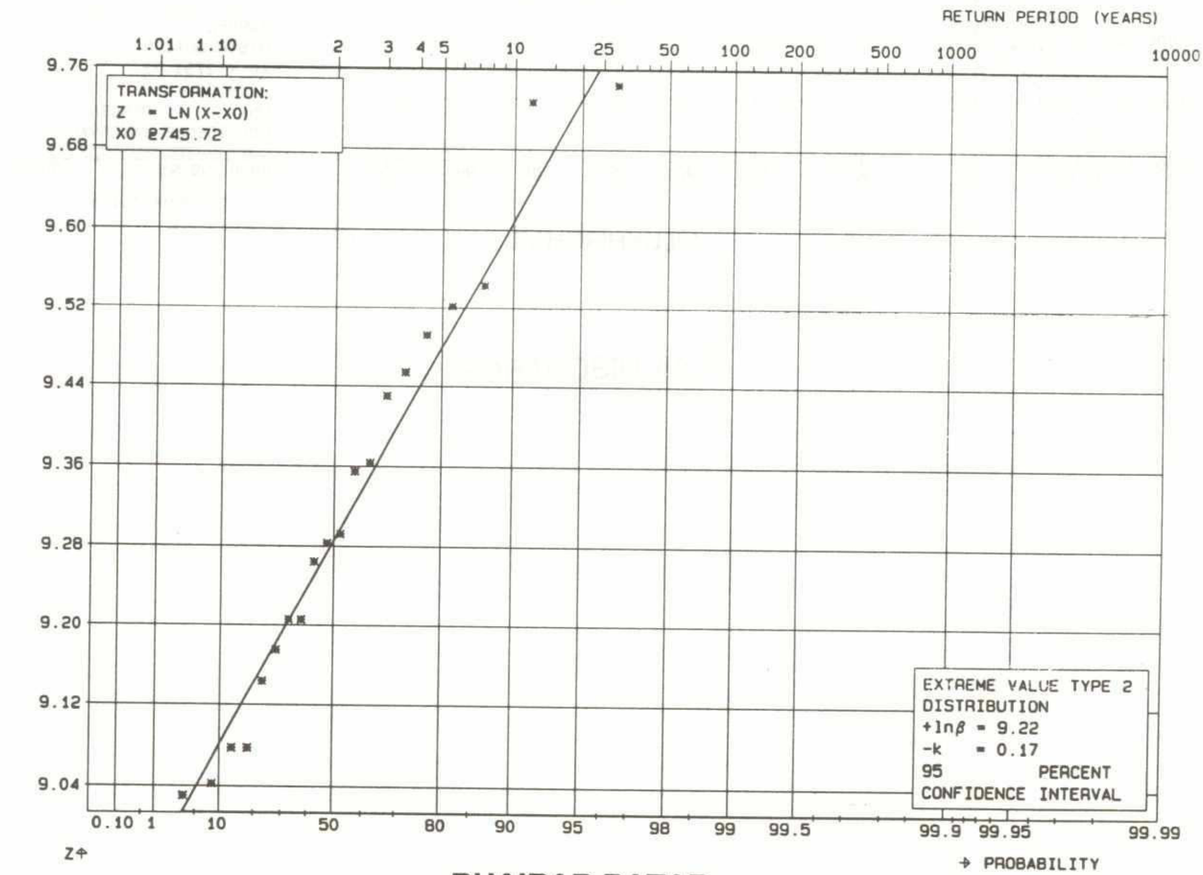
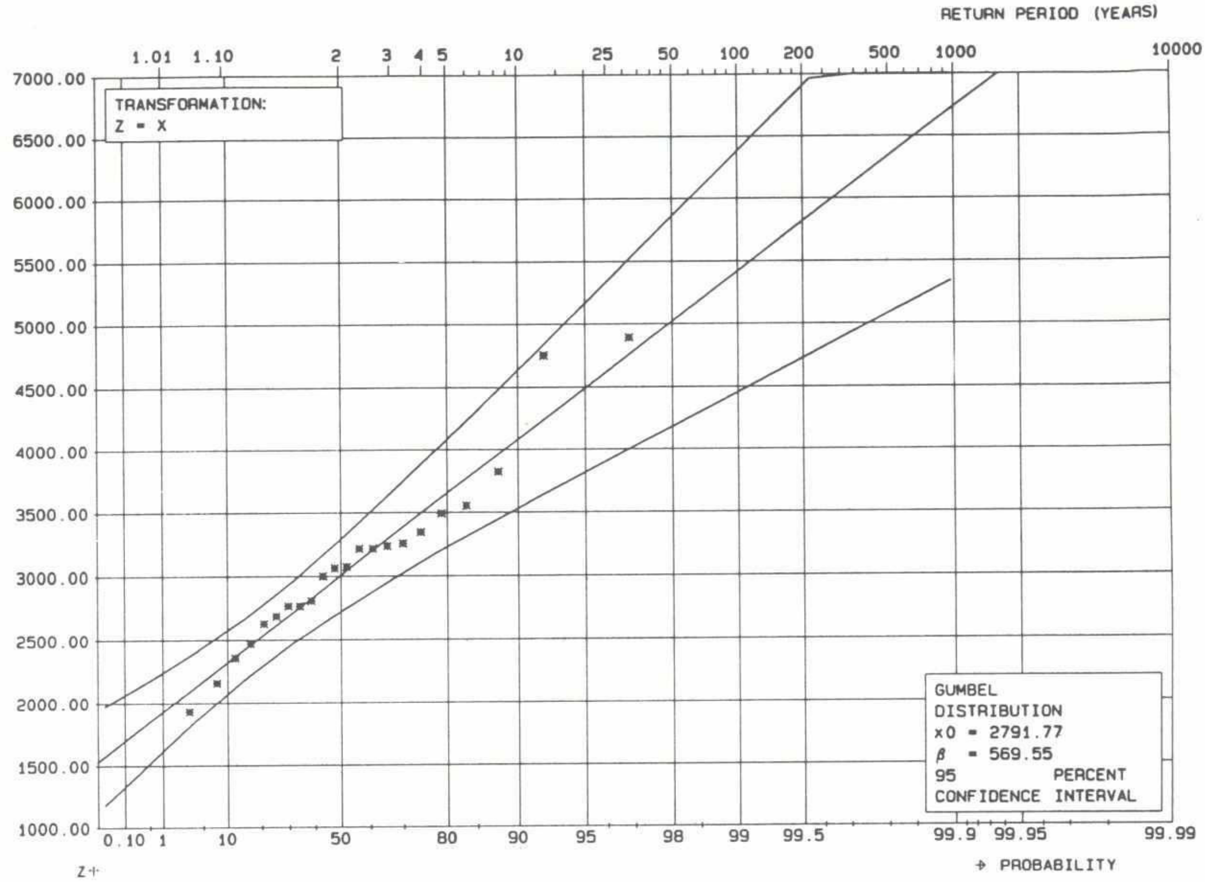


BHAIRAB BAZAR

PEAK DISCHARGE



NILUKHIRCHAR

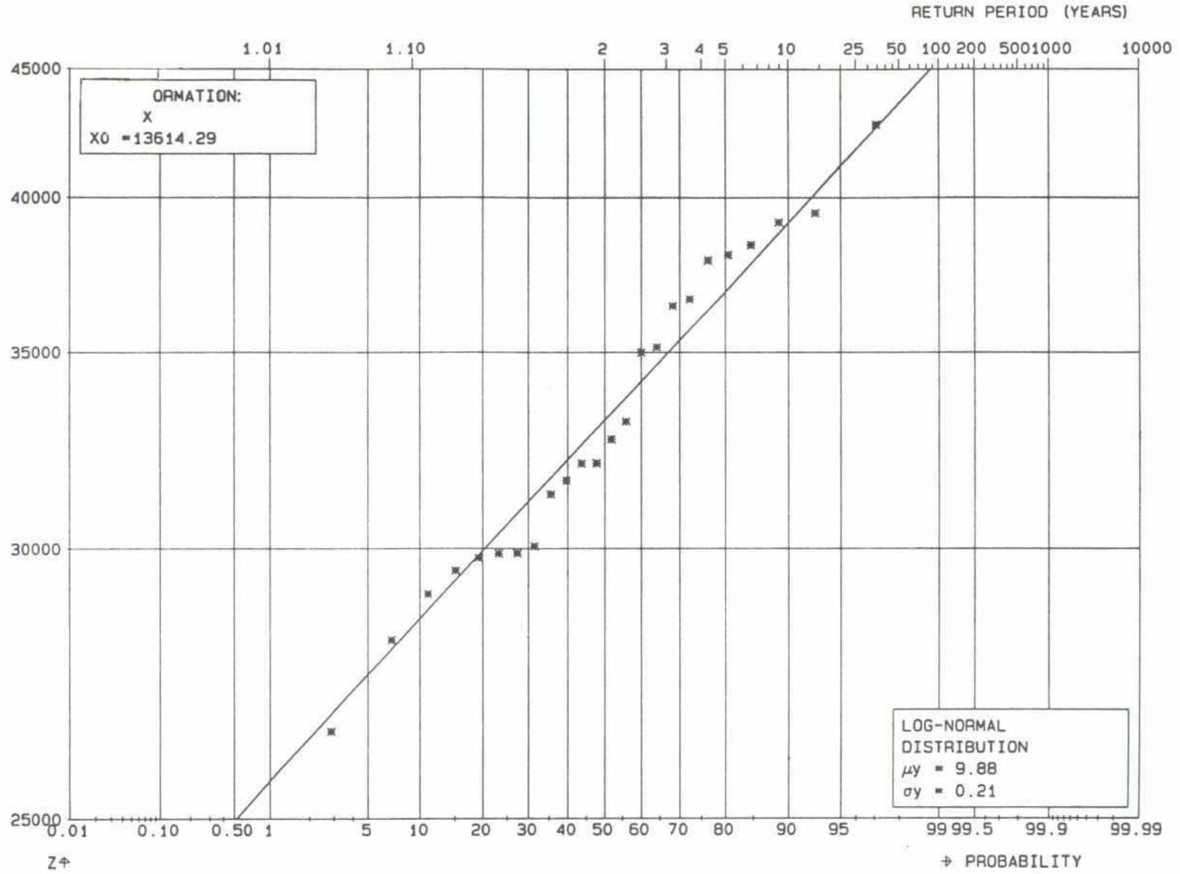
PEAK DISCHARGE

MEAN SEASONAL DISCHARGE

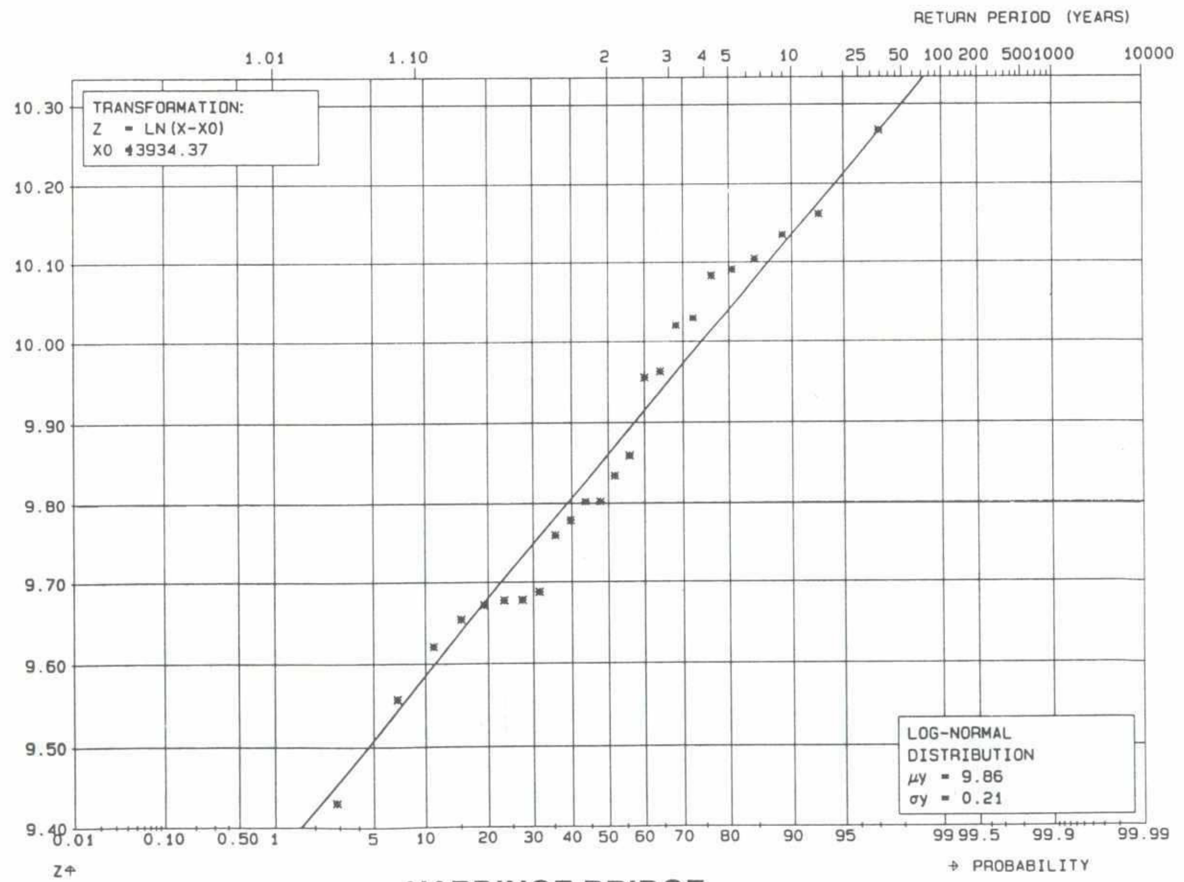
ESTIMATED (BY RATING CURVE) SEASONAL (MAY-OCTOBER) MEAN DISCHARGES AND RELATED RETURN PERIODS

RIVERS	JAMUNA		GANGES		PADMA		UPPER MEGHNA		OLD BRAHMAPUTRA	
STATIONS	BAHADURABAD		HARDINGE BR.		BARURIA		BHAIRAB BAZAR		NILUKHIRCHAR	
YEARS	PEAK	R.P	PEAK	R.P	PEAK	R.P	PEAK	R.P	PEAK	R.P
1965	31500	1.54	12300	1.03	(-)	(-)	7600	1.78	1400	3.72
1966	37800	6.85	13400	1.06	41600	1.21	9100	4.16	1700	18.16
1967	31200	1.47	17800	1.59	38000	1.05	6500	1.15	1200	1.80
1968	31900	1.65	17400	1.48	40300	1.13	7200	1.50	1400	2.95
1969	28000	1.09	20500	3.00	40700	1.15	6500	1.16	1200	1.84
1970	36600	4.73	18000	1.64	46800	2.06	8500	2.81	1500	4.59
1972	29800	1.25	14300	1.10	40400	1.14	6300	1.11	(-)	(-)
1973	29700	1.23	23700	11.46	48700	2.76	9100	4.00	(-)	(-)
1974	39100	10.23	20700	3.24	59700	36.83	10600	10.34	1700	15.32
1975	29800	1.25	23500	10.34	50800	4.02	(-)	(-)	1300	2.10
1976	29000	1.15	18300	1.75	42700	1.32	(-)	(-)	1200	1.84
1977	38300	8.00	20100	2.67	49000	2.90	(-)	(-)	1900	39.40
1978	30000	1.27	24800	21.97	48400	2.63	(-)	(-)	1200	1.69
1979	34900	3.06	11700	1.02	39000	1.08	(-)	(-)	1200	1.77
1980	38000	7.24	22600	6.83	53300	6.87	(-)	(-)	1400	2.67
1981	32500	1.83	19500	2.28	44600	1.57	(-)	(-)	1100	1.25
1982	29500	1.20	19000	2.02	44300	1.52	(-)	(-)	1000	1.11
1983	31900	1.65	18400	1.78	48800	2.80	(-)	(-)	1000	1.17
1984	35100	3.18	20600	3.14	54300	8.64	(-)	(-)	(-)	(-)
1985	33000	2.00	21900	5.05	52000	5.21	(-)	(-)	(-)	(-)
1986	26300	1.02	19500	2.26	41200	1.19	6400	1.12	800	1.03
1987	36400	4.45	21300	4.07	51400	4.57	8700	3.28	1300	1.92
1988	39800	11.40	20600	3.15	57200	18.23	12000	25.39	1400	2.66
1989	42700	36.50	15700	1.20	49300	3.08	(-)	(-)	900	1.06

Note : A Log-Normal distribution is used for all stations

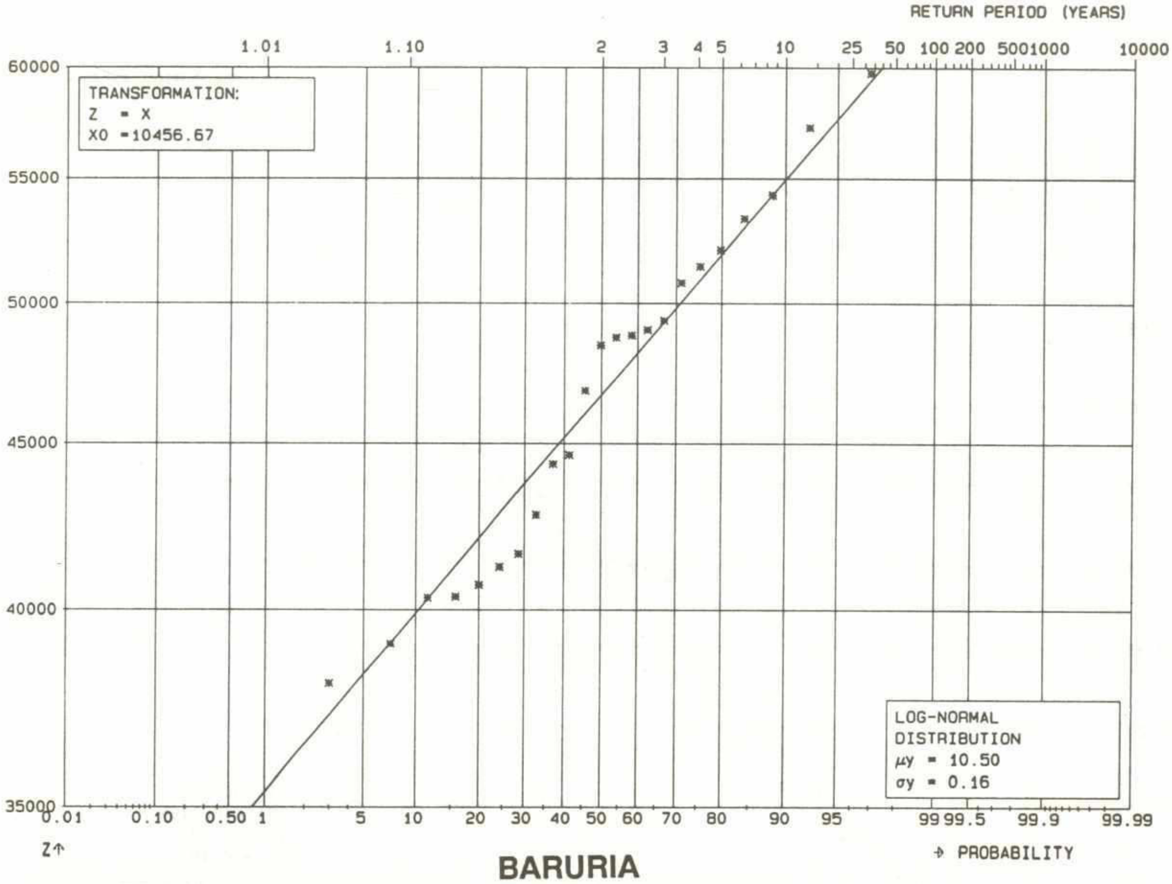


BAHADURABAD

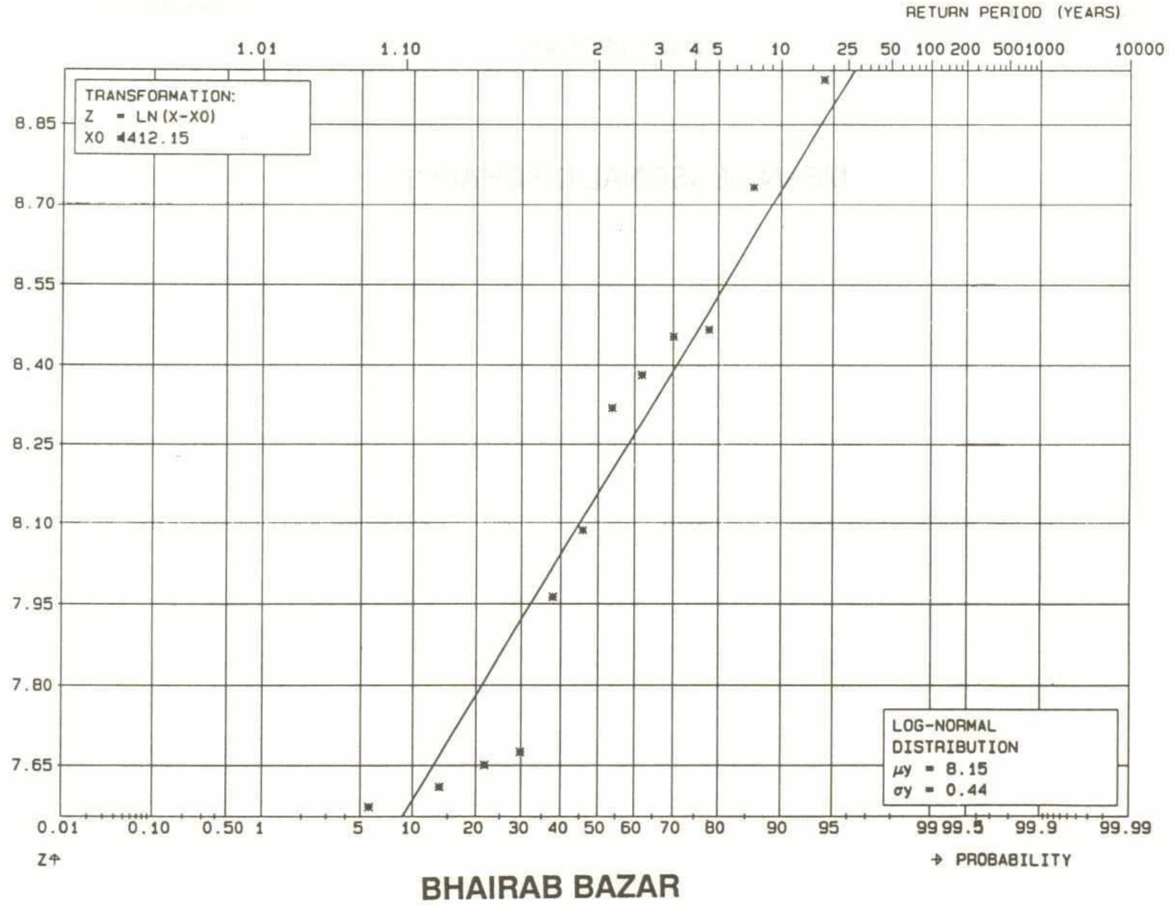


HARDINGE BRIDGE

MEAN SEASONAL DISCHARGE

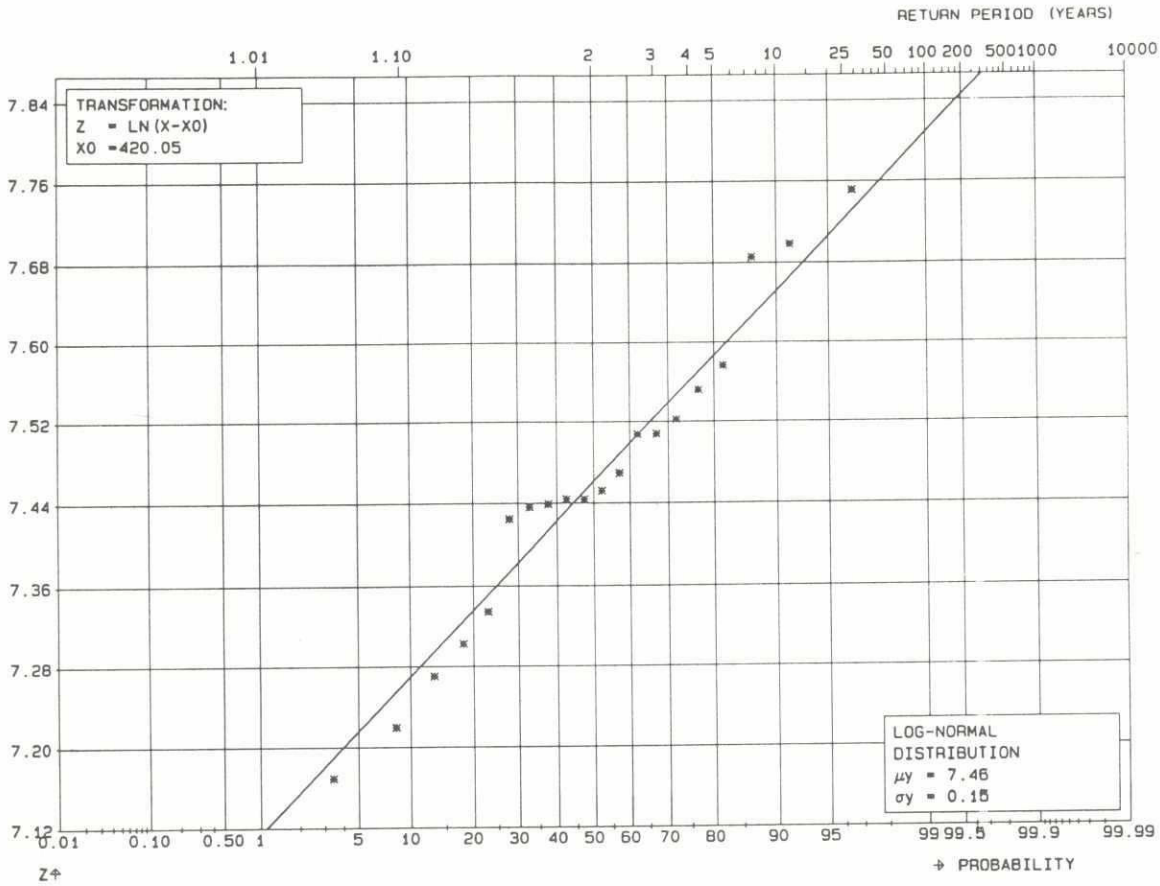


BARURIA



BHAIRAB BAZAR

MEAN SEASONAL DISCHARGE



NILUKHIRCHAR

MEAN SEASONAL DISCHARGE

mDL

APPENDIX 7

Statistical Error Analysis of FAP 25-GM Run

Appendix 7 presents statistical error analysis of FAP 25-GM 6th run. The discrepancies between observed and simulated peak and mean seasonal water level for a total of 20 stations are available at pages A.7-2 to A.7-14. Tables of statistical analysis for each of the stations showing errors at peak, seasonal, subseasonal values as well as maximum, minimum, average and standard deviation of those errors are shown in pages A.7-15 to A.7-36.

Discrepancies in peak discharges for 7 stations on the major river and important distributaries are shown in graphical form in pages A.7-37 to A.7-40. Statistical error analysis in tabular form are shown in pages A.7-41 to A.7-47. A Comparison of observed and simulated water level hydrographs for 1965-89 for the stations Baruria, Bhairab Bazar, Bahadurabad and Hardinge Bridge is available in pages A.7-48 to A.7-63.

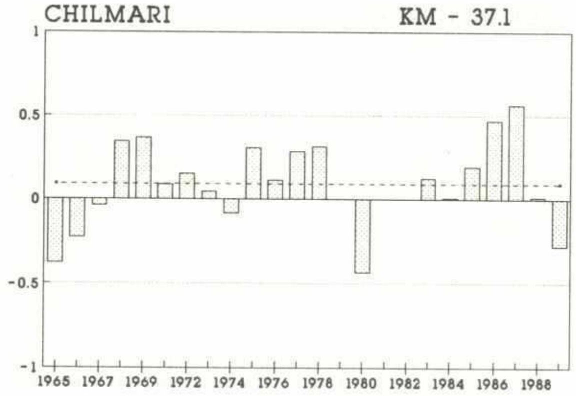
STATISTICAL ERROR ANALYSIS FOR WATER LEVELS

RIVER : JAMUNA

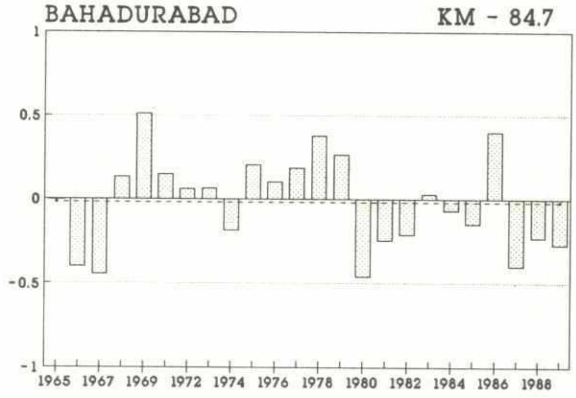
DISCREPANCIES IN PEAK WATER LEVEL
(OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value

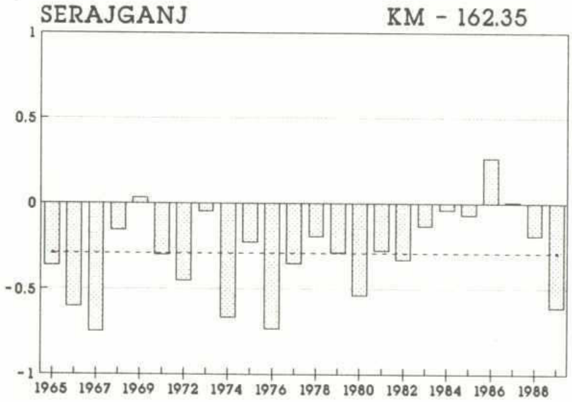
CHILMARI KM - 37.1



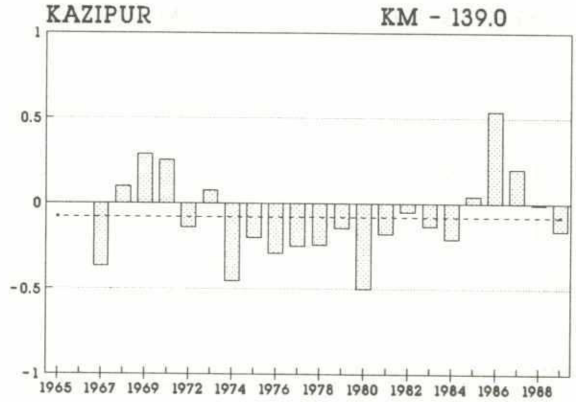
BAHADURABAD KM - 84.7



SERAJGANJ KM - 162.35



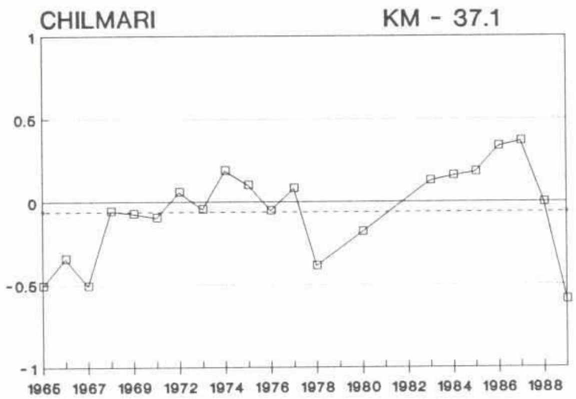
KAZIPUR KM - 139.0

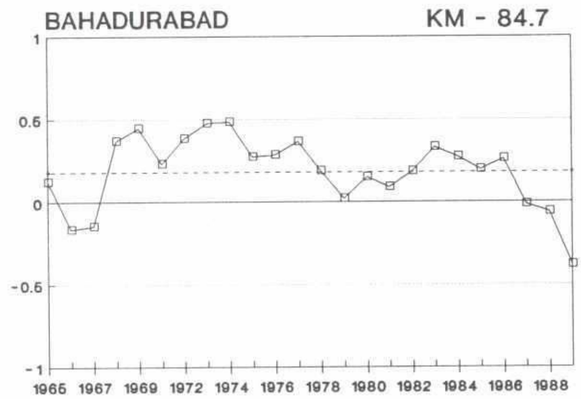


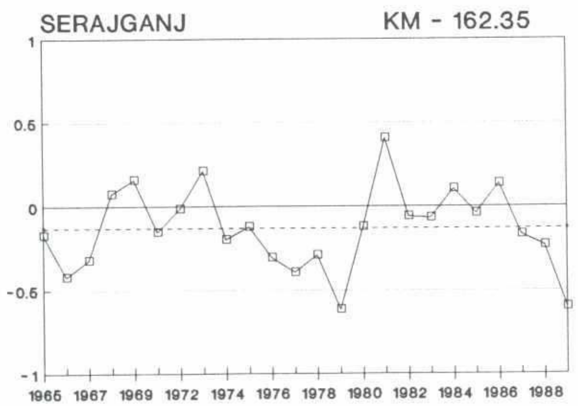
RIVER : JAMUNA

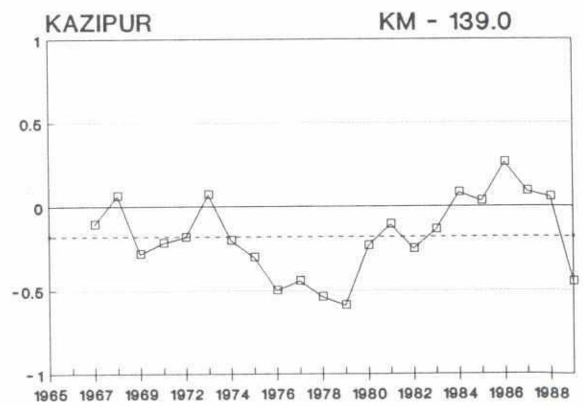
DISCREPANCIES IN MEAN SEASONAL
WATER LEVEL (OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value









RIVER : JAMUNA

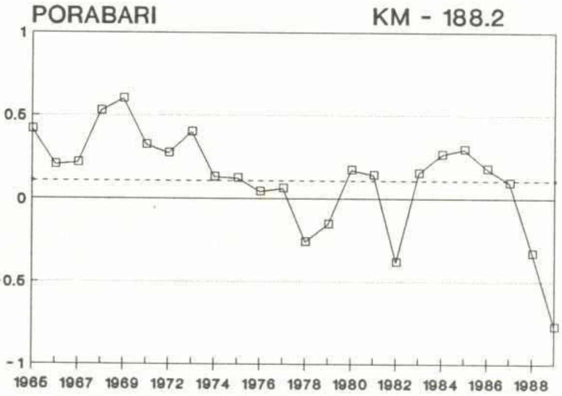
DISCREPANCIES IN WATER LEVEL
(OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value

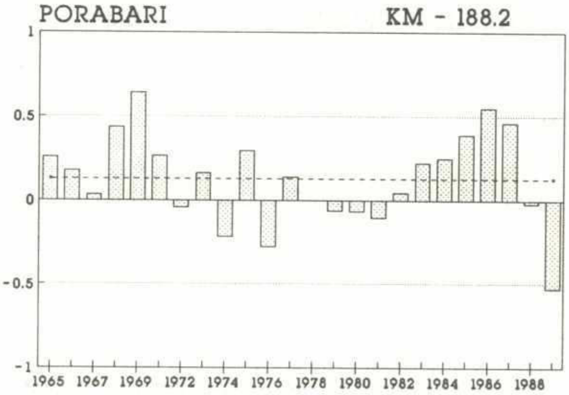
MEAN SEASONAL VALUE

ANNUAL PEAK VALUE

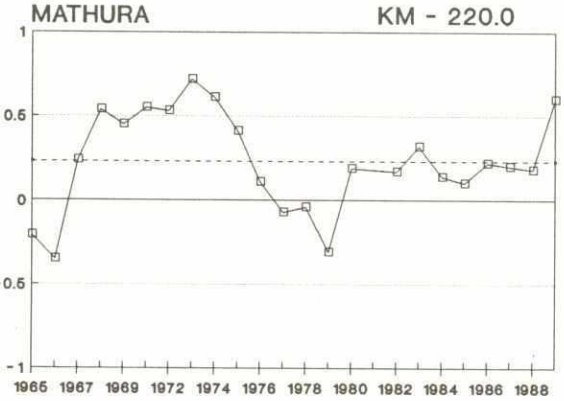
PORABARI KM - 188.2



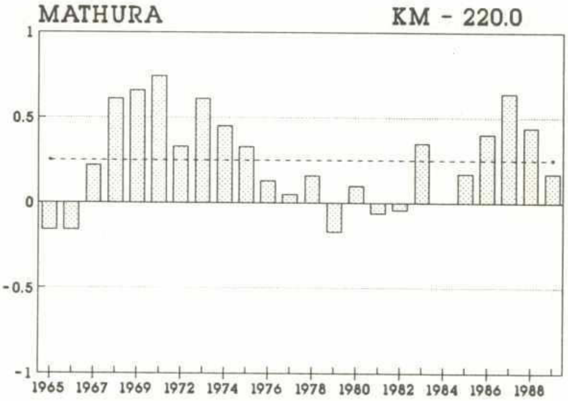
PORABARI KM - 188.2



MATHURA KM - 220.0



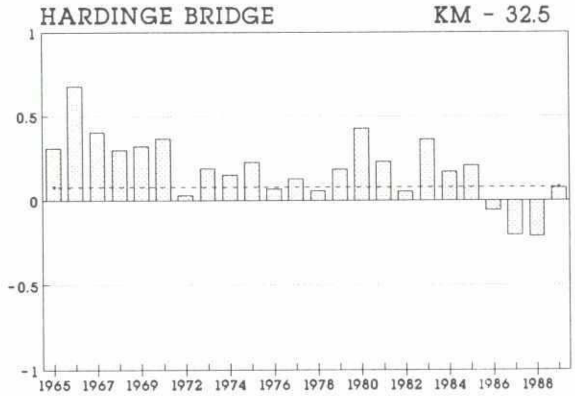
MATHURA KM - 220.0

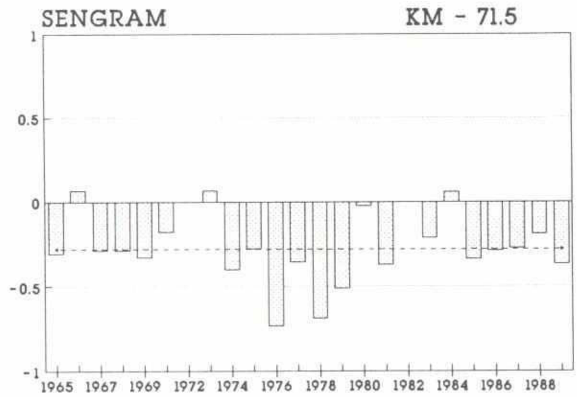


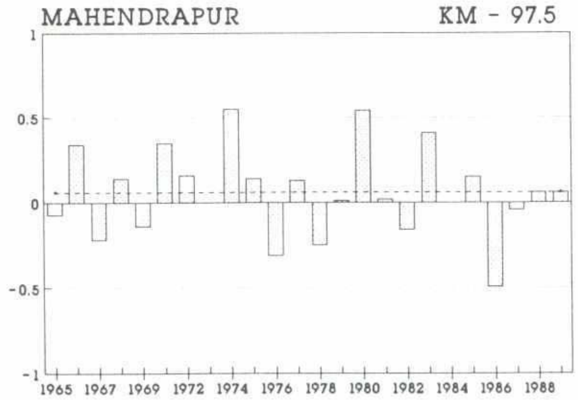
RIVER : GANGES

DISCREPANCIES IN PEAK WATER LEVEL
(OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value



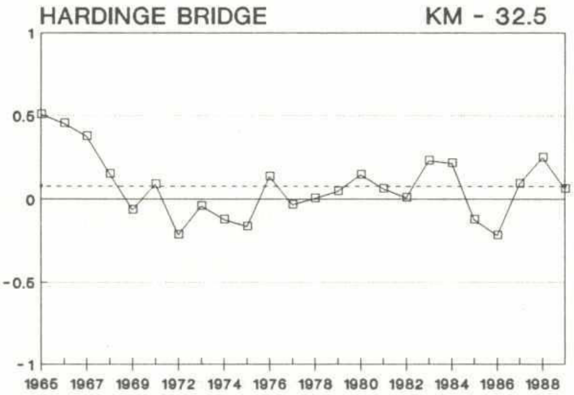


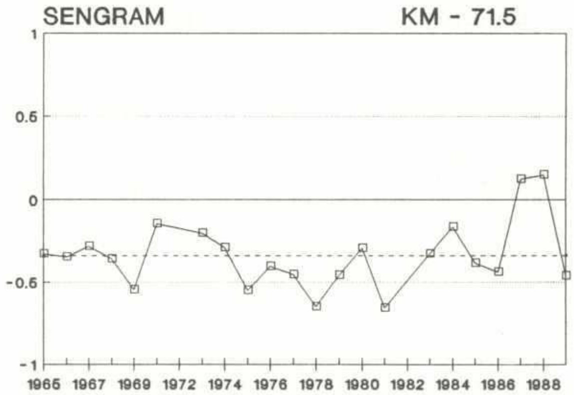


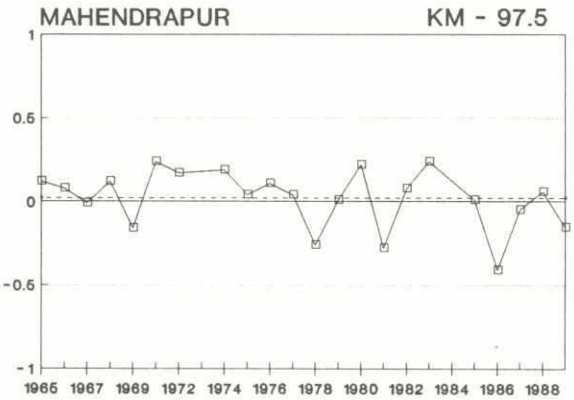
RIVER : GANGES

DISCREPANCIES IN MEAN SEASONAL
WATER LEVEL (OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value







200

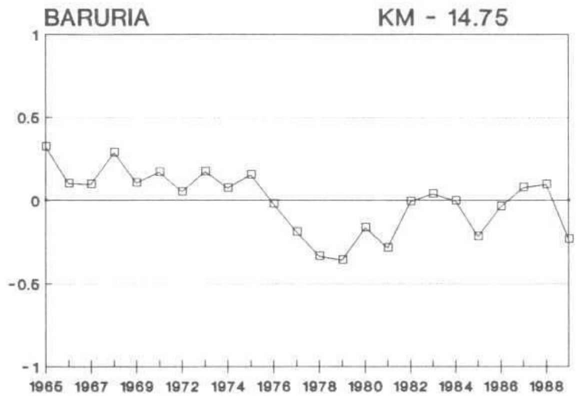
RIVER : PADMA

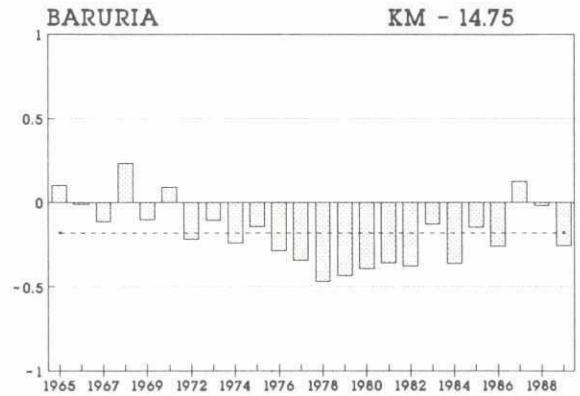
DISCREPANCIES IN WATER LEVEL
(OBSERVED-SIMULATED)

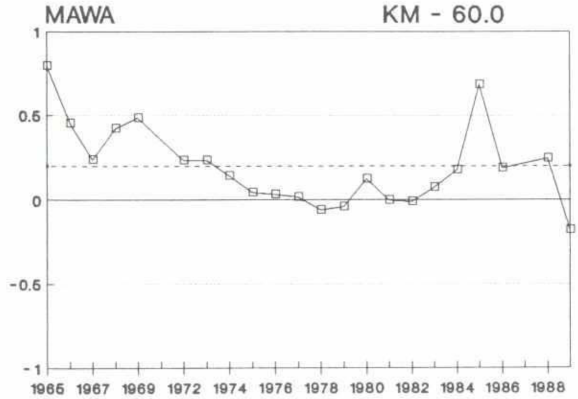
Legend :
Error in Meter
Broken Line = Mean Value

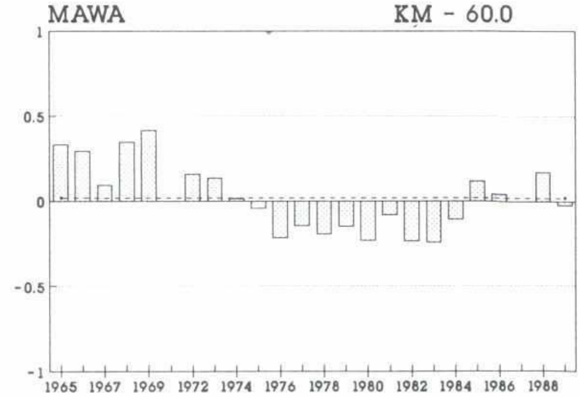
MEAN SEASONAL VALUE

ANNUAL PEAK VALUE







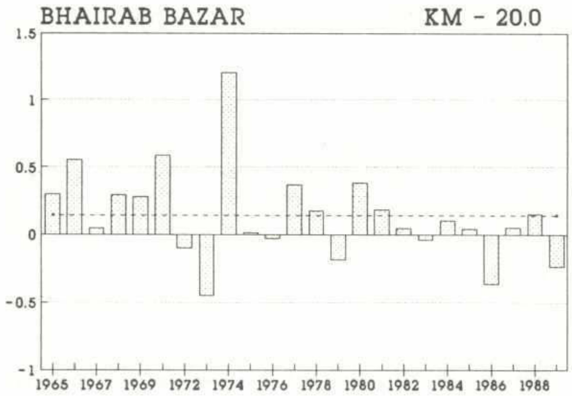


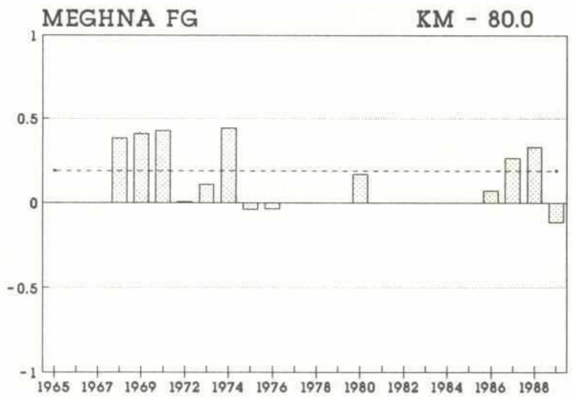
207

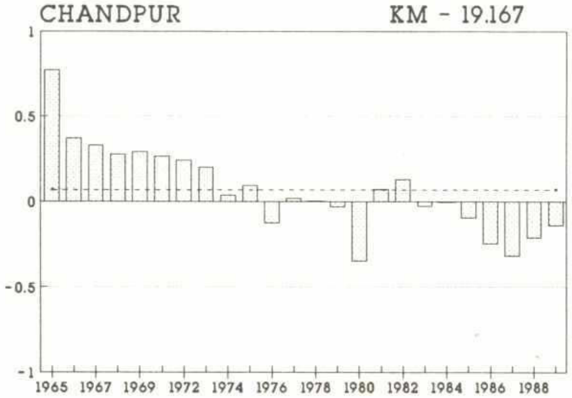
RIVER : MEGHNA

DISCREPANCIES IN PEAK WATER LEVEL
(OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value





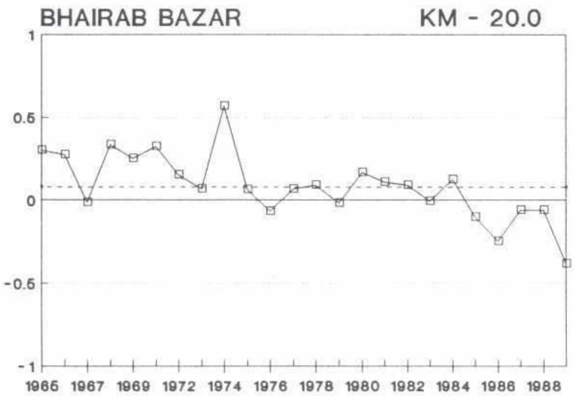


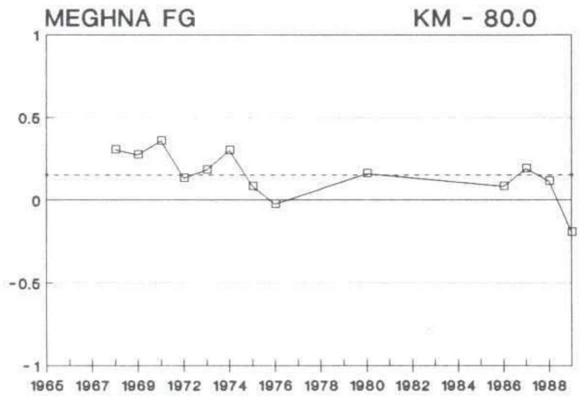
202

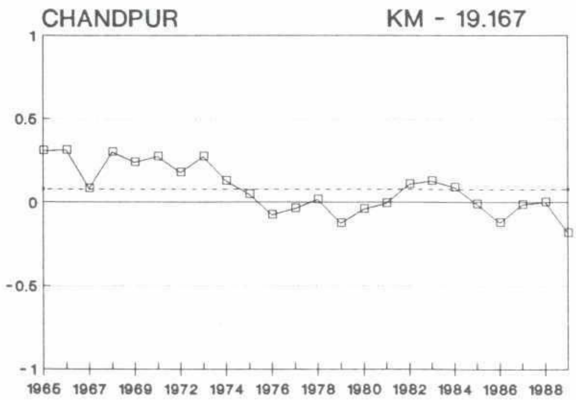
RIVER : MEGHNA

DISCREPANCIES IN MEAN SEASONAL
WATER LEVEL (OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value



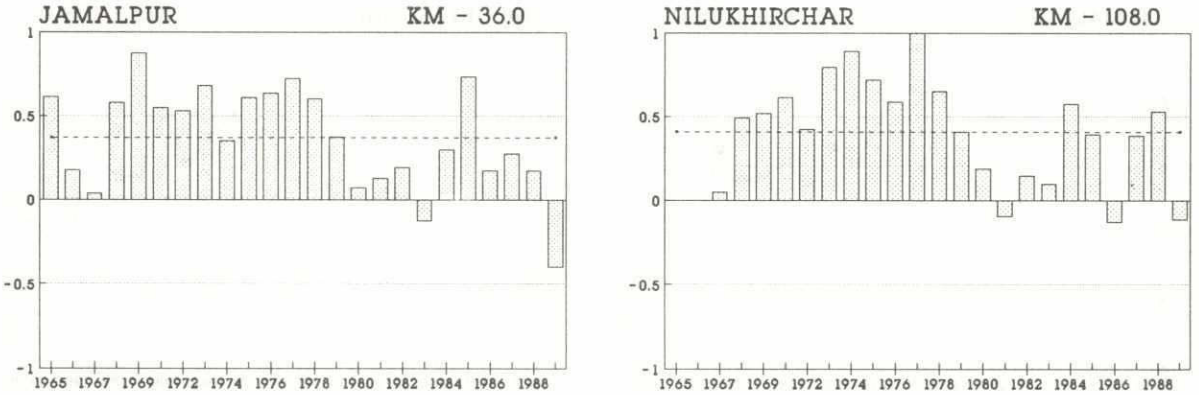


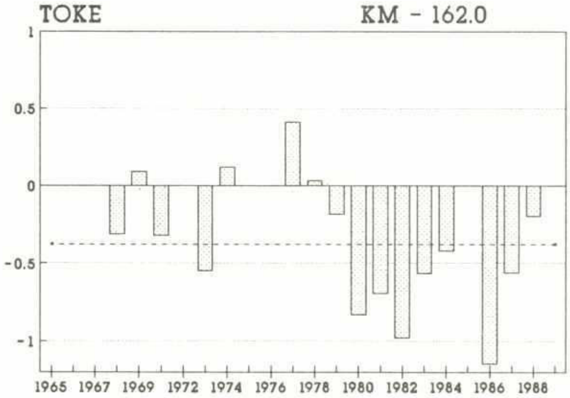


RIVER : OLD BRAHMAPUTRA

DISCREPANCIES IN PEAK WATER LEVEL
(OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value





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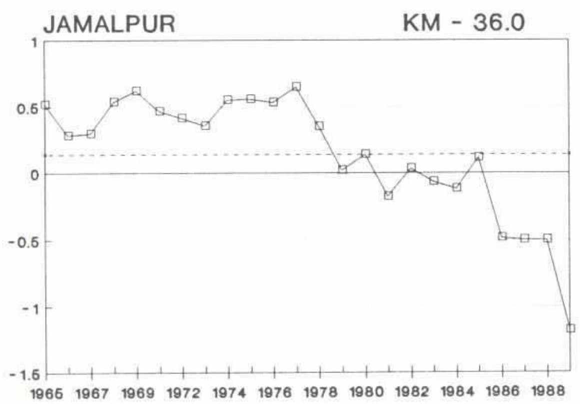
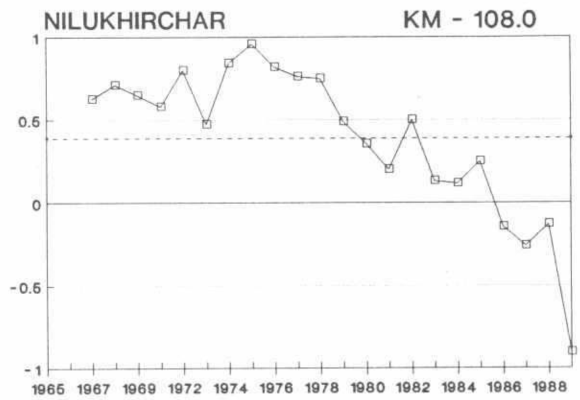
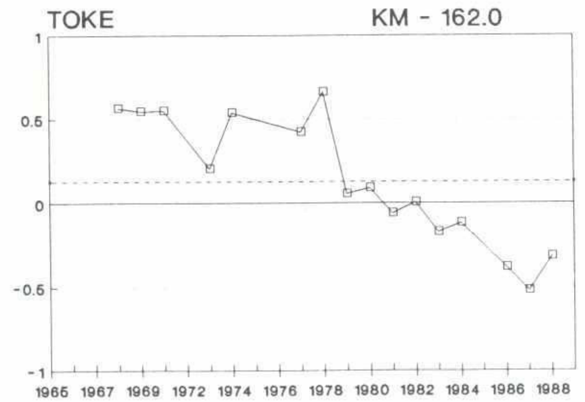
RIVER : OLD BRAHMAPUTRA

DISCREPANCIES IN MEAN SEASONAL WATER LEVEL (OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value







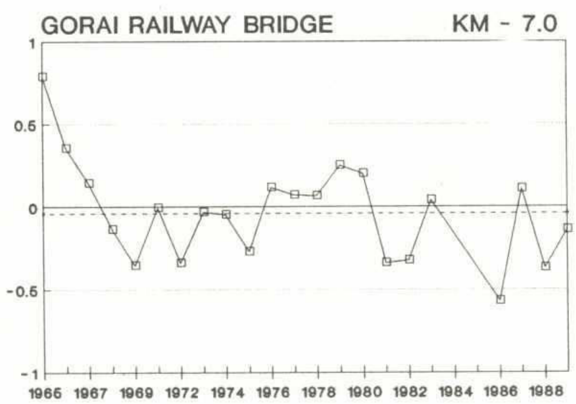
RIVER : GORAI

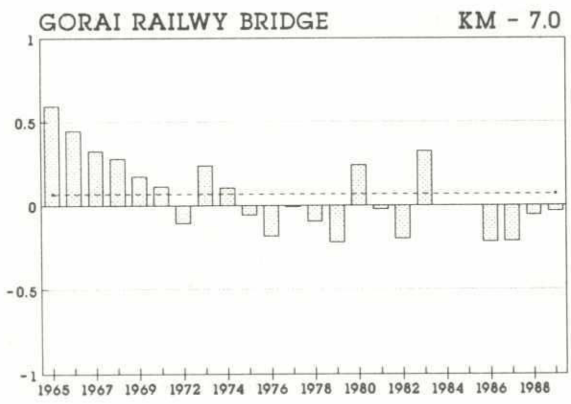
DISCREPANCIES IN WATER LEVEL
(OBSERVED-SIMULATED)

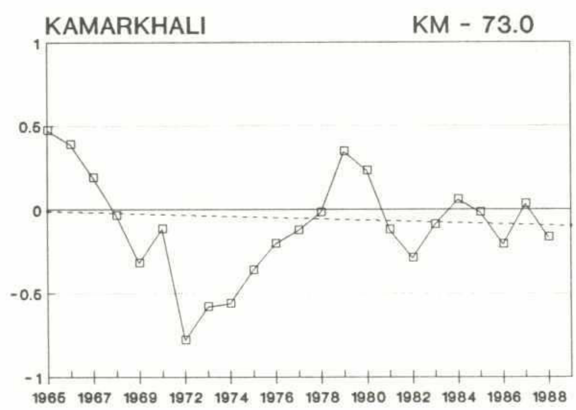
Legend :
Error in Meter
Broken Line = Mean Value

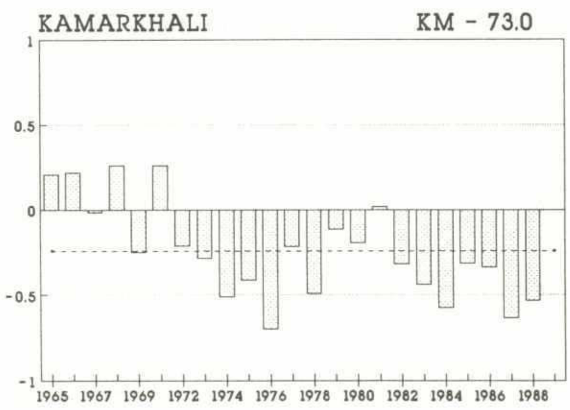
MEAN SEASONAL VALUE

ANNUAL PEAK VALUE









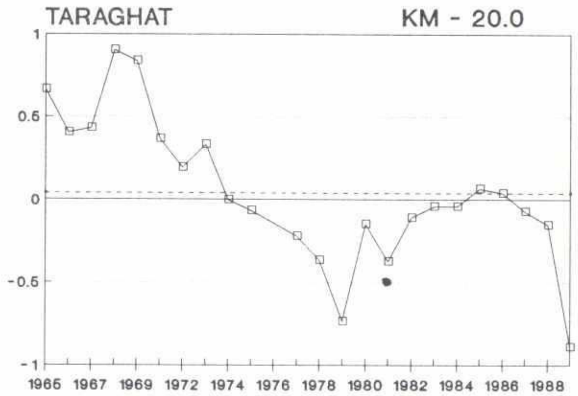
RIVER : DHALESWARI/LAKHYA

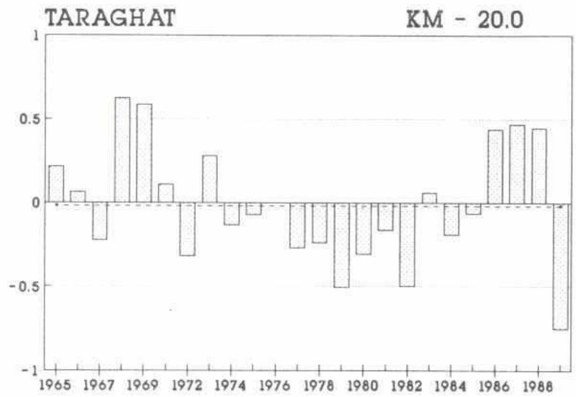
DISCREPANCIES IN WATER LEVEL
(OBSERVED-SIMULATED)

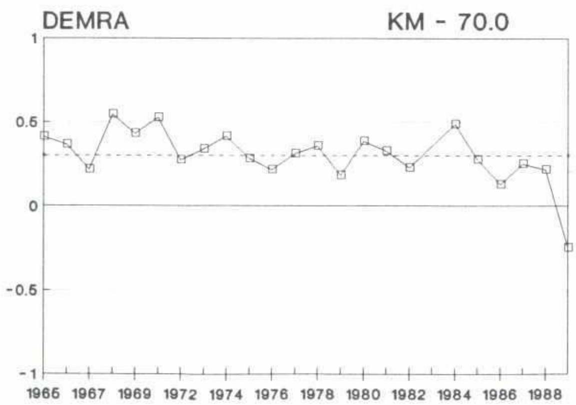
Legend :
Error in Meter
Broken Line = Mean Value

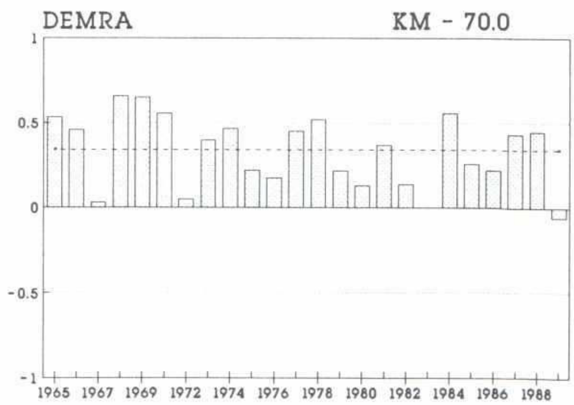
MEAN SEASONAL VALUE

ANNUAL PEAK VALUE









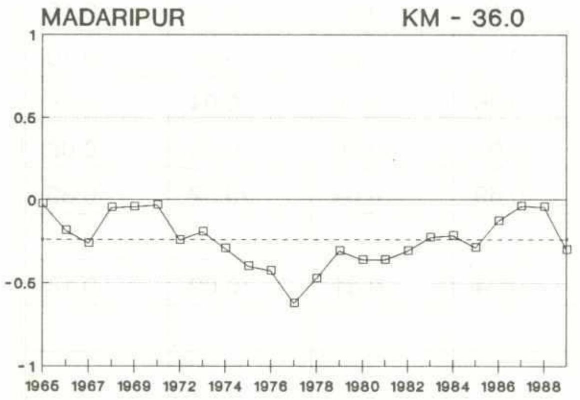
207

RIVER : ARIAL KHAN

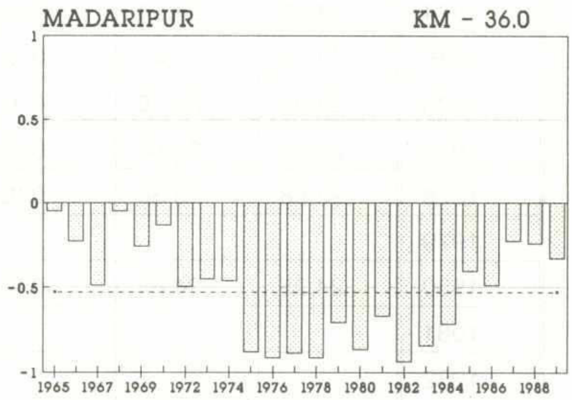
DISCREPANCIES IN WATER LEVEL
(OBSERVED-SIMULATED)

Legend :
Error in Meter
Broken Line = Mean Value

MEAN SEASONAL VALUE



ANNUAL PEAK VALUE



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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : JAMUNA
STATION : 45.5 CHILMARI

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	23.34	23.71	-0.38	-0.43	-0.50	-0.60	-0.51
1966	23.81	24.03	-0.23	-1.00	0.01	-0.05	-0.34
1967	23.97	24.00	-0.04	-0.97	-0.18	-0.38	-0.51
1968	24.04	23.70	0.34	-0.18	0.05	-0.03	-0.05
1969	23.79	23.42	0.37	-0.33	0.17	-0.06	-0.07
1970	24.19	24.10	0.09	-0.26	0.06	-0.08	-0.09
1972	24.09	23.94	0.15	0.13	0.03	0.02	0.06
1973	23.88	23.83	0.05	-0.12	0.16	-0.17	-0.04
1974	24.46	24.54	-0.08	0.19	0.27	0.11	0.19
1975	23.78	23.47	0.31	-0.17	0.25	0.22	0.10
1976	23.90	23.78	0.11	-0.36	0.16	0.04	-0.05
1977	24.11	23.83	0.28	0.01	0.20	0.03	0.08
1978	23.68	23.36	0.32	-0.69	0.04	-0.52	-0.39
1979							
1980	24.25	24.68	-0.43	-0.24	-0.31	0.02	-0.18
1981							
1982							
1983	24.04	23.92	0.13	-0.05	0.27	0.17	0.13
1984	24.25	24.24	0.01	0.12	0.17	0.19	0.16
1985	23.92	23.73	0.19	0.08	0.24	0.22	0.18
1986	23.44	22.97	0.47	0.27	0.39	0.34	0.33
1987	24.69	24.13	0.57	0.39	0.55	0.15	0.36
1988	25.04	25.03	0.01	-0.23	0.10	0.12	-0.00
1989	23.58	23.86	-0.28	-0.76	-0.41	-0.62	-0.59
AVG	24.01	23.92	0.09	-0.22	0.08	-0.04	-0.06
STD	0.39	0.45	0.26	0.38	0.25	0.27	0.27
MAX	25.04	25.03	0.57	0.39	0.55	0.34	0.36
MIN	23.34	22.97	-0.43	-1.00	-0.50	-0.62	-0.59

NOTES :
1. AVG1 = Mean relative errors for period May-June.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

20?

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : JAMUNA
STATION : 46.9L BAHADURABAD

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	19.69	19.69	-0.00	0.09	0.09	0.20	0.12
1966	19.62	20.01	-0.40	-0.28	-0.05	-0.16	-0.16
1967	19.50	19.94	-0.45	-0.16	-0.18	-0.10	-0.14
1968	19.80	19.66	0.13	0.30	0.37	0.45	0.37
1969	19.84	19.33	0.51	0.23	0.67	0.45	0.45
1970	20.20	20.05	0.15	0.15	0.29	0.26	0.23
1972	19.98	19.92	0.06	0.33	0.39	0.44	0.38
1973	19.88	19.82	0.06	0.34	0.53	0.57	0.48
1974	20.26	20.44	-0.18	0.60	0.28	0.58	0.49
1975	19.60	19.39	0.21	0.02	0.45	0.35	0.27
1976	19.87	19.76	0.10	0.17	0.37	0.32	0.29
1977	19.99	19.81	0.18	0.35	0.39	0.36	0.37
1978	19.63	19.25	0.38	0.02	0.39	0.16	0.19
1979	19.78	19.52	0.27	-0.17	0.12	0.10	0.02
1980	20.10	20.56	-0.46	0.21	-0.10	0.35	0.15
1981	19.48	19.73	-0.25	0.12	-0.02	0.18	0.09
1982	19.42	19.63	-0.21	0.15	0.17	0.24	0.19
1983	19.92	19.89	0.03	0.18	0.47	0.35	0.33
1984	20.10	20.17	-0.07	0.28	0.26	0.28	0.27
1985	19.61	19.76	-0.15	0.18	0.15	0.26	0.20
1986	19.15	18.75	0.40	0.08	0.35	0.35	0.26
1987	19.68	20.08	-0.40	-0.00	-0.10	0.07	-0.01
1988	20.61	20.84	-0.23	-0.07	-0.12	0.01	-0.06
1989	19.57	19.84	-0.27	-0.42	-0.37	-0.36	-0.38
AVG	19.80	19.83	-0.02	0.11	0.20	0.24	0.18
STD	0.31	0.43	0.27	0.22	0.25	0.22	0.21
MAX	20.61	20.84	0.51	0.60	0.67	0.58	0.49
MIN	19.15	18.75	-0.46	-0.42	-0.37	-0.36	-0.38

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : JAMUNA
STATION : 49A KAZIPUR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965							
1966							
1967	15.46	15.82	-0.37	-0.05	-0.23	-0.04	-0.11
1968	15.62	15.52	0.10	0.49	-0.05	-0.25	0.06
1969	15.52	15.23	0.29	-0.63	-0.02	-0.20	-0.28
1970	16.20	15.94	0.26	-0.29	-0.03	-0.34	-0.22
1972	15.65	15.78	-0.14	-0.13	-0.24	-0.18	-0.18
1973	15.77	15.69	0.08	0.46	0.01	-0.26	0.07
1974	15.90	16.35	-0.45	-0.31	-0.16	-0.13	-0.20
1975	15.07	15.27	-0.20	-0.28	-0.30	-0.32	-0.30
1976	15.35	15.64	-0.29	-0.64	-0.30	-0.65	-0.50
1977	15.42	15.67	-0.25	-0.69	-0.28	-0.36	-0.44
1978	14.91	15.16	-0.24	-0.63	-0.39	-0.61	-0.54
1979	15.25	15.39	-0.15	-0.72	-0.57	-0.47	-0.59
1980	15.99	16.48	-0.50	-0.37	-0.35	0.01	-0.23
1981	15.41	15.58	-0.18	0.04	-0.16	-0.19	-0.11
1982	15.43	15.48	-0.05	-0.42	-0.28	-0.05	-0.25
1983	15.61	15.74	-0.13	-0.28	-0.20	0.07	-0.14
1984	15.87	16.08	-0.21	0.11	0.05	0.10	0.08
1985	15.69	15.64	0.04	-0.09	0.05	0.14	0.03
1986	15.39	14.86	0.54	0.10	0.34	0.35	0.26
1987	16.18	15.98	0.20	0.01	0.14	0.13	0.09
1988	16.76	16.77	-0.01	-0.13	0.20	0.09	0.05
1989	15.54	15.70	-0.16	-0.64	-0.29	-0.42	-0.45
AVG	15.63	15.72	-0.08	-0.23	-0.14	-0.16	-0.18
STD	0.40	0.43	0.25	0.34	0.21	0.25	0.23
MAX	16.76	16.77	0.54	0.49	0.34	0.35	0.26
MIN	14.91	14.86	-0.50	-0.72	-0.57	-0.65	-0.59

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : JAMUNA
STATION : 49 SERAJGANJ

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	13.77	14.13	-0.36	-0.15	-0.41	0.05	-0.17
1966	13.87	14.47	-0.60	-0.57	-0.47	-0.22	-0.42
1967	13.64	14.38	-0.75	-0.29	-0.44	-0.23	-0.32
1968	13.94	14.10	-0.16	0.10	0.00	0.12	0.07
1969	13.82	13.79	0.03	0.06	0.10	0.32	0.16
1970	14.22	14.52	-0.30	-0.23	-0.20	-0.02	-0.15
1972	13.90	14.35	-0.45	-0.00	-0.19	0.15	-0.01
1973	14.22	14.27	-0.05	0.05	0.27	0.32	0.21
1974	14.24	14.90	-0.67	-0.22	-0.29	-0.09	-0.20
1975	13.60	13.83	-0.23	-0.06	-0.23	-0.07	-0.12
1976	13.46	14.19	-0.73	-0.53	-0.35	-0.03	-0.30
1977	13.90	14.25	-0.35	-0.51	-0.37	-0.31	-0.39
1978	13.52	13.71	-0.19	-0.60	-0.02	-0.26	-0.29
1979	13.67	13.96	-0.29	-0.62	-0.60	-0.63	-0.62
1980	14.50	15.03	-0.54	-0.15	-0.32	0.12	-0.12
1981	13.87	14.15	-0.28	1.14	-0.34	-0.09	0.41
1982	13.73	14.06	-0.33	0.00	-0.22	0.04	-0.06
1983	14.19	14.32	-0.13	-0.17	-0.13	0.10	-0.07
1984	14.62	14.66	-0.04	-0.05	0.08	0.29	0.10
1985	14.14	14.21	-0.07	-0.16	-0.03	0.07	-0.04
1986	13.66	13.39	0.27	-0.08	0.25	0.23	0.13
1987	14.57	14.56	0.01	-0.40	-0.09	-0.00	-0.17
1988	15.11	15.30	-0.19	-0.51	-0.19	0.00	-0.23
1989	13.65	14.26	-0.61	-0.83	-0.53	-0.44	-0.60
AVG	13.99	14.28	-0.29	-0.20	-0.20	-0.02	-0.13
STD	0.40	0.41	0.26	0.38	0.23	0.23	0.24
MAX	15.11	15.30	0.27	1.14	0.27	0.32	0.41
MIN	13.46	13.39	-0.75	-0.83	-0.60	-0.63	-0.62

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : JAMUNA
STATION : 50 PORABARI

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	12.24	11.98	0.26	0.40	0.16	0.70	0.42
1966	12.49	12.31	0.18	0.05	0.13	0.43	0.20
1967	12.19	12.16	0.04	-0.19	0.29	0.54	0.21
1968	12.40	11.96	0.44	0.33	0.52	0.73	0.53
1969	12.31	11.66	0.64	0.32	0.72	0.76	0.60
1970	12.61	12.34	0.27	0.09	0.36	0.52	0.32
1972	12.12	12.16	-0.04	0.22	0.08	0.53	0.27
1973	12.30	12.14	0.16	0.40	0.39	0.41	0.40
1974	12.54	12.75	-0.21	0.24	0.10	0.05	0.13
1975	12.06	11.76	0.29	-0.18	0.30	0.25	0.12
1976	11.68	11.96	-0.28	-0.06	-0.03	0.22	0.04
1977	12.28	12.14	0.14	0.22	0.03	-0.06	0.06
1978	11.55	11.55	-0.00	-0.57	-0.01	-0.20	-0.26
1979	11.74	11.80	-0.06	0.03	-0.31	-0.17	-0.15
1980	12.81	12.87	-0.06	0.33	0.04	0.15	0.17
1981	11.83	11.93	-0.10	0.32	-0.14	0.25	0.14
1982	12.00	11.95	0.05	0.01	-1.29	0.15	-0.38
1983	12.41	12.19	0.22	-0.22	0.27	0.41	0.16
1984	12.77	12.52	0.25	0.16	0.27	0.36	0.27
1985	12.44	12.05	0.39	0.45	0.29	0.15	0.30
1986	11.90	11.35	0.55	-0.37	0.46	0.45	0.18
1987	12.88	12.42	0.46	0.05	0.21	0.04	0.10
1988	13.14	13.16	-0.02	-0.53	-0.21	-0.24	-0.33
1989	11.53	12.06	-0.53	-0.88	-0.70	-0.66	-0.74
AVG	12.26	12.13	0.13	0.03	0.08	0.24	0.12
STD	0.42	0.40	0.27	0.34	0.41	0.34	0.30
MAX	13.14	13.16	0.64	0.45	0.72	0.76	0.60
MIN	11.53	11.35	-0.53	-0.88	-1.29	-0.66	-0.74

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : JAMUNA
STATION : 50.3 MATHURA

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	9.45	9.61	-0.16	-0.43	-0.18	-0.03	-0.21
1966	9.84	10.00	-0.16	-0.76	-0.18	-0.12	-0.35
1967	9.91	9.68	0.22	-0.10	0.40	0.43	0.24
1968	10.27	9.66	0.61	0.24	0.64	0.73	0.54
1969	10.08	9.42	0.66	0.04	0.61	0.70	0.45
1970	10.67	9.93	0.74	0.20	0.67	0.79	0.55
1972	9.98	9.65	0.33	0.37	0.51	0.72	0.53
1973	10.49	9.88	0.61	0.54	0.86	0.75	0.72
1974	10.87	10.42	0.45	0.67	0.61	0.55	0.61
1975	10.01	9.68	0.33	0.40	0.40	0.43	0.41
1976	9.60	9.47	0.13	-0.10	0.11	0.32	0.11
1977	9.97	9.92	0.05	-0.22	0.14	-0.12	-0.07
1978	9.53	9.37	0.16	-0.24	0.05	0.07	-0.04
1979	9.36	9.53	-0.17	-0.35	-0.35	-0.24	-0.31
1980	10.67	10.57	0.10	0.08	0.09	0.39	0.19
1981	9.63	9.69	-0.06			0.00	
1982	9.74	9.78	-0.04	0.02	0.22	0.26	0.17
1983	10.36	10.01	0.35	0.13	0.38	0.44	0.32
1984	10.25	10.25	-0.00	0.06	0.13	0.23	0.14
1985	9.92	9.75	0.17	-0.15	0.15	0.30	0.10
1986	9.70	9.30	0.40	0.00	0.32	0.34	0.22
1987	10.88	10.24	0.64	-0.10	0.35	0.34	0.20
1988	11.35	10.91	0.44	-0.12	0.34	0.32	0.18
1989	9.71	9.54	0.17	1.39	0.61	-0.21	0.60
AVG	10.09	9.84	0.25	0.07	0.30	0.31	0.23
STD	0.50	0.39	0.27	0.42	0.30	0.31	0.29
MAX	11.35	10.91	0.74	1.39	0.86	0.79	0.72
MIN	9.36	9.30	-0.17	-0.76	-0.35	-0.24	-0.35

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : GANGES
STATION : 90 HARDINGE BRIDGE

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	13.72	13.41	0.31	0.20	0.66	0.65	0.51
1966	14.28	13.60	0.68	0.01	0.61	0.74	0.45
1967	14.44	14.03	0.41	0.17	0.40	0.56	0.38
1968	14.04	13.74	0.30	0.00	0.18	0.28	0.15
1969	14.68	14.36	0.32	-0.32	0.07	0.06	-0.06
1970	13.92	13.55	0.37	-0.21	0.21	0.26	0.09
1972	13.40	13.37	0.03	-0.47	-0.11	-0.05	-0.21
1973	14.18	13.99	0.19	-0.36	0.15	0.10	-0.04
1974	14.39	14.24	0.15	-0.41	0.02	0.02	-0.12
1975	14.31	14.08	0.23	-0.41	0.01	-0.10	-0.17
1976	14.64	14.57	0.07	0.22	0.10	0.09	0.14
1977	14.11	13.98	0.13	-0.31	0.13	0.08	-0.03
1978	14.69	14.63	0.06	-0.08	0.06	0.04	0.01
1979	13.64	13.45	0.19	-0.30	0.21	0.23	0.05
1980	14.86	14.43	0.43	-0.11	0.32	0.22	0.15
1981	14.19	13.96	0.23	-0.03	0.15	0.07	0.06
1982	14.65	14.59	0.05	-0.18	0.13	0.07	0.01
1983	14.81	14.44	0.37	-0.13	0.43	0.39	0.23
1984	14.51	14.34	0.17	0.05	0.31	0.29	0.22
1985	14.16	13.95	0.21	-0.41	0.03	0.02	-0.12
1986	14.11	14.17	-0.05	-0.36	-0.11	-0.18	-0.22
1987	14.79	15.00	-0.21	-0.12	0.23	0.17	0.09
1988	14.87	15.08	-0.21	0.18	0.21	0.36	0.25
1989	13.26	13.18	0.08	-0.09	0.14	0.14	0.06
AVG	14.28	14.09	0.19	-0.15	0.19	0.19	0.08
STD	0.44	0.50	0.20	0.21	0.19	0.22	0.19
MAX	14.87	15.08	0.68	0.22	0.66	0.74	0.51
MIN	13.26	13.18	-0.21	-0.47	-0.11	-0.18	-0.22

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : GANGES
STATION : 91.1 SENGRAM

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	11.07	11.37	-0.30	-0.67	-0.11	-0.21	-0.33
1966	11.63	11.56	0.07	-0.71	-0.19	-0.14	-0.35
1967	11.60	11.88	-0.29	-0.57	-0.20	-0.07	-0.28
1968	11.37	11.66	-0.29	-0.43	-0.34	-0.20	-0.36
1969	11.83	12.15	-0.33	-0.76	-0.43	-0.46	-0.55
1970	11.32	11.49	-0.18	-0.21	-0.10	-0.11	-0.14
1972							
1973	11.93	11.86	0.07	-0.26	-0.01	-0.34	-0.20
1974	11.65	12.05	-0.40	-0.23	-0.26	-0.38	-0.29
1975	11.65	11.93	-0.28	-0.47	-0.39	-0.80	-0.55
1976	11.61	12.34	-0.73	-0.06	-0.40	-0.75	-0.41
1977	11.51	11.86	-0.35	-0.34	-0.38	-0.65	-0.46
1978	11.72	12.41	-0.69	-0.37	-0.62	-0.95	-0.65
1979	10.91	11.42	-0.51	-0.66	-0.46	-0.26	-0.46
1980	12.25	12.27	-0.02	-0.01	-0.20	-0.67	-0.29
1981	11.47	11.84	-0.37	-0.56	-0.44	-0.98	-0.66
1982							
1983	12.02	12.24	-0.21	-0.45	-0.23	-0.32	-0.33
1984	12.22	12.16	0.06	-0.29	-0.14	-0.06	-0.16
1985	11.49	11.83	-0.34	0.07	-0.25	-0.98	-0.39
1986	11.71	12.00	-0.29	-0.20	-0.51	-0.61	-0.44
1987	12.50	12.77	-0.27	0.15	0.45	-0.23	0.12
1988	12.70	12.89	-0.19	0.39	0.07	0.01	0.15
1989	10.79	11.16	-0.37	-0.97	-0.16	-0.16	-0.43
AVG	11.68	11.96	-0.28	-0.35	-0.24	-0.42	-0.34
STD	0.46	0.42	0.20	0.32	0.22	0.31	0.20
MAX	12.70	12.89	0.07	0.39	0.45	0.01	0.15
MIN	10.79	11.16	-0.73	-0.97	-0.62	-0.98	-0.66

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : GANGES
STATION : 91.2 MAHENDRAPUR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	10.14	10.20	-0.07	0.01	0.28	0.07	0.12
1966	10.76	10.42	0.34	-0.23	0.23	0.24	0.08
1967	10.38	10.60	-0.22	-0.03	0.00	-0.01	-0.01
1968	10.58	10.43	0.14	0.20	0.06	0.11	0.12
1969	10.72	10.86	-0.14	-0.13	-0.01	-0.33	-0.16
1970	10.65	10.30	0.35	0.22	0.29	0.20	0.24
1972	10.33	10.17	0.16	0.32	0.32	-0.13	0.17
1973							
1974	11.34	10.79	0.55	0.31	0.31	-0.06	0.19
1975	10.79	10.65	0.14	0.33	-0.06	-0.16	0.04
1976	10.67	10.98	-0.31	0.43	0.20	-0.30	0.11
1977	10.76	10.63	0.13	0.23	0.19	-0.30	0.04
1978	10.79	11.04	-0.25	-0.03	-0.29	-0.46	-0.26
1979	10.29	10.28	0.01	-0.16	-0.02	0.22	0.01
1980	11.59	11.05	0.54	0.57	0.26	-0.16	0.22
1981	10.63	10.61	0.02	0.13	-0.10	-0.39	-0.28
1982	10.82	10.98	-0.16	0.30	0.15	-0.21	0.08
1983	11.34	10.93	0.41	0.33	0.37	0.03	0.24
1984							
1985	10.74	10.59	0.15	0.28	0.10	-0.35	0.01
1986	10.23	10.72	-0.49	0.10	-0.67	-0.66	-0.41
1987	11.29	11.33	-0.04	-0.06	0.20	-0.29	-0.05
1988	11.59	11.53	0.06	0.10	0.02	0.06	0.06
1989	10.09	10.03	0.06	-0.23	0.03	-0.25	-0.15
AVG	10.75	10.69	0.06	0.14	0.08	-0.14	0.02
STD	0.43	0.37	0.26	0.22	0.23	0.23	0.17
MAX	11.59	11.53	0.55	0.57	0.37	0.24	0.24
MIN	10.09	10.03	-0.49	-0.23	-0.67	-0.66	-0.41

NOTES : 1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : GORAI
STATION : 99 GORAI RAILWAY BRIDGE

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	12.79	12.19	0.60	0.44	1.09	0.83	0.79
1966	12.88	12.43	0.45	0.07	0.61	0.38	0.35
1967	13.13	12.80	0.32	-0.27	0.31	0.38	0.14
1968	12.84	12.56	0.28	-0.53	0.02	0.09	-0.14
1969	13.28	13.10	0.18	-0.68	-0.07	-0.32	-0.35
1970	12.49	12.37	0.11	-0.14	0.12	-0.00	-0.01
1972	12.04	12.15	-0.11	-0.60	-0.19	-0.22	-0.34
1973	13.00	12.76	0.24	-0.07	0.04	-0.07	-0.03
1974	13.09	12.98	0.11	0.02	-0.00	-0.16	-0.05
1975	12.79	12.84	-0.06	-0.02	-0.24	-0.55	-0.27
1976	13.13	13.31	-0.18	0.64	-0.04	-0.25	0.12
1977	12.76	12.76	-0.01	0.31	-0.02	-0.08	0.07
1978	13.27	13.36	-0.09	0.59	-0.09	-0.30	0.07
1979	12.04	12.26	-0.22	0.44	0.06	0.26	0.25
1980	13.43	13.18	0.24	0.57	0.15	-0.12	0.20
1981	12.72	12.74	-0.02	-0.56	-0.08	-0.39	-0.34
1982	13.13	13.33	-0.20	-0.43	-0.16	-0.39	-0.32
1983	13.51	13.19	0.32	-0.16	0.12	0.15	0.04
1984							
1985							
1986	12.71	12.93	-0.22	-0.94	-0.40	-0.37	-0.57
1987	13.43	13.64	-0.21	0.40	0.15	-0.23	0.11
1988	13.65	13.71	-0.06	-0.98	-0.09	-0.05	-0.37
1989	11.86	11.89	-0.03	-0.39	-0.04	0.00	-0.14
AVG	12.91	12.84	0.07	-0.10	0.06	-0.06	-0.04
STD	0.47	0.48	0.23	0.49	0.30	0.31	0.30
MAX	13.65	13.71	0.60	0.64	1.09	0.83	0.79
MIN	11.86	11.89	-0.22	-0.98	-0.40	-0.55	-0.57

NOTES :
1. **AVG1 = Mean relative errors for period May-Jun.**
2. **AVG2 = Mean relative errors for period Jul-Aug.**
3. **AVG3 = Mean relative errors for period Sep-Oct.**
4. **AVGS = Mean relative errors for period May-Oct.**
5. **Observed-Simulated is termed as Error**

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : GORAI-MADHUMATI
STATION : 101 KAMARKHALI

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	8.63	8.42	0.21	0.93	0.25	0.24	0.47
1966	8.84	8.61	0.22	0.84	0.18	0.15	0.39
1967	9.02	9.03	-0.01	0.35	0.16	0.07	0.19
1968	8.97	8.71	0.26	-0.10	0.08	-0.09	-0.04
1969	9.12	9.37	-0.25	-0.47	-0.24	-0.25	-0.32
1970	8.83	8.57	0.26	-0.28	0.03	-0.10	-0.12
1972	8.19	8.40	-0.21	-0.99	-0.53	-0.83	-0.78
1973	8.67	8.95	-0.28	-0.76	-0.58	-0.41	-0.58
1974	8.72	9.22	-0.51	-0.22	-0.73	-0.74	-0.56
1975	8.63	9.04	-0.41	0.25	-0.58	-0.76	-0.36
1976	8.78	9.48	-0.70	0.60	-0.49	-0.72	-0.21
1977	8.73	8.95	-0.21	0.34	-0.36	-0.35	-0.12
1978	9.05	9.55	-0.49	0.60	-0.26	-0.38	-0.02
1979	8.35	8.47	-0.11	1.48	-0.14	-0.29	0.35
1980	9.21	9.40	-0.19	1.19	-0.04	-0.46	0.23
1981	8.91	8.88	0.02	0.29	-0.13	-0.52	-0.12
1982	9.18	9.50	-0.32	0.20	-0.51	-0.56	-0.29
1983	8.98	9.42	-0.44	0.13	-0.25	-0.14	-0.09
1984	8.81	9.38	-0.57	0.64	-0.20	-0.25	0.06
1985	8.57	8.89	-0.31	0.82	-0.35	-0.52	-0.02
1986	8.82	9.16	-0.34	0.19	-0.37	-0.44	-0.21
1987	9.26	9.90	-0.63	0.69	-0.17	-0.43	0.03
1988	9.47	10.00	-0.53	0.05	-0.09	-0.45	-0.17
1989							
AVG	8.86	9.10	-0.24	0.29	-0.23	-0.36	-0.10
STD	0.29	0.44	0.28	0.58	0.26	0.28	0.30
MAX	9.47	10.00	0.26	1.48	0.25	0.24	0.47
MIN	8.19	8.40	-0.70	-0.99	-0.73	-0.83	-0.78

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : PADMA
STATION : 91.9L BARURIA

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	8.11	8.00	0.10	0.38	0.21	0.38	0.32
1966	8.46	8.47	-0.01	-0.23	0.16	0.37	0.10
1967	7.87	7.98	-0.11	0.02	0.11	0.16	0.10
1968	8.43	8.19	0.24	0.32	0.24	0.32	0.29
1969	8.19	8.29	-0.10	-0.00	0.08	0.24	0.11
1970	8.41	8.31	0.09	0.11	0.14	0.26	0.17
1972	7.74	7.96	-0.22	0.22	-0.06	-0.00	0.05
1973	8.27	8.38	-0.11	0.42	0.09	0.01	0.17
1974	8.61	8.85	-0.24	0.30	-0.09	0.02	0.07
1975	8.18	8.32	-0.14	0.49	-0.04	0.02	0.15
1976	7.91	8.20	-0.29	0.05	-0.04	-0.07	-0.02
1977	8.12	8.46	-0.34	-0.08	-0.20	-0.28	-0.19
1978	7.83	8.30	-0.47	-0.15	-0.37	-0.49	-0.33
1979	7.68	8.11	-0.43	-0.38	-0.36	-0.33	-0.36
1980	8.65	9.04	-0.39	-0.04	-0.28	-0.17	-0.17
1981	7.96	8.32	-0.36	-0.20	-0.33	-0.33	-0.29
1982	7.99	8.36	-0.38	0.12	-0.01	-0.18	-0.01
1983	8.48	8.61	-0.13	-0.00	0.20	-0.07	0.04
1984	8.37	8.73	-0.36	0.18	-0.06	-0.13	-0.00
1985	8.06	8.21	-0.15	-0.16	-0.23	-0.32	-0.22
1986	7.88	8.14	-0.26	0.10	-0.14	-0.07	-0.04
1987	9.04	8.91	0.13	0.11	0.15	-0.02	0.08
1988	9.35	9.37	-0.02	0.14	-0.05	0.20	0.10
1989	7.74	7.97	-0.23	-0.21	-0.18	-0.14	-0.17
AVG	8.22	8.39	-0.17	0.06	-0.04	-0.03	-0.00
STD	0.40	0.35	0.19	0.22	0.18	0.23	0.18
MAX	9.35	9.37	0.24	0.49	0.24	0.38	0.32
MIN	7.68	7.96	-0.47	-0.38	-0.37	-0.49	-0.36

NOTES : 1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : PADMA
STATION : 93.5L MAWA

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	5.97	5.63	0.33	1.15	0.32	0.54	0.80
1966	6.38	6.08	0.30	0.43	0.31	0.63	0.46
1967	5.73	5.64	0.09	0.31	0.19	0.23	0.24
1968	6.20	5.85	0.35	0.44	0.34	0.50	0.42
1969	6.30	5.89	0.42	0.27	0.52	0.66	0.48
1970							
1972	5.75	5.59	0.16	0.36	0.20	0.14	0.24
1973	6.12	5.98	0.14	0.34	0.22	0.14	0.23
1974	6.47	6.45	0.02	0.20	0.09	0.15	0.14
1975	5.87	5.91	-0.04	0.23	-0.11	0.02	0.05
1976	5.61	5.82	-0.21	0.14	-0.04	0.01	0.03
1977	5.89	6.03	-0.14	0.21	-0.10	-0.07	0.02
1978	5.72	5.91	-0.19	0.20	-0.19	-0.19	-0.06
1979	5.59	5.74	-0.15	0.15	-0.20	-0.06	-0.04
1980	6.33	6.56	-0.23	0.39	-0.09	0.07	0.12
1981	5.84	5.91	-0.08	0.30	-0.14	-0.17	-0.00
1982	5.64	5.87	-0.23	0.18	-0.07	-0.14	-0.01
1983	5.91	6.15	-0.24	0.17	0.10	-0.05	0.07
1984	6.15	6.26	-0.10	0.34	0.05	0.14	0.18
1985	5.94	5.82	0.12		0.11	0.04	0.68
1986	5.76	5.72	0.04	0.23	0.16	0.17	0.19
1987							
1988	7.06	6.89	0.17	0.35	0.14	0.26	0.25
1989	5.69	5.69	0.00	-0.06	-0.16	-0.16	-0.11
AVG	5.99	5.97	0.02	0.30	0.08	0.13	0.20
STD	0.35	0.32	0.20	0.22	0.19	0.25	0.23
MAX	7.06	6.89	0.42	1.15	0.52	0.66	0.80
MIN	5.59	5.59	-0.24	-0.06	-0.20	-0.19	-0.11

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : MEGHNA
STATION : 273 BHAIRAB BAZAR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	6.49	6.19	0.30	0.11	0.21	0.58	0.30
1966	6.91	6.35	0.55	-0.09	0.28	0.63	0.28
1967	6.25	6.20	0.05	-0.38	-0.01	0.34	-0.01
1968	6.77	6.47	0.29	-0.02	0.39	0.63	0.34
1969	6.71	6.43	0.28	-0.21	0.20	0.76	0.25
1970	7.10	6.51	0.58	-0.12	0.39	0.71	0.32
1972	6.09	6.19	-0.10	0.03	0.02	0.41	0.15
1973	6.48	6.92	-0.45	-0.49	0.05	0.50	0.07
1974	7.65	6.44	1.21	-0.16	0.90	0.96	0.57
1975	6.48	6.46	0.02	-0.30	0.13	0.36	0.06
1976	7.02	7.04	-0.03	-0.41	0.08	0.13	-0.07
1977	6.57	6.20	0.37	-0.41	0.12	0.50	0.07
1978	5.99	5.82	0.17	-0.12	0.14	0.25	0.09
1979	6.33	6.52	-0.19	-0.04	-0.15	0.14	-0.02
1980	6.41	6.03	0.38	-0.37	0.28	0.60	0.17
1981	6.46	6.28	0.18	-0.22	0.32	0.22	0.11
1982	6.43	6.39	0.05	-0.17	-0.04	0.47	0.09
1983	6.79	6.83	-0.04	-0.49	0.13	0.34	-0.01
1984	6.89	6.78	0.11	-0.28	0.45	0.20	0.12
1985	6.38	6.34	0.04	-0.29	-0.04	0.02	-0.10
1986	5.67	6.04	-0.37	-0.28	-0.33	-0.13	-0.25
1987	6.90	6.85	0.05	-0.51	0.10	0.23	-0.06
1988	7.65	7.50	0.15	-0.29	0.08	0.03	-0.06
1989	6.41	6.50	-0.09	-0.40	-0.19	-0.19	-0.26
AVG	6.62	6.47	0.15	-0.25	0.15	0.36	0.09
STD	0.45	0.36	0.33	0.17	0.24	0.28	0.19
MAX	7.65	7.50	1.21	0.11	0.90	0.96	0.57
MIN	5.67	5.82	-0.45	-0.51	-0.33	-0.19	-0.26

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : UPPER MEGHNA
STATION : 275.5 MEGHNA FERRY GHAT

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965							
1966							
1967							
1968	5.67	5.28	0.38	0.14	0.37	0.41	0.30
1969	5.60	5.19	0.41	-0.13	0.36	0.59	0.27
1970	5.84	5.41	0.43	0.11	0.37	0.59	0.36
1972	5.08	5.07	0.01	0.10	0.09	0.21	0.13
1973	5.40	5.29	0.11	0.07	0.13	0.35	0.18
1974	6.17	5.72	0.44	0.04	0.39	0.47	0.30
1975	5.23	5.27	-0.04	0.06	0.03	0.16	0.08
1976	5.24	5.27	-0.03	-0.09	-0.02	0.04	-0.02
1977							
1978							
1979							
1980	5.78	5.61	0.17	-0.12	0.13	0.46	0.16
1981							
1982							
1983							
1984							
1985							
1986	4.97	4.89	0.07	0.02	0.10	0.11	0.08
1987	5.98	5.71	0.27	0.03	0.27	0.27	0.19
1988	6.53	6.20	0.33	0.04	0.15	0.15	0.11
1989	5.14	5.21	-0.07	-0.11	-0.12	-0.15	-0.12
AVG	5.58	5.39	0.19	0.01	0.17	0.28	0.16
STD	0.45	0.33	0.19	0.09	0.16	0.21	0.13
MAX	6.53	6.20	0.44	0.14	0.39	0.59	0.36
MIN	4.97	4.89	-0.07	-0.13	-0.12	-0.15	-0.12

NOTES : 1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : LOWER MEGHNA
STATION : 277 CHANDPUR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	4.80	4.03	0.77	0.31	0.31	0.30	0.31
1966	4.85	4.48	0.37	0.17	0.32	0.45	0.31
1967	4.42	4.09	0.33	-0.10	0.14	0.20	0.08
1968	4.64	4.37	0.28	0.20	0.33	0.37	0.30
1969	4.60	4.30	0.29	-0.02	0.34	0.40	0.24
1970	4.71	4.44	0.27	0.16	0.31	0.35	0.27
1972	4.42	4.17	0.24	0.18	0.25	0.10	0.18
1973	4.73	4.53	0.20	0.36	0.21	0.25	0.28
1974	4.98	4.94	0.04	0.03	0.17	0.19	0.13
1975	4.50	4.40	0.10	0.03	0.03	0.06	0.05
1976	4.16	4.28	-0.12	-0.05	-0.06	-0.11	-0.07
1977	4.39	4.37	0.02	-0.01	-0.10	0.01	-0.04
1978	4.27	4.26	0.01	0.09	-0.05	0.01	0.02
1979	4.35	4.37	-0.03	0.04	-0.20	-0.22	-0.13
1980	4.52	4.87	-0.35	0.04	-0.25	0.09	-0.04
1981	4.38	4.30	0.07	0.09	0.00	-0.11	-0.01
1982	4.28	4.15	0.13	0.05	0.12	0.16	0.11
1983	4.46	4.48	-0.02	0.07	0.21	0.10	0.13
1984	4.65	4.65	-0.00	0.22	0.04	0.01	0.09
1985	4.27	4.37	-0.10	0.06	0.00	-0.09	-0.01
1986	3.82	4.07	-0.25	-0.13	-0.16	-0.07	-0.12
1987	4.50	4.82	-0.32	0.01	0.03	-0.08	-0.02
1988	4.99	5.20	-0.21	0.06	-0.08	0.04	0.00
1989	4.29	4.41	-0.12	-0.03	-0.14	-0.30	-0.15
AVG	4.50	4.43	0.07	0.08	0.07	0.09	0.08
STD	0.26	0.28	0.25	0.12	0.18	0.19	0.14
MAX	4.99	5.20	0.77	0.36	0.34	0.45	0.31
MIN	3.82	4.03	-0.35	-0.13	-0.25	-0.30	-0.15

NOTES :
1. **AVG1 = Mean relative errors for period May-Jun.**
2. **AVG2 = Mean relative errors for period Jul-Aug.**
3. **AVG3 = Mean relative errors for period Sep-Oct.**
4. **AVGS = Mean relative errors for period May-Oct.**
5. **Observed-Simulated is termed as Error**

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : OLD BRAHMAPUTRA
STATION : 225 JAMALPUR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	17.07	16.46	0.61	0.51	0.50	0.55	0.52
1966	17.04	16.86	0.18	0.00	0.29	0.57	0.29
1967	16.83	16.79	0.04	0.21	0.30	0.39	0.30
1968	16.98	16.40	0.58	0.30	0.65	0.66	0.54
1969	17.09	16.21	0.87	0.17	0.95	0.75	0.62
1970	17.38	16.83	0.55	0.39	0.57	0.43	0.47
1972	17.28	16.74	0.53	0.29	0.54	0.41	0.42
1973	17.28	16.60	0.68	-0.03	0.69	0.41	0.36
1974	17.56	17.20	0.35	0.16	0.78	0.71	0.55
1975	16.90	16.29	0.61	0.14	0.75	0.78	0.56
1976	17.22	16.58	0.64	0.22	0.73	0.64	0.53
1977	17.28	16.56	0.72	0.50	0.72	0.74	0.65
1978	16.81	16.20	0.60	0.04	0.71	0.29	0.35
1979	16.74	16.36	0.37	-0.26	0.12	0.19	0.02
1980	17.40	17.32	0.07	-0.07	0.18	0.31	0.14
1981	16.68	16.55	0.13	-0.55	0.04	-0.02	-0.17
1982	16.62	16.42	0.19	-0.18	0.26	0.02	0.03
1983	16.52	16.64	-0.12	-0.23	0.26	-0.23	-0.07
1984	17.30	17.00	0.30	-0.75	0.19	0.20	-0.12
1985	17.50	16.77	0.73	-0.20	0.47	0.08	0.12
1986	15.96	15.78	0.18	-0.76	-0.32	-0.38	-0.49
1987	17.20	16.93	0.28	-1.36	0.05	-0.20	-0.50
1988	17.81	17.64	0.17	-0.96	-0.21	-0.36	-0.50
1989	16.28	16.68	-0.40	-1.47	-1.03	-1.06	-1.18
AVG	17.03	16.66	0.37	-0.16	0.34	0.25	0.14
STD	0.42	0.39	0.30	0.54	0.43	0.44	0.45
MAX	17.81	17.64	0.87	0.51	0.95	0.78	0.65
MIN	15.96	15.78	-0.40	-1.47	-1.03	-1.06	-1.18

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : OLD BRAHMAPUTRA
STATION : 228.5 NILUKHIRCHAR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965							
1966							
1967	12.06	12.00	0.05	0.99	0.27	0.63	0.63
1968	12.08	11.58	0.49	0.99	0.46	0.68	0.71
1969	12.04	11.52	0.52	0.41	0.64	0.90	0.65
1970	12.62	12.01	0.61	0.75	0.46	0.54	0.58
1972	12.42	12.00	0.42	1.15	0.49	0.77	0.80
1973	12.85	12.05	0.80	-0.15	0.86	0.70	0.47
1974	13.29	12.40	0.89	0.31	1.19	1.02	0.84
1975	12.31	11.59	0.72	0.97	0.90	1.00	0.96
1976	12.49	11.90	0.58	0.75	0.67	1.03	0.82
1977	12.81	11.81	1.00	0.57	0.76	0.96	0.76
1978	12.19	11.54	0.65	0.61	0.89	0.75	0.75
1979	12.16	11.75	0.41	0.95	0.16	0.37	0.49
1980	12.80	12.61	0.19	0.19	0.29	0.59	0.35
1981	11.78	11.88	-0.09	0.00	0.07	0.54	0.20
1982	12.00	11.85	0.15	0.75	0.33	0.43	0.50
1983	11.97	11.87	0.10	0.37	0.14	-0.11	0.13
1984	12.82	12.24	0.58	-0.45	0.39	0.40	0.12
1985	12.50	12.11	0.39	0.18	0.42	0.15	0.25
1986	11.36	11.49	-0.13	-0.25	-0.03	-0.15	-0.14
1987	12.72	12.33	0.39	-0.95	0.11	0.06	-0.26
1988	13.70	13.17	0.53	-0.55	0.05	0.12	-0.13
1989	11.84	11.95	-0.11	-1.06	-0.80	-0.86	-0.91
AVG	12.40	11.98	0.41	0.30	0.40	0.48	0.39
STD	0.52	0.39	0.31	0.63	0.41	0.45	0.44
MAX	13.70	13.17	1.00	1.15	1.19	1.03	0.96
MIN	11.36	11.49	-0.13	-1.06	-0.80	-0.86	-0.91

NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : OLD BRAHMAPUTRA
STATION : 229 TOKE

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965							
1966							
1967							
1968	8.44	8.75	-0.31	0.68	0.32	0.70	0.56
1969	8.23	8.13	0.09	0.13	0.55	0.95	0.55
1970	8.84	9.16	-0.32	0.77	0.13	0.75	0.55
1972							
1973	8.87	9.42	-0.55	-0.39	0.50	0.50	0.21
1974	9.68	9.56	0.12	0.12	0.58	0.92	0.54
1975							
1976							
1977	9.09	8.67	0.41	0.18	0.40	0.69	0.43
1978	8.35	8.32	0.03	0.17	0.97	0.84	0.66
1979	8.35	8.53	-0.18	0.24	-0.09	0.02	0.05
1980	8.83	9.66	-0.83	0.00	-0.35	0.62	0.09
1981	7.79	8.48	-0.69	-0.16	-0.19	0.17	-0.06
1982	8.01	8.99	-0.98	0.20	-0.15	-0.03	0.01
1983	7.98	8.54	-0.56	-0.20	-0.06	-0.26	-0.17
1984	8.96	9.38	-0.42	-0.64	0.05	0.24	-0.12
1985							
1986	7.38	8.53	-1.15	-0.50	-0.29	-0.36	-0.38
1987	8.92	9.48	-0.56	-0.94	-0.63	0.01	-0.52
1988	9.81	10.01	-0.20	-0.61	-0.31	-0.02	-0.32
1989							
AVG	8.59	8.98	-0.38	-0.06	0.09	0.36	0.13
STD	0.63	0.54	0.41	0.46	0.42	0.42	0.37
MAX	9.81	10.01	0,41	0.77	0.97	0.95	0.66
MIN	7.38	8.13	-1.15	-0.94	-0.63	-0.36	-0.52

NOTES : 1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : ARIAL KHAN
STATION : 5 MADARIPUR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	4.37	4.42	-0.05	0.38	-0.17	-0.27	-0.02
1966	4.74	4.97	-0.23	0.05	-0.29	-0.32	-0.19
1967	3.95	4.44	-0.49	0.09	-0.46	-0.41	-0.26
1968	4.66	4.70	-0.05	0.28	-0.12	-0.30	-0.05
1969	4.49	4.74	-0.26	0.17	-0.15	-0.16	-0.05
1970	4.69	4.82	-0.13	0.19	-0.12	-0.17	-0.03
1972	3.92	4.41	-0.49	0.22	-0.39	-0.55	-0.24
1973	4.41	4.85	-0.45	0.30	-0.39	-0.50	-0.19
1974	4.93	5.39	-0.46	0.18	-0.49	-0.57	-0.29
1975	3.91	4.79	-0.88	0.27	-0.74	-0.72	-0.40
1976	3.74	4.65	-0.92	0.05	-0.53	-0.80	-0.43
1977	4.01	4.89	-0.89	-0.16	-0.80	-0.90	-0.62
1978	3.87	4.79	-0.91	0.14	-0.72	-0.83	-0.47
1979	3.86	4.57	-0.71	0.35	-0.58	-0.70	-0.31
1980	4.63	5.50	-0.87	0.22	-0.74	-0.56	-0.36
1981	4.10	4.76	-0.67	0.22	-0.55	-0.75	-0.36
1982	3.70	4.64	-0.94	0.35	-0.51	-0.77	-0.31
1983	4.14	4.99	-0.84	0.19	-0.26	-0.62	-0.23
1984	4.41	5.12	-0.71	0.24	-0.47	-0.42	-0.22
1985	4.27	4.67	-0.40	-0.05	-0.34	-0.48	-0.29
1986	4.04	4.52	-0.49	0.19	-0.22	-0.35	-0.13
1987	5.17	5.39	-0.23	0.15	-0.02	-0.25	-0.04
1988	5.59	5.83	-0.24	0.30	-0.23	-0.20	-0.05
1989	4.20	4.62	-0.42	0.37	-0.10	-0.20	0.02
AVG	4.32	4.85	-0.53	0.20	-0.39	-0.49	-0.23
STD	0.46	0.36	0.29	0.13	0.22	0.23	0.16
MAX	5.59	5.83	-0.05	0.38	-0.02	-0.16	0.02
MIN	3.70	4.41	-0.94	-0.16	-0.80	-0.90	-0.62

NOTES : **1. AVG1 = Mean relative errors for period May-Jun.**
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : DHALESWARI
STATION : 137A TARAGHAT

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	9.05	8.83	0.22	0.60	0.42	0.98	0.66
1966	9.30	9.23	0.07	0.12	0.49	0.59	0.40
1967	8.73	8.95	-0.22	0.06	0.42	0.83	0.43
1968	9.19	8.56	0.63	0.75	0.87	1.09	0.90
1969	8.82	8.23	0.59	0.76	0.80	0.95	0.84
1970	9.33	9.22	0.11	0.16	0.39	0.54	0.36
1972	8.56	8.88	-0.32	-0.05	0.10	0.54	0.19
1973	9.19	8.90	0.28	-0.13	0.63	0.48	0.33
1974	9.47	9.60	-0.13	-0.37	0.01	0.35	-0.00
1975	8.28	8.35	-0.07	-0.33	-0.03	0.15	-0.07
1976							
1977	8.63	8.90	-0.27	-0.67	-0.02	0.04	-0.22
1978	7.96	8.20	-0.24	-1.17	0.16	-0.10	-0.37
1979	8.02	8.53	-0.51	-1.28	-0.51	-0.43	-0.74
1980	9.40	9.70	-0.30	-0.63	-0.23	0.41	-0.15
1981	8.31	8.47	-0.16	-1.11	-0.02	0.01	-0.37
1982	8.16	8.66	-0.50	-0.47	-0.05	0.19	-0.11
1983	8.92	8.86	0.06	-0.69	0.15	0.42	-0.04
1984	9.22	9.41	-0.19	-0.59	0.16	0.31	-0.04
1985	8.72	8.79	-0.07	-0.40	0.16	0.43	0.07
1986	8.38	7.94	0.44	-0.51	0.27	0.36	0.04
1987	9.70	9.23	0.47	-0.83	0.10	0.52	-0.07
1988	10.37	9.92	0.45	-1.02	0.42	0.14	-0.15
1989	7.87	8.59	-0.72	-1.44	-0.55	-0.61	-0.86
AVG	8.85	8.87	-0.02	-0.40	0.18	0.36	0.05
STD	0.61	0.49	0.36	0.61	0.35	0.41	0.43
MAX	10.37	9.92	0.63	0.76	0.87	1.09	0.90
MIN	7.87	7.94	-0.72	-1.44	-0.55	-0.61	-0.86

NOTES :
1. **AVG1 = Mean relative errors for period May-Jun.**
2. **AVG2 = Mean relative errors for period Jul-Aug.**
3. **AVG3 = Mean relative errors for period Sep-Oct.**
4. **AVGS = Mean relative errors for period May-Oct.**
5. **Observed-Simulated is termed as Error**

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STATISTICAL ERROR ANALYSIS

DATA : WATER LEVEL
RIVER : LAKHYA
STATION : 7.5 DEMRA

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	5.80	5.26	0.53	0.35	0.40	0.49	0.41
1966	6.23	5.77	0.46	0.12	0.45	0.52	0.36
1967	5.42	5.39	0.03	0.07	0.18	0.40	0.22
1968	6.06	5.40	0.66	0.35	0.63	0.66	0.55
1969	5.83	5.17	0.65	0.03	0.52	0.74	0.43
1970	6.23	5.67	0.56	0.25	0.55	0.79	0.53
1972	5.38	5.33	0.05	0.23	0.23	0.36	0.27
1973	5.86	5.46	0.40	0.23	0.36	0.43	0.34
1974	6.57	6.11	0.46	0.13	0.51	0.61	0.42
1975	5.58	5.36	0.22	0.21	0.27	0.37	0.28
1976	5.45	5.28	0.17	0.08	0.28	0.28	0.21
1977	5.90	5.44	0.45	0.22	0.38	0.34	0.31
1978	5.48	4.96	0.52	0.31	0.40	0.36	0.36
1979	5.56	5.35	0.22	0.24	0.18	0.13	0.18
1980	6.21	6.08	0.13	0.29	0.28	0.58	0.38
1981	5.72	5.35	0.37	0.27	0.40	0.31	0.33
1982	5.47	5.33	0.14	0.14	0.25	0.30	0.23
1983							
1984	6.30	5.74	0.56	0.19	0.61	0.67	0.49
1985	5.68	5.42	0.26	0.19	0.30	0.34	0.28
1986	5.12	4.90	0.22	0.03	0.18	0.18	0.13
1987	6.38	5.95	0.43	0.01	0.32	0.43	0.25
1988	6.92	6.47	0.45	0.01	0.34	0.29	0.22
1989	5.32	5.38	-0.06	-0.26	-0.18	-0.30	-0.25
AVG	5.84	5.50	0.34	0.16	0.34	0.40	0.30
STD	0.44	0.36	0.20	0.14	0.17	0.23	0.16
MAX	6.92	6.47	0.66	0.35	0.63	0.79	0.55
MIN	5.12	4.90	-0.06	-0.26	-0.18	-0.30	-0.25

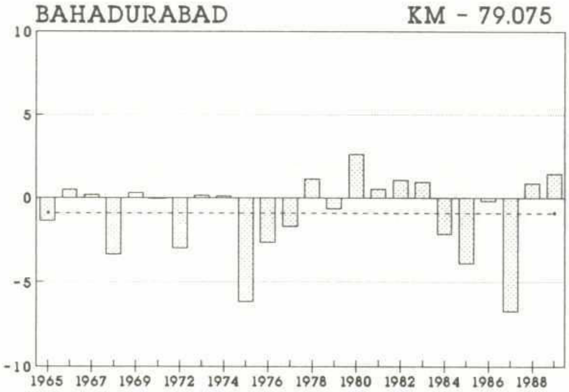
NOTES :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. Observed-Simulated is termed as Error

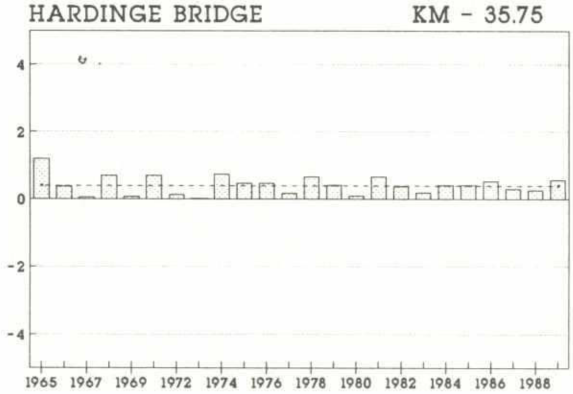
2GD

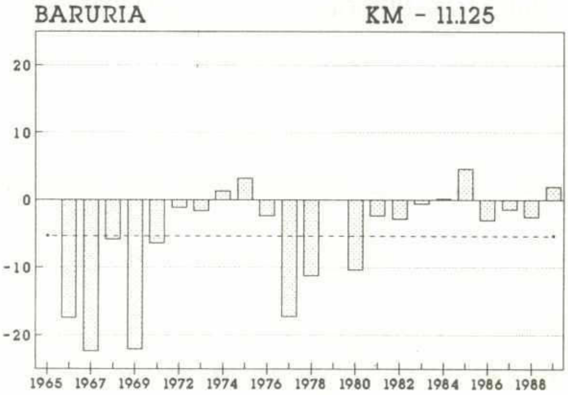
STATISTICAL ERROR ANALYSIS FOR DISCHARGES

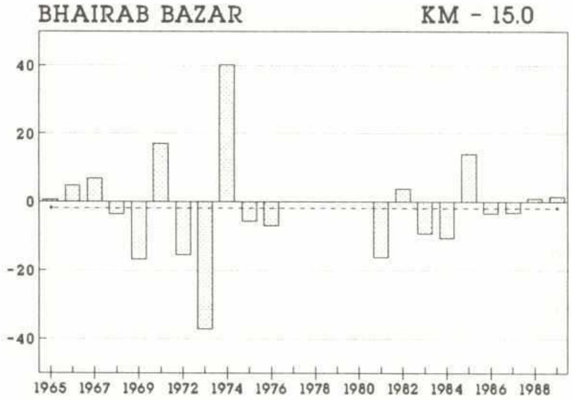
DISCREPANCIES IN PEAK DISCHARGES (OBSERVED-SIMULATED)

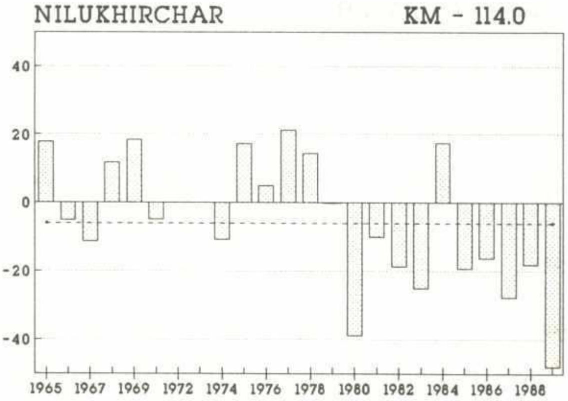
Legend :
Y-axis = Percentage of Error (Obs-Sim)/Obs
X-axis = Years
Broken Line = Mean Value











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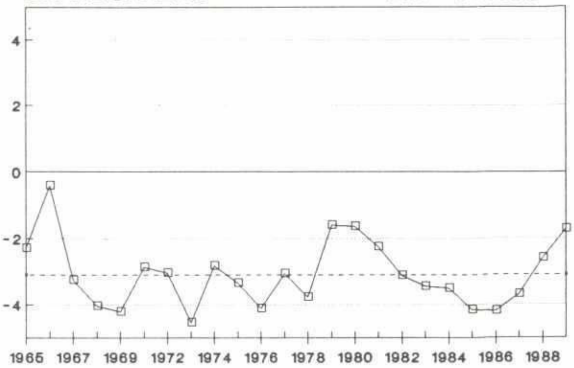
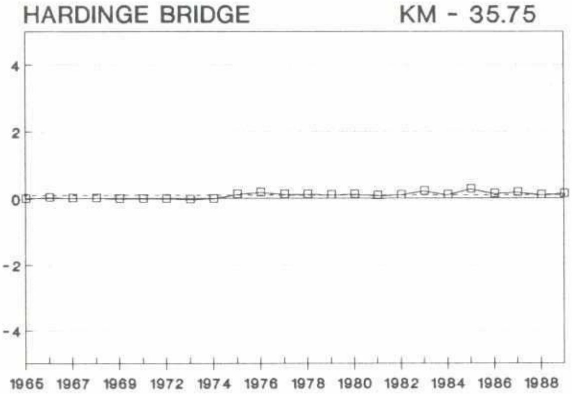
DISCREPANCIES IN MEAN SEASONAL DISCHARGES (OBSERVED-SIMULATED)

Legend :
Y-axis = Percentage of Error (Obs-Sim)/Obs
X-axis = Years
Broken Line = Mean Value

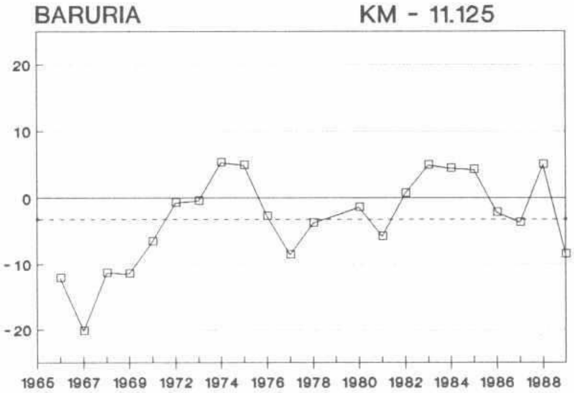
BAHADURABAD KM - 79.075



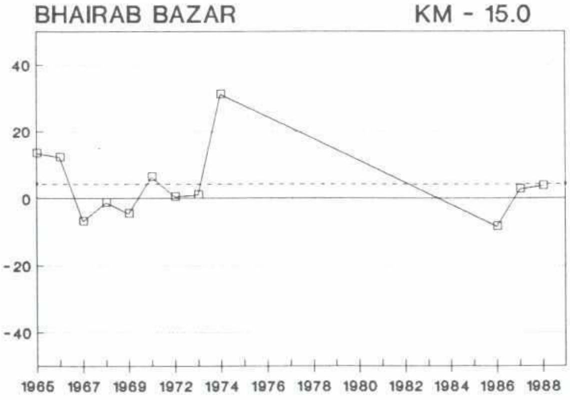
HARDINGE BRIDGE KM - 35.75



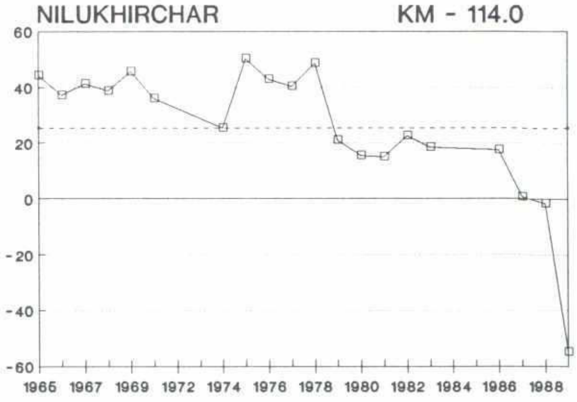
BARURIA KM - 11.125



BHAIRAB BAZAR KM - 15.0

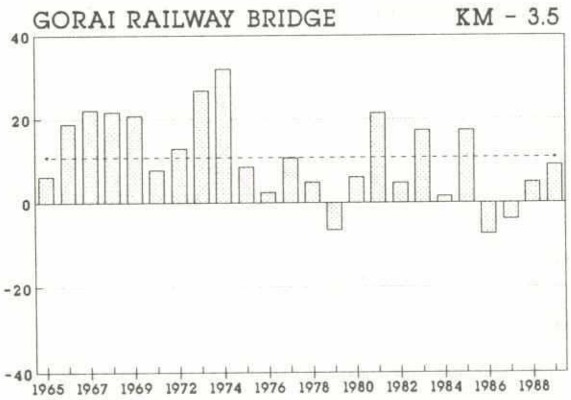


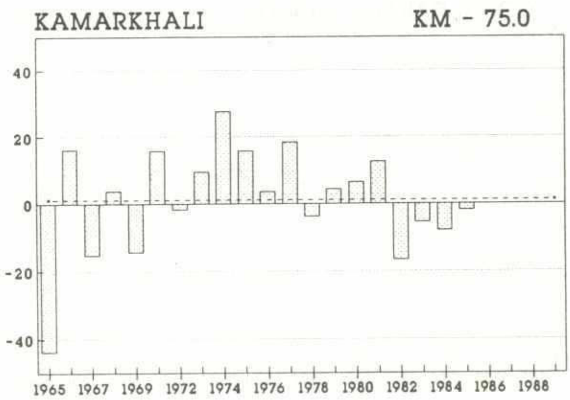
NILUKHIRCHAR KM - 114.0



DISCREPANCIES IN PEAK DISCHARGES
(OBSERVED-SIMULATED)

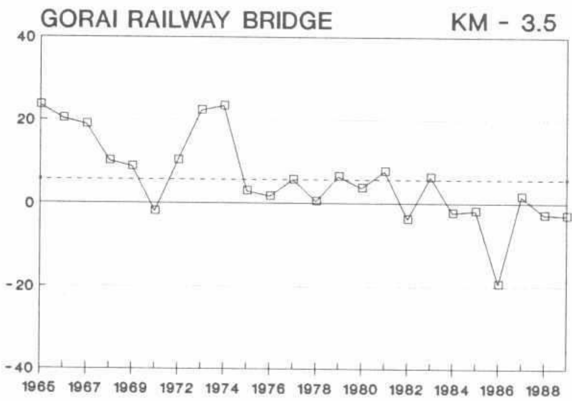
Legend :
Y-axis = Percentage of Error (Obs-Sim)/Obs
X-axis = Years
Broken Line = Mean Value

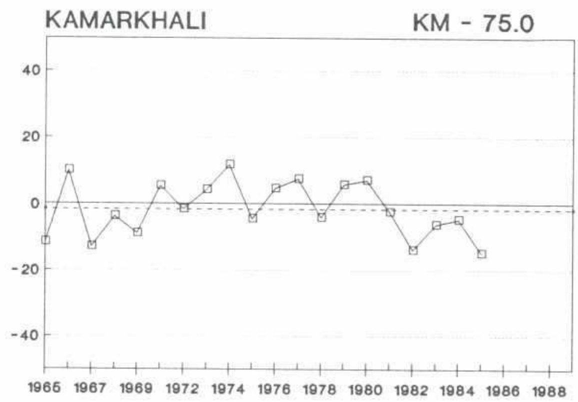




DISCREPANCIES IN MEAN SEASONAL
DISCHARGES (OBSERVED-SIMULATED)

Legend :
Y-axis = Percentage of Error (Obs-Sim)/Obs
X-axis = Years
Broken Line = Mean Value





STATISTICAL ERROR ANALYSIS

DATA : DISCHARGES
RIVER : JAMUNA
STATION : 46.9L BAHADURABAD

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	64200	65071	-1.36	-3.5	-2.3	-1.5	-2.3
1966	73716	73344	0.50	-1.1	-0.7	0.5	-0.4
1967	72046	71892	0.21	-5.8	-2.1	-3.3	-3.3
1968	62370	64464	-3.36	-4.2	-3.7	-4.5	-4.0
1969	57020	56849	0.30	-6.9	-4.1	-2.3	-4.2
1970	74478	74492	-0.02	-4.0	-2.6	-2.3	-2.9
1972	68824	70880	-2.99	-4.1	-2.5	-2.9	-3.0
1973	68274	68163	0.16	-5.9	-2.7	-6.0	-4.5
1974	85411	85301	0.13	-4.4	-2.3	-2.6	-2.8
1975	54719	58086	-6.15	-4.5	-2.5	-3.9	-3.4
1976	65074	66792	-2.64	-3.2	-4.7	-3.9	-4.1
1977	66842	67963	-1.68	-3.3	-3.4	-2.4	-3.1
1978	56120	55476	1.15	-4.0	-3.8	-3.5	-3.8
1979	60372	60762	-0.65	-2.2	-2.1	-0.9	-1.6
1980	91252	88880	2.60	-3.1	-0.3	-3.1	-1.6
1981	66401	66053	0.52	-4.0	-1.8	-2.0	-2.3
1982	64331	63642	1.07	-3.9	-3.4	-2.2	-3.1
1983	70979	70305	0.95	-3.8	-4.1	-2.5	-3.5
1984	76303	77936	-2.14	-4.6	-2.6	-4.0	-3.5
1985	63897	66371	-3.87	-3.7	-3.8	-4.9	-4.1
1986	47614	47700	-0.18	-4.4	-4.6	-3.7	-4.2
1987	70465	75208	-6.73	-4.4	-4.0	-2.9	-3.7
1988	98415	97568	0.86	-2.9	-4.2	-0.3	-2.6
1989	69891	68884	1.44	-3.5	-1.4	-0.9	-1.7
AVG	68709	69253	-0.9	-4.0	-2.9	-2.8	-3.1
STD	11062	10636	2.3	1.2	1.2	1.5	1.0
MAX	98415	97568	2.6	-1.1	-0.3	0.5	-0.4
MIN	47614	47700	-6.7	-6.9	-4.7	-6.0	-4.5

NOTE :

1. **AVG1 = Mean relative errors for period May-Jun.**
2. **AVG2 = Mean relative errors for period Jul-Aug.**
3. **AVG3 = Mean relative errors for period Sep-Oct.**
4. **AVGS = Mean relative errors for period May-Oct.**
5. **(Observed-Simulated)/Observed is termed as Percentage of Error.**

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STATISTICAL ERROR ANALYSIS

DATA : DISCHARGES
RIVER : GANGES
STATION : 90 HARDINGE BRIDGE

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	36800	36359	1.20	0.0	-0.5	0.5	-0.0
1966	40525	40369	0.39	0.4	-1.0	1.4	0.0
1967	49083	49055	0.06	0.2	-1.0	0.9	0.0
1968	43315	43009	0.71	-0.3	-0.7	1.1	-0.0
1969	56083	56039	0.08	0.1	-1.0	1.1	-0.0
1970	39459	39186	0.69	-0.1	-0.4	0.4	-0.0
1972	35565	35515	0.14	-0.0	-0.4	0.4	-0.0
1973	48089	48081	0.02	-0.9	-0.4	0.4	-0.0
1974	53907	53510	0.74	-0.1	-0.9	1.2	-0.0
1975	50248	50010	0.47	3.0	0.4	-0.5	0.1
1976	60993	60708	0.47	3.9	0.8	-0.6	0.2
1977	48034	47952	0.17	1.6	0.4	-0.4	0.1
1978	62587	62173	0.66	2.4	0.3	-0.5	0.1
1979	37309	37149	0.43	1.2	0.7	-1.2	0.1
1980	57602	57541	0.11	3.2	0.5	-0.6	0.1
1981	47768	47447	0.67	1.1	0.6	-0.7	0.1
1982	61430	61192	0.39	2.6	0.6	-0.6	0.1
1983	57958	57842	0.20	2.7	0.8	-0.3	0.2
1984	55757	55529	0.41	3.0	0.3	-0.6	0.1
1985	47507	47304	0.43	2.9	0.7	-0.2	0.3
1986	52270	51995	0.53	3.5	0.5	-0.6	0.1
1987	70806	70593	0.30	3.1	0.6	-0.3	0.2
1988	72385	72196	0.26	2.4	0.7	-1.0	0.1
1989	31874	31695	0.56	2.5	0.5	-0.6	0.1
AVG	50723	50519	0.4	1.6	0.1	-0.1	0.1
STD	10568	10562	0.3	1.4	0.6	0.7	0.1
MAX	72385	72196	1.2	3.9	0.8	1.4	0.3
MIN	31874	31695	0.0	-0.9	-1.0	-1.2	-0.0

NOTE :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. (Observed-Simulated)/Observed is termed as Percentage of Error.

STATISTICAL ERROR ANALYSIS

DATA : DISCHARGES
RIVER : PADMA
STATION : 91.9L BARURIA

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965							
1966	75756	95510	-26.08	-13.3	-13.3	-2.0	-9.1
1967	61470	77841	-26.63	-17.7	-18.7	-15.8	-17.4
1968	75005	84879	-13.16	-6.9	-14.1	-12.6	-12.3
1969	72114	88795	-23.13	-8.1	-16.1	-6.8	-11.4
1970	77824	89589	-15.12	-4.8	-9.3	-2.5	-6.0
1972	73541	77431	-5.29	2.8	0.5	-0.0	0.8
1973	86519	92370	-6.76	2.0	-0.4	-4.7	-1.5
1974	126047	111541	11.51	7.4	11.6	8.7	10.0
1975	94701	90273	4.68	14.8	1.6	4.3	4.5
1976	80629	85500	-6.04	-0.8	-1.9	-3.4	-2.3
1977	81800	95916	-17.26	-7.9	-13.1	-3.5	-8.6
1978	80400	89441	-11.25	7.3	-4.7	-8.3	-3.7
1979	80897	82177	-1.58	-12.0	-6.4	-7.9	-7.7
1980	109000	120319	-10.38	3.8	-6.5	3.2	-1.4
1981	87427	90258	-3.24	-0.8	-3.5	-10.2	-5.5
1982	87113	92165	-5.80	9.9	0.9	-5.7	0.6
1983	101889	101580	0.30	11.9	7.2	0.9	5.2
1984	98682	106746	-8.17	16.6	4.3	1.3	5.6
1985	93327	86033	7.82	6.2	4.1	0.4	3.5
1986	81692	83507	-2.22	-2.1	-4.3	-2.6	-3.3
1987	112457	114584	-1.89	-0.3	-0.7	-6.7	-3.0
1988	137110	135326	1.30	7.7	0.1	9.8	5.0
1989	73140	78174	-6.88	-17.6	-6.3	-4.3	-7.7
AVG	89067	94346	-7.2	-0.1	-3.9	-3.0	-2.9
STD	17822	14312	9.7	9.6	7.5	6.1	6.6
MAX	137110	135326	11.5	16.6	11.6	9.8	10.0
MIN	61470	77431	-26.6	-17.7	-18.7	-15.8	-17.4

NOTE :
1. **AVG1 = Mean relative errors for period May-Jun.**
2. **AVG2 = Mean relative errors for period Jul-Aug.**
3. **AVG3 = Mean relative errors for period Sep-Oct.**
4. **AVGS = Mean relative errors for period May-Oct.**
5. **(Observed-Simulated)/Observed is termed as Percentage of Error.**

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STATISTICAL ERROR ANALYSIS

DATA : DISCHARGES
RIVER : UPPER MEGHNA
STATION : 273 BHAIRAB BAZAR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	12100	12023	0.64	12.8	4.8	23.9	13.5
1966	14400	13724	4.69	-9.9	7.8	26.8	12.3
1967	12700	11835	6.81	-36.9	-6.4	7.0	-6.8
1968	13300	13770	-3.53	-12.3	-4.2	8.4	-1.3
1969	11500	13435	-16.83	-32.8	-16.1	18.8	-4.6
1970	16400	13616	16.98	-8.3	2.0	18.8	6.5
1972	11500	13286	-15.53	-8.0	-6.1	16.7	0.4
1973	12400	17004	-37.13	-31.3	-3.0	25.7	0.9
1974	19500	11662	40.19	14.3	31.9	38.9	31.2
1975	12700	13405	-5.55		10.1	14.1	
1976	16700	17860	-6.95		-0.9	7.7	
1977							
1978							
1979							
1980							
1981	11200	13017	-16.22		7.6	7.4	
1982	13500	12974	3.90		0.8	35.9	
1983	16000	17477	-9.23		7.2	18.4	
1984	13600	15031	-10.52		16.7	10.5	
1985	14300	12297	14.01			11.9	
1986	11100	11483	-3.45	0.9	-21.1	-1.2	-8.3
1987	15200	15681	-3.16	-39.8	4.3	13.7	2.9
1988	19800	19592	1.05	1.7	3.0	5.5	3.6
1989	15500	15276	1.45		3.3	0.8	
AVG	14170	14222	-1.9	-12.5	2.2	15.5	4.2
STD	2485	2220	15.1	18.0	11.1	10.5	10.4
MAX	19800	19592	40.2	14.3	31.9	38.9	31.2
MIN	11100	11483	-37.1	-39.8	-21.1	-1.2	-8.3

NOTE :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. (Observed-Simulated)/Observed is termed as Percentage of Error.

STATISTICAL ERROR ANALYSIS

DATA : DISCHARGES
RIVER : OLD BRAHMAPUTRA
STATION : 228.5 NILUKHIRCHAR

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	3230	2655	17.80	64.6	32.7	52.4	44.3
1966	3490	3669	-5.13	51.0	28.3	42.6	37.1
1967	3000	3339	-11.30	60.4	25.9	57.0	41.2
1968	2810	2478	11.81	45.4	30.9	47.2	38.7
1969	2770	2261	18.38	42.0	38.9	59.6	45.7
1970	3250	3407	-4.83	52.5	24.2	45.9	36.1
1972							
1973							
1974	3820	4234	-10.84	25.5	18.2	37.1	25.5
1975	3060	2535	17.16	56.5	43.8	57.4	50.2
1976	3210	3051	4.95	40.5	35.2	62.1	43.0
1977	3550	2795	21.27	41.9	33.5	48.7	40.3
1978	2770	2371	14.40	35.9	50.1	55.0	48.6
1979	2630	2635	-0.19	53.5	14.9	23.3	21.1
1980	3340	4642	-38.98	34.7	-5.7	42.9	15.5
1981	2690	2958	-9.96	20.6	7.8	26.9	15.0
1982	2470	2933	-18.74	33.9	19.1	22.3	22.6
1983	2360	2951	-25.04	42.8	21.9	6.2	18.6
1984	4750	3920	17.47		13.4	29.5	
1985	3070	3663	-19.32			32.4	
1986	1930	2243	-16.22	-11.1	22.6	17.6	17.5
1987	3210	4101	-27.76	-53.6	-5.4	19.8	0.7
1988	4890	5773	-18.06	-29.7	-6.8	14.8	-1.5
1989	2160	3196	-47.96	-100.0	-45.6	-49.6	-54.7
AVG	3112	3264	-6.0	25.4	19.0	34.1	25.3
STD	701	851	19.3	41.2	20.9	24.2	23.7
MAX	4890	5773	21.3	64.6	50.1	62.1	50.2
MIN	1930	2243	-48.0	-100.0	-45.6	-49.6	-54.7

NOTE :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. (Observed-Simulated)/Observed is termed as Percentage of Error.

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STATISTICAL ERROR ANALYSIS

DATA : DISCHARGES
RIVER : GORAI-MADHUMATI
STATION : 99 GORAI RB

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	4770	4470	6.29	70.1	22.0	14.5	23.5
1966	5850	4748	18.84	65.9	17.4	16.6	20.3
1967	6880	5359	22.11	47.9	16.9	18.4	18.9
1968	6280	4920	21.66	20.2	12.7	5.0	10.2
1969	7560	5991	20.75	5.0	12.1	5.2	8.8
1970	5070	4675	7.79	2.4	0.3	-4.9	-1.9
1972	5040	4388	12.94	-36.4	12.5	12.1	10.4
1973	7190	5269	26.72	16.4	23.3	22.2	22.3
1974	8460	5755	31.97	44.6	27.9	13.0	23.3
1975	5970	5462	8.51	40.2	5.3	-3.4	3.0
1976	6620	6456	2.48	39.1	3.2	-3.2	1.7
1977	5890	5263	10.65	32.2	6.4	1.8	5.8
1978	6960	6625	4.81	39.3	0.9	-7.1	0.5
1979	4250	4524	-6.45	79.9	-1.1	8.1	6.6
1980	6570	6176	6.00	63.2	3.0	-3.4	3.7
1981	6630	5218	21.30	43.1	10.3	2.5	7.8
1982	6810	6487	4.74	9.1	0.7	-9.9	-3.8
1983	7470	6181	17.26	28.0	5.6	6.2	6.4
1984	6050	5961	1.47	21.6	-5.4	-3.8	-2.3
1985	6290	5201	17.31	48.3	-0.9	-5.0	-1.8
1986	5230	5613	-7.32	-45.3	-20.1	-17.9	-19.4
1987	7500	7789	-3.85	56.3	4.4	-3.3	1.8
1988	8490	8076	4.88	-27.9	2.4	-10.1	-2.8
1989	4500	4100	8.89	-94.5	2.1	-2.1	-2.8
AVG	6347	5613	10.8	23.7	6.7	2.1	5.8
STD	1127	985	10.2	40.1	10.1	9.9	10.1
MAX	8490	8076	32.0	79.9	27.9	22.2	23.5
MIN	4250	4100	-7.3	-94.5	-20.1	-17.9	-19.4

NOTE :
1. AVG1 = Mean relative errors for period May-Jun.
2. AVG2 = Mean relative errors for period Jul-Aug.
3. AVG3 = Mean relative errors for period Sep-Oct.
4. AVGS = Mean relative errors for period May-Oct.
5. (Observed-Simulated)/Observed is termed as Percentage of Error.

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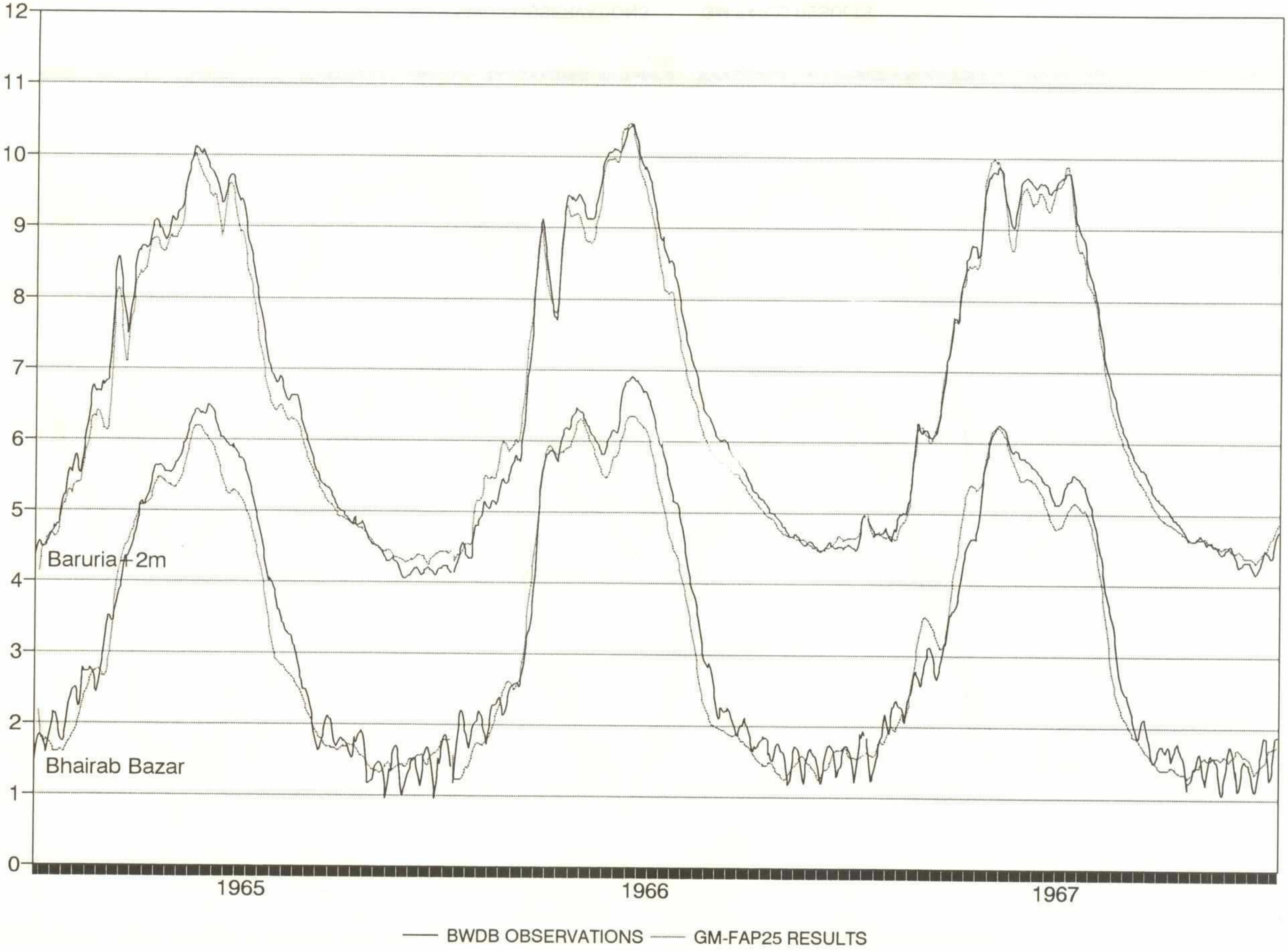
STATISTICAL ERROR ANALYSIS

DATA : DISCHARGES
RIVER : GORAI-MADHUMATI
STATION : 101 KAMARKHALI

YEARS	PEAK OBS	PEAK RUN6	PEAK	AVG1	AVG2	AVG3	AVGS
1965	3090	4446	-43.88	61.2	-19.9	-20.1	-11.6
1966	5660	4750	16.08	61.2	7.2	6.0	10.1
1967	4700	5414	-15.19	47.3	-14.5	-18.2	-13.0
1968	5090	4892	3.89	18.6	-2.3	-9.7	-3.8
1969	5290	6046	-14.29	-6.2	-11.8	-6.1	-8.9
1970	5550	4677	15.73	9.1	8.6	1.1	5.4
1972	4330	4400	-1.62	-14.5	3.3	-5.5	-1.7
1973	5830	5275	9.52	-6.5	5.4	4.4	4.2
1974	7960	5756	27.69	28.4	15.7	3.9	11.7
1975	6420	5416	15.64	45.2	-3.3	-11.2	-4.6
1976	6620	6375	3.70	25.6	4.2	3.5	4.6
1977	6440	5263	18.28	38.2	6.7	4.8	7.5
1978	6320	6561	-3.81	41.9	-4.2	-12.9	-4.1
1979	4740	4530	4.43	80.4	0.2	4.1	5.8
1980	6590	6170	6.37	59.8	13.2	-8.2	7.1
1981	5920	5175	12.58	22.2	6.9	-18.0	-2.5
1982	5510	6430	-16.70	-9.6	-12.1	-15.8	-13.8
1983	5880	6198	-5.41	31.5	-10.4	-5.4	-6.3
1984	5640	6087	-7.93	11.5	-5.3	-7.2	-4.7
1985	5070	5169	-1.95	44.9	-14.4	-18.1	-14.9
1986							
1987							
1988							
1989							
AVG	5633	5452	1.2	29.5	-1.3	-6.4	-1.7
STD	995	691	15.7	26.0	9.8	8.8	8.1
MAX	7960	6561	27.7	80.4	15.7	6.0	11.7
MIN	3090	4400	-43.9	-14.5	-19.9	-20.1	-14.9

NOTE :
1. **AVG1 = Mean relative errors for period May-Jun.**
2. **AVG2 = Mean relative errors for period Jul-Aug.**
3. **AVG3 = Mean relative errors for period Sep-Oct.**
4. **AVGS = Mean relative errors for period May-Oct.**
5. **(Observed-Simulated)/Observed is termed as Percentage of Error.**

COMPARISON HYDROGRAPHS FOR WATER LEVELS



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Baruria + 2m
Bhairab Bazar
1965
1966
1967
BWDB OBSERVATIONS
GM-FAP25 RESULTS

A.7-48

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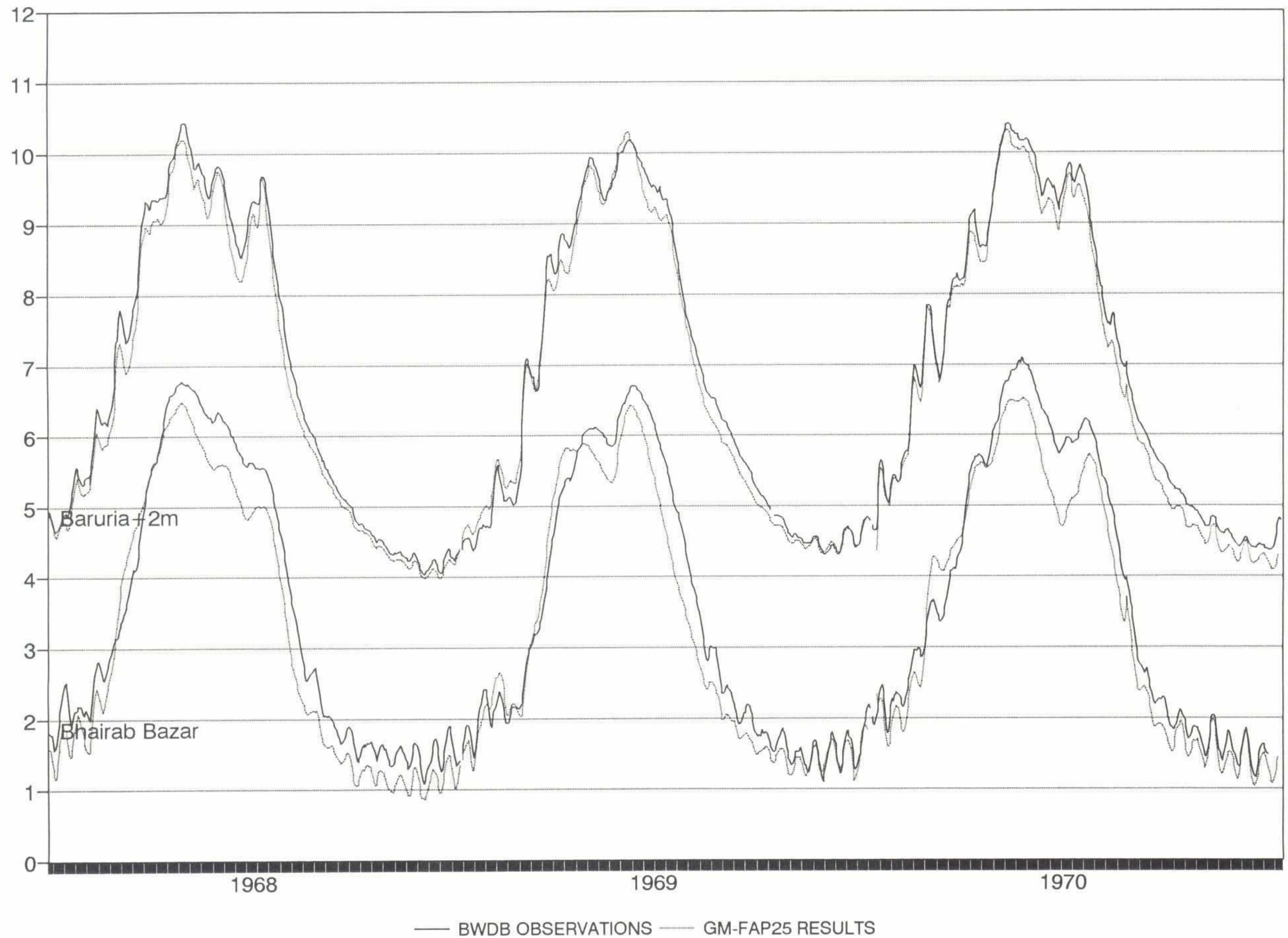
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Baruria+2m
Bhairab Bazar
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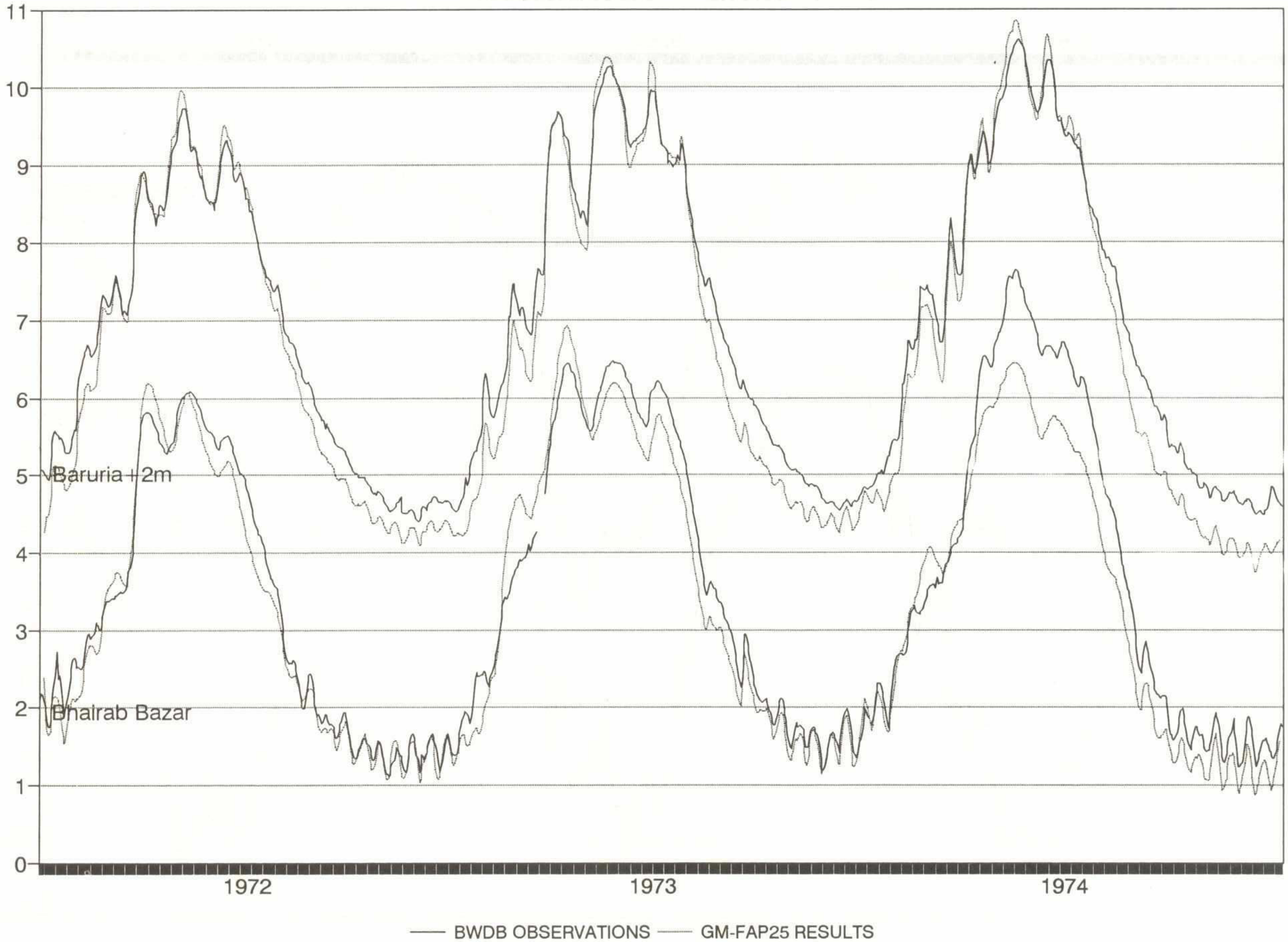
1970
BWDB OBSERVATIONS
GM-FAP25 RESULTS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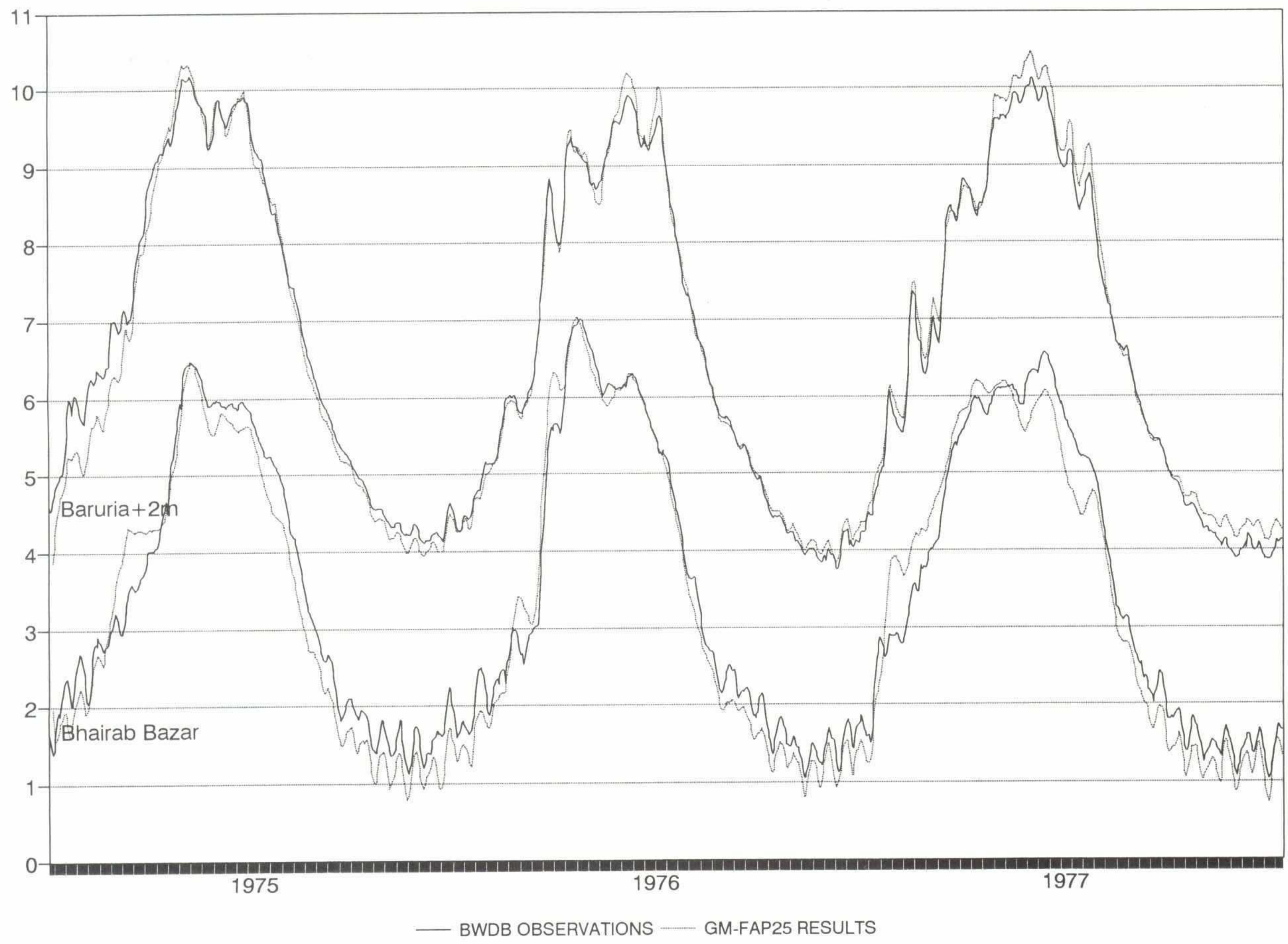
Baruria + 2m
Bhairab Bazar
1972
1973
1974
BWDB OBSERVATIONS
GM-FAP25 RESULTS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Baruria+2m
Bhairab Bazar
1975
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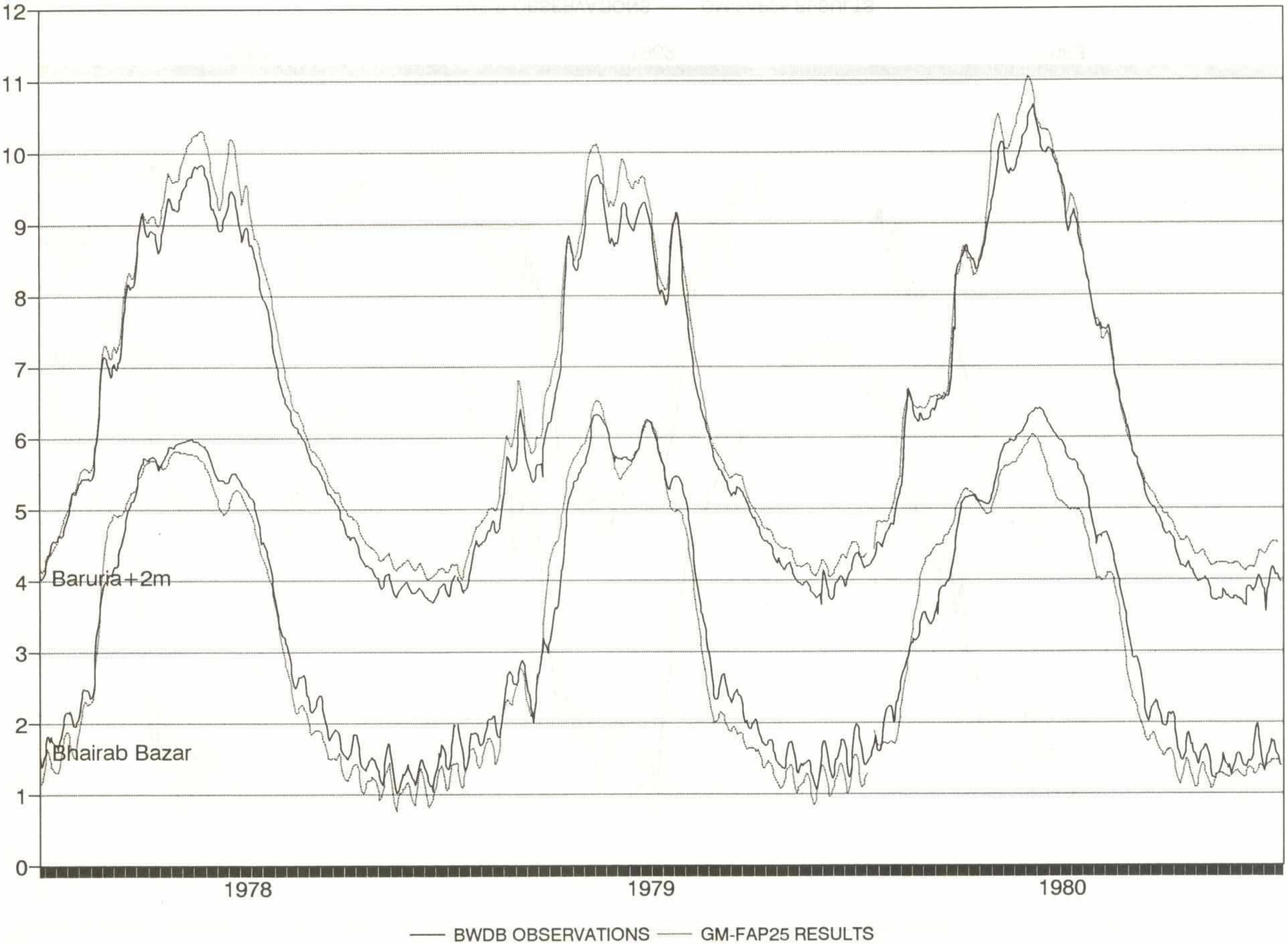
1977
BWDB OBSERVATIONS
GM-FAP25 RESULTS



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Baruria+2m
Bhairab Bazar
1978
1979
1980
BWDB OBSERVATIONS
GM-FAP25 RESULTS

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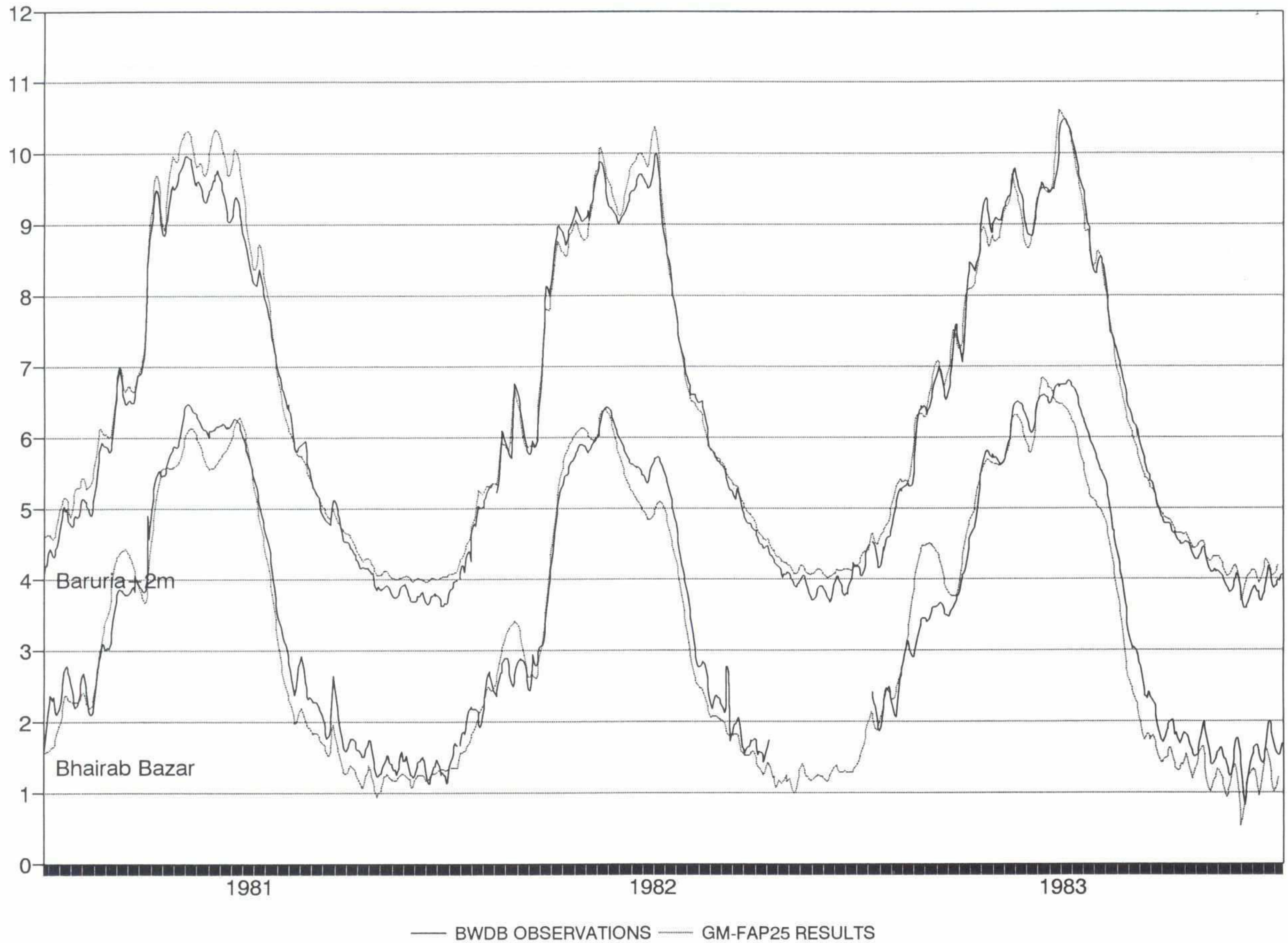

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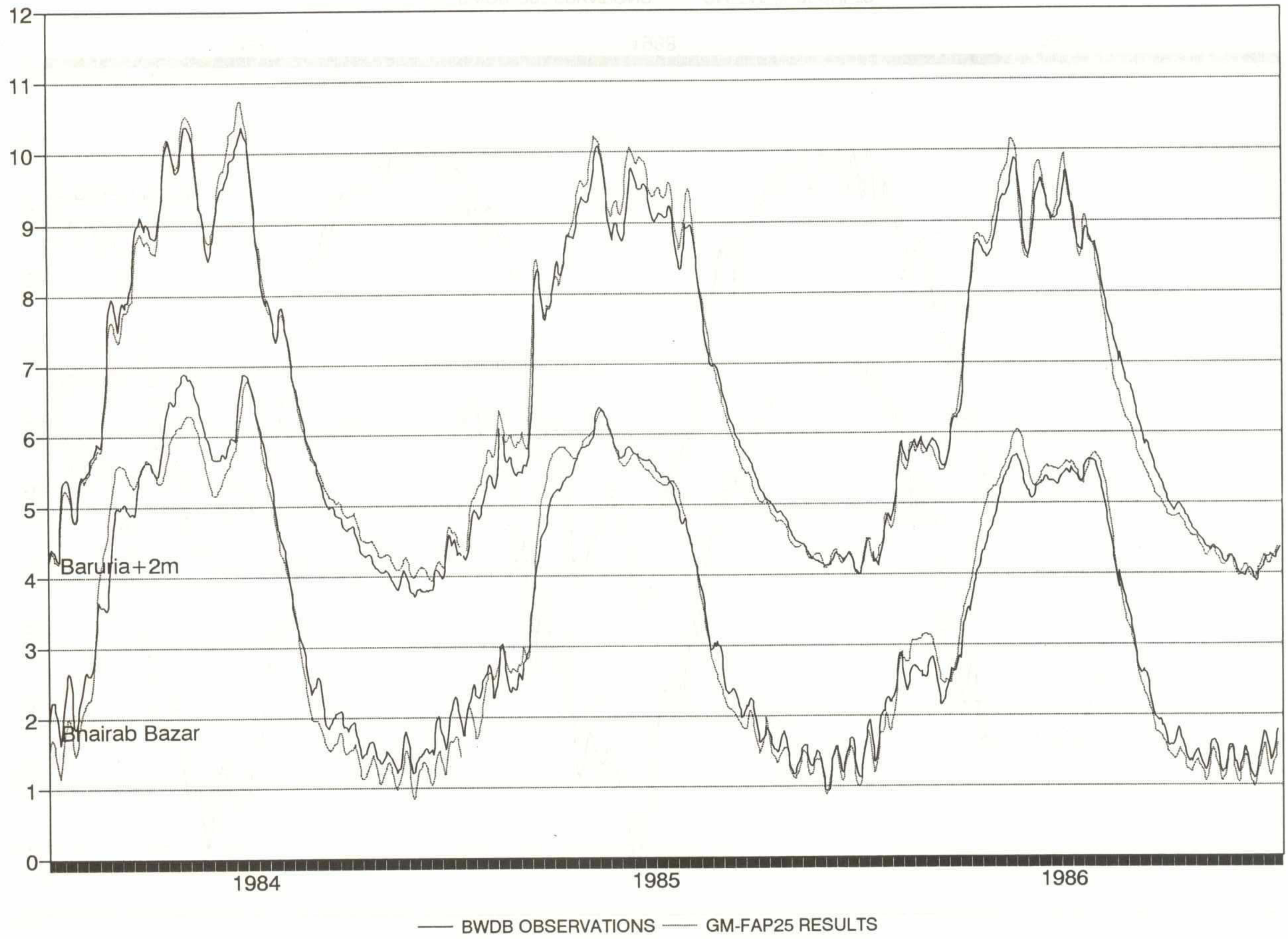
Baruria + 2m
Bhairab Bazar
1981
1982
1983
BWDB OBSERVATIONS
GM-FAP25 RESULTS



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Baruria+2m
Bhairab Bazar
1984
1985
1986
BWDB OBSERVATIONS
GM-FAP25 RESULTS

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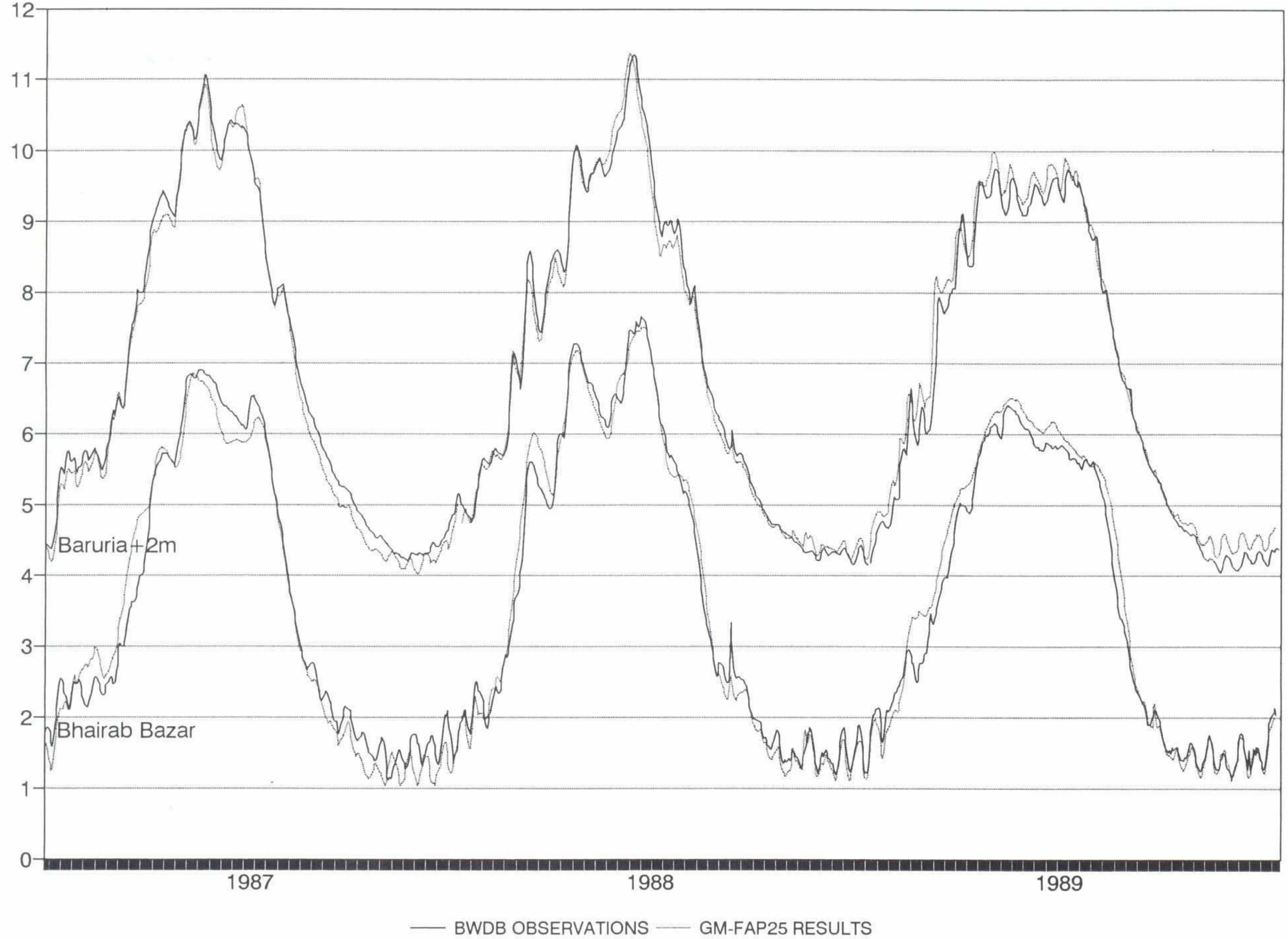

Baruria+2m
Bhairab Bazar
1987
1988
1989
BWDB OBSERVATIONS
GM-FAP25 RESULTS

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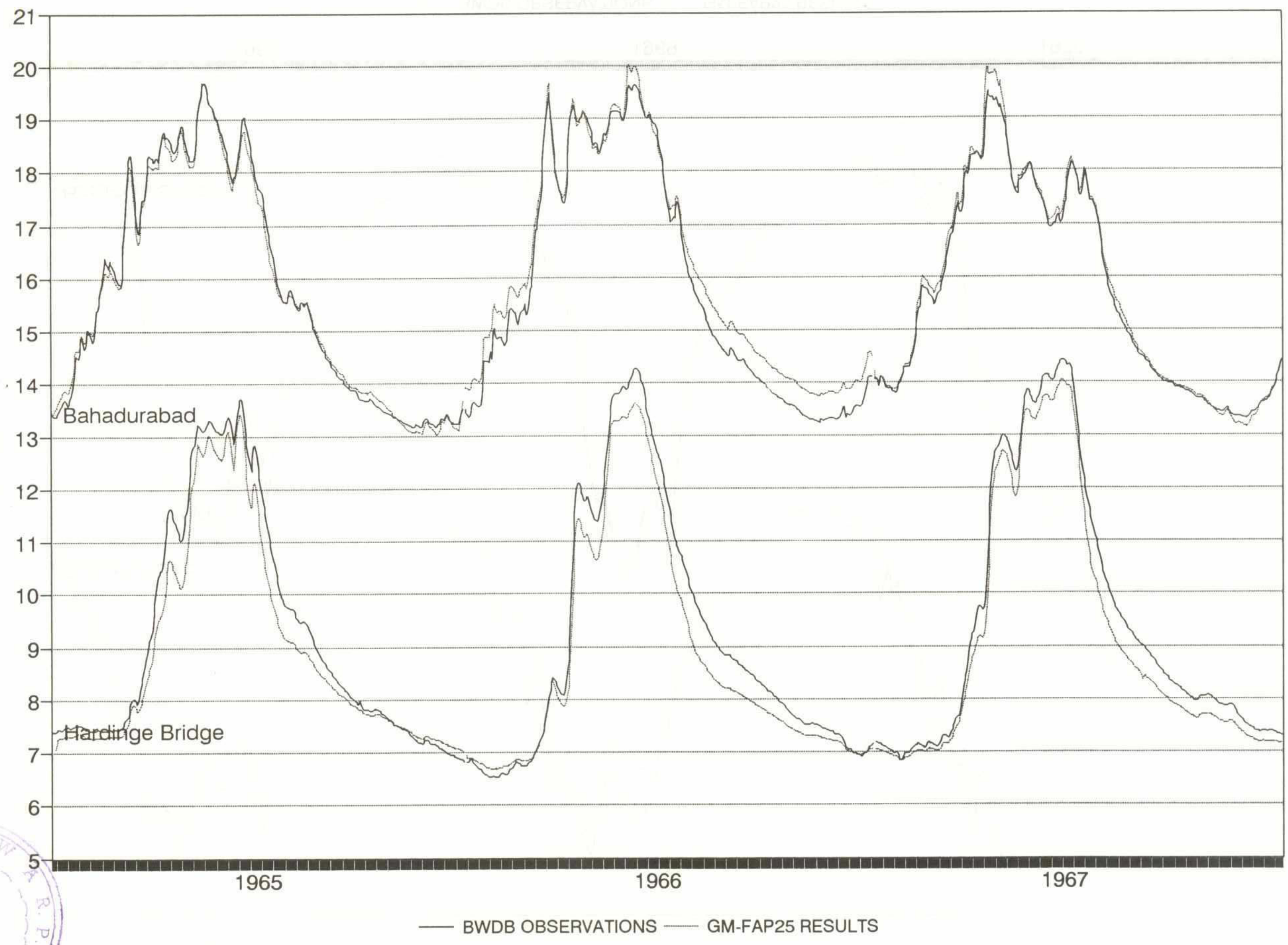

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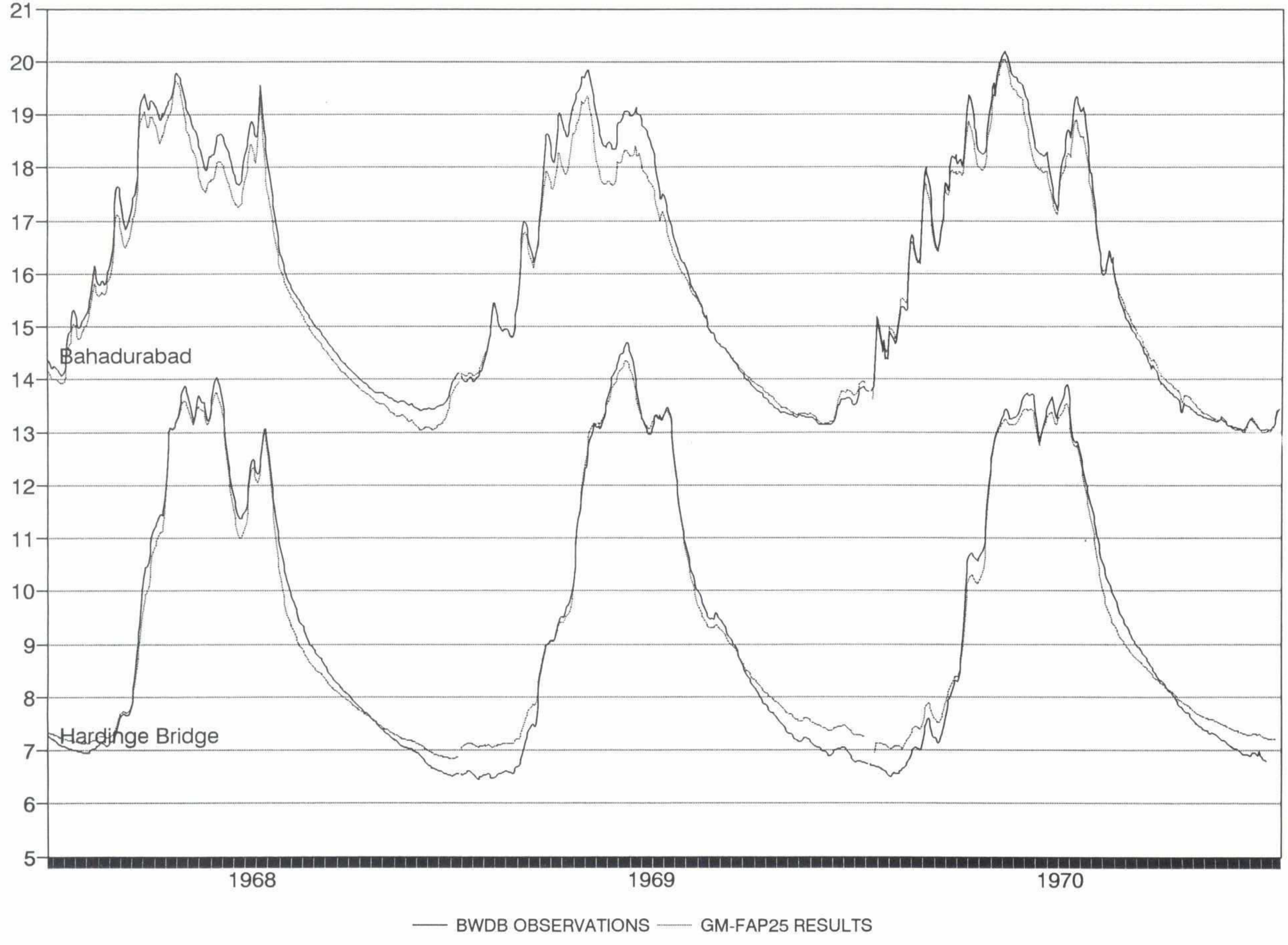
Bahadurabad
Hardinge Bridge
1965
1966
1967
BWDB OBSERVATIONS
GM-FAP25 RESULTS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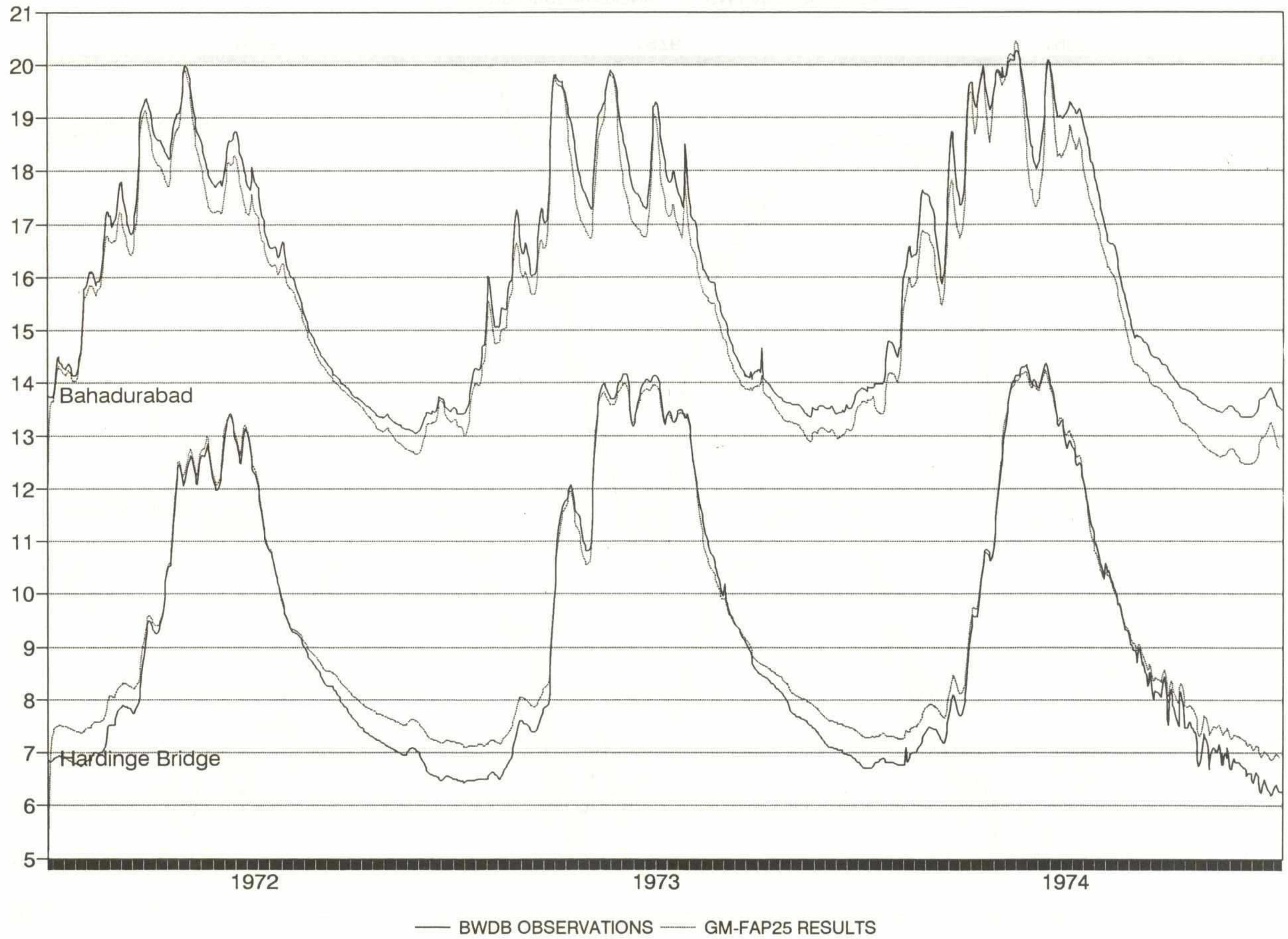
Bahadurabad
Hardinge Bridge
1968
1969
1970
BWDB OBSERVATIONS
GM-FAP25 RESULTS



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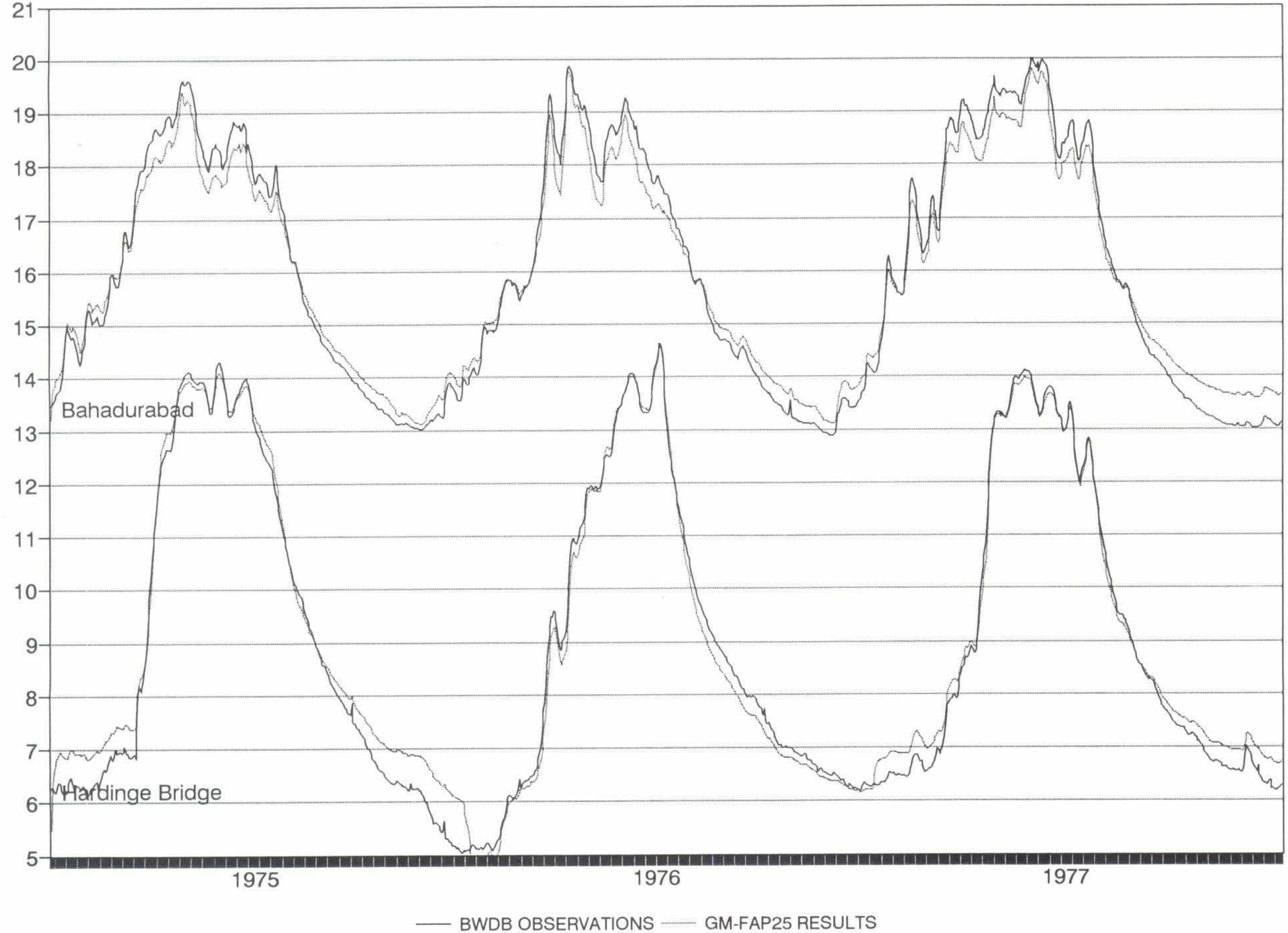
Bahadurabad
Hardinge Bridge
1972
1973
1974
BWDB OBSERVATIONS
GM-FAP25 RESULTS

A.7-58

270

203



21
20
19
18
17
16
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12
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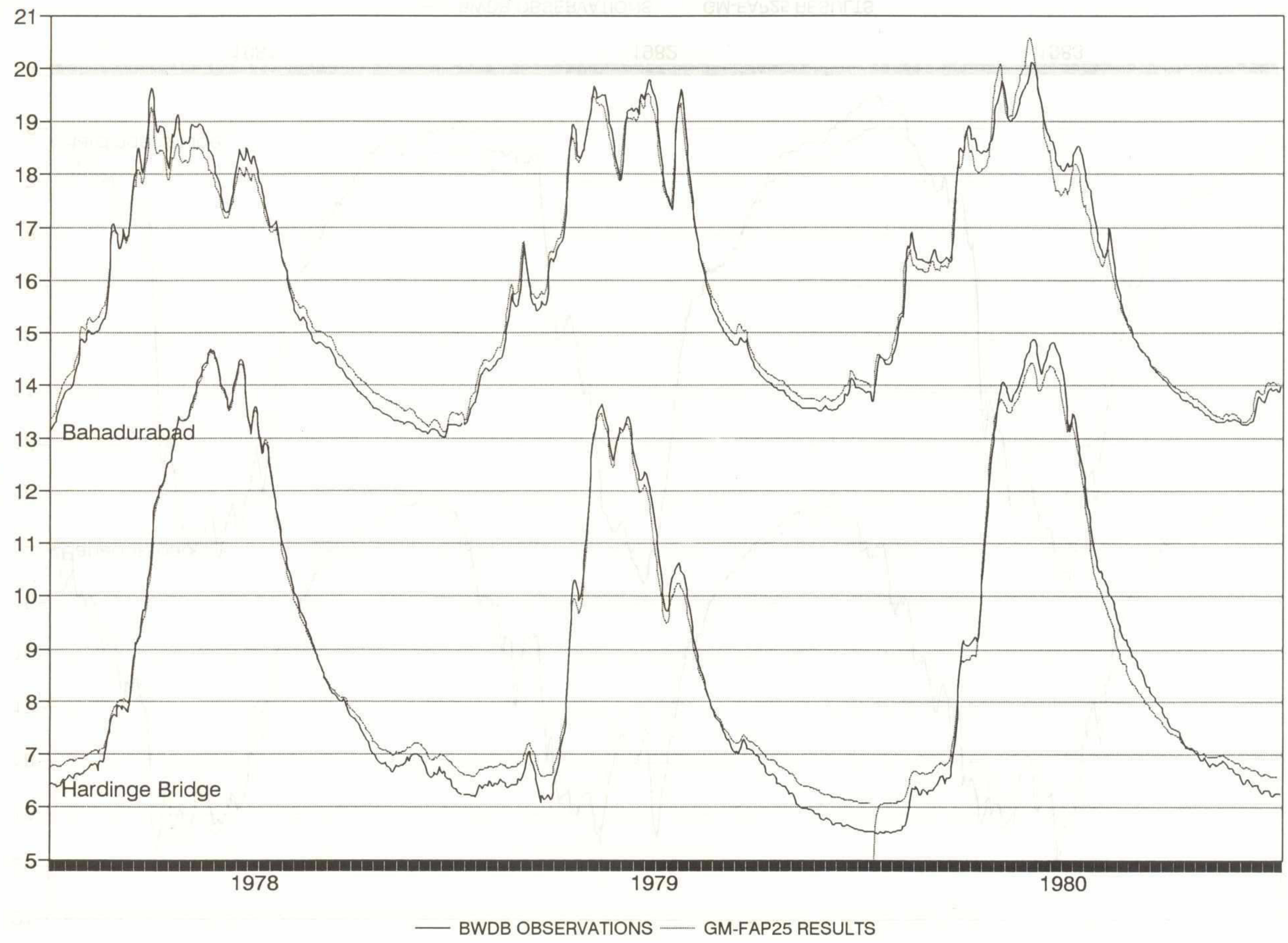
Bahadurabad
Hardinge Bridge
1975
1976
1977
BWDB OBSERVATIONS
GM-FAP25 RESULTS

A.7-59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19
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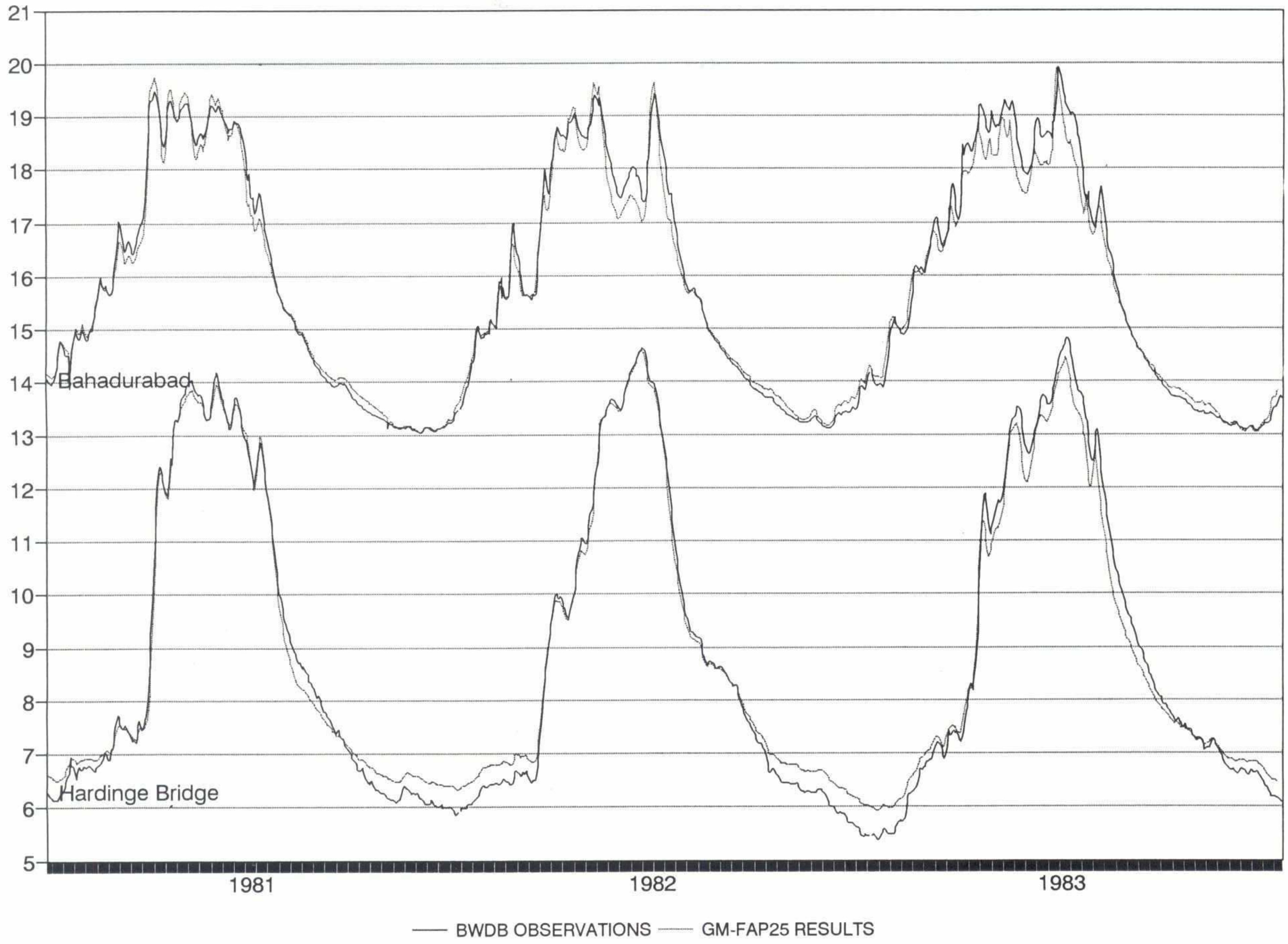
Bahadurabad
Hardinge Bridge
1978
1979
1980
BWDB OBSERVATIONS
GM-FAP25 RESULTS



21
20
19
18
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16
15
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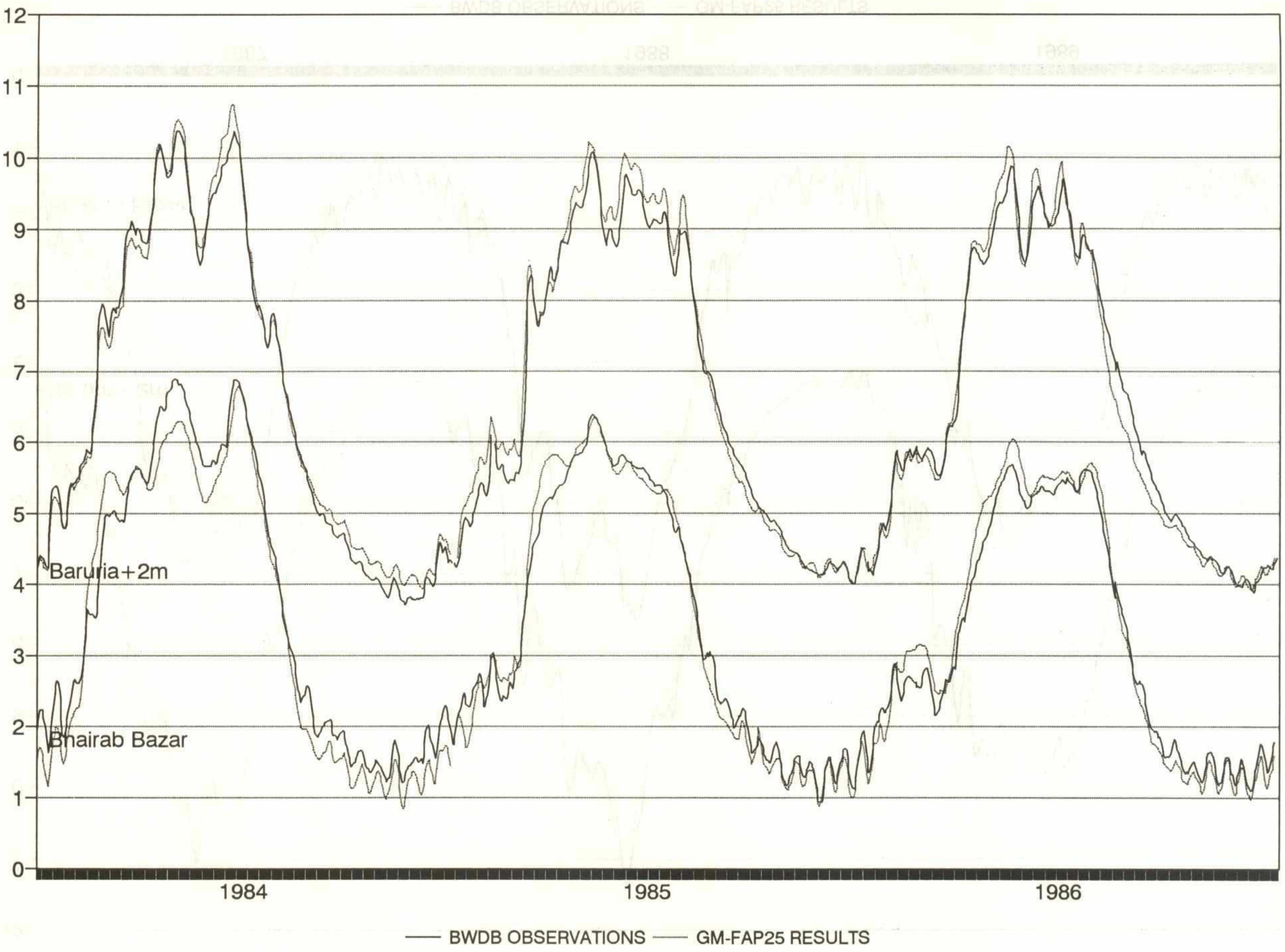
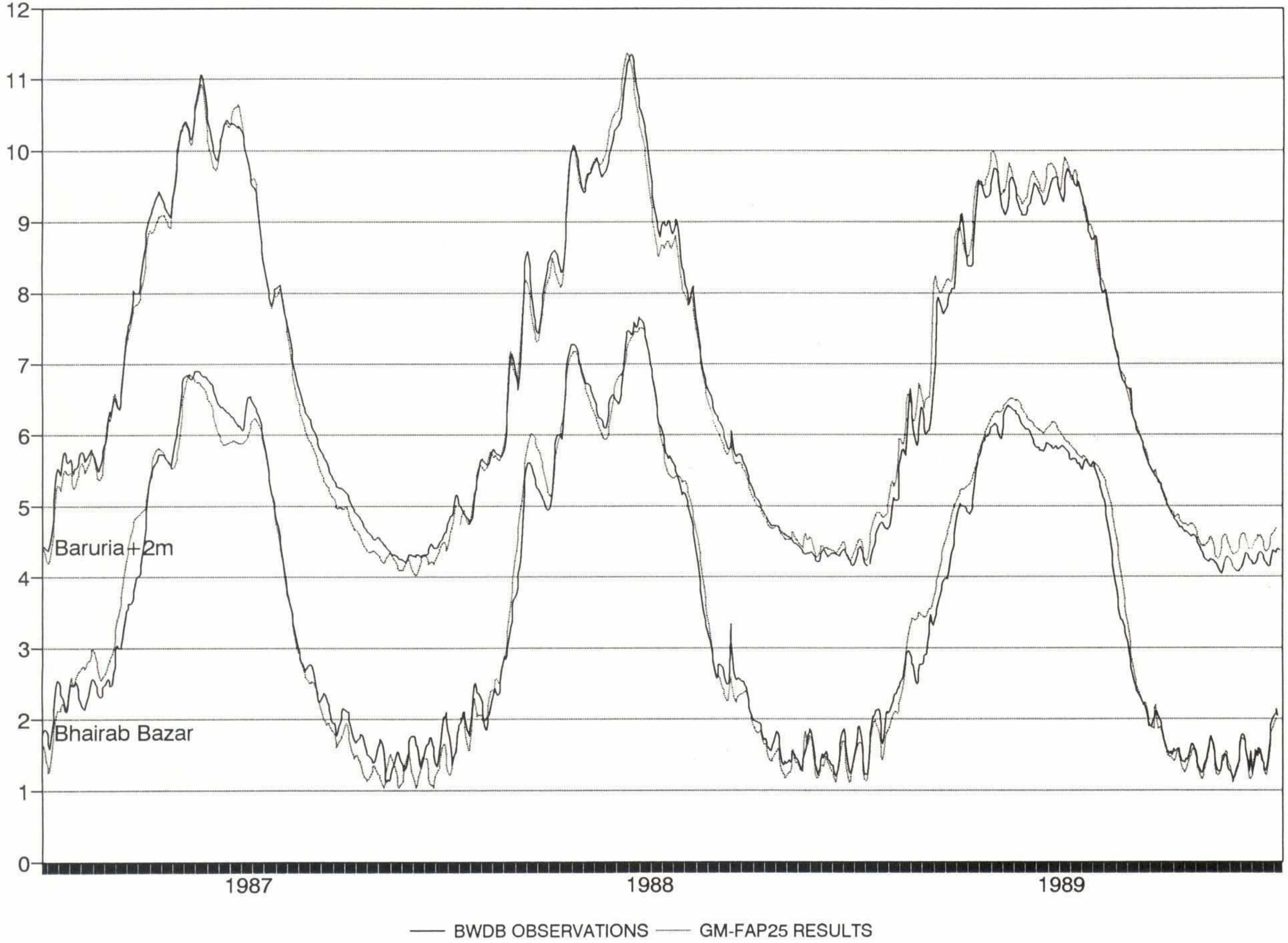
13
12
11
10
9
8
7
6
5
Bahadurabad
Hardinge Bridge
1981
1982
1983
BWDB OBSERVATIONS
GM-FAP25 RESULTS

A.7-61



12
11
10
9
8
7
6
5
4
3
2
1
0
Baruria+2m
Bhairab Bazar
1984
1985
1986
BWDB OBSERVATIONS
GM-FAP25 RESULTS


12
11
10
9
8
7
6
5
4
3
2
1
0
Baruria+2m
Bhairab Bazar
1987
1988
1989
BWDB OBSERVATIONS
GM-FAP25 RESULTS

APPENDIX 8

FAP 25 - GM
Model Schematization

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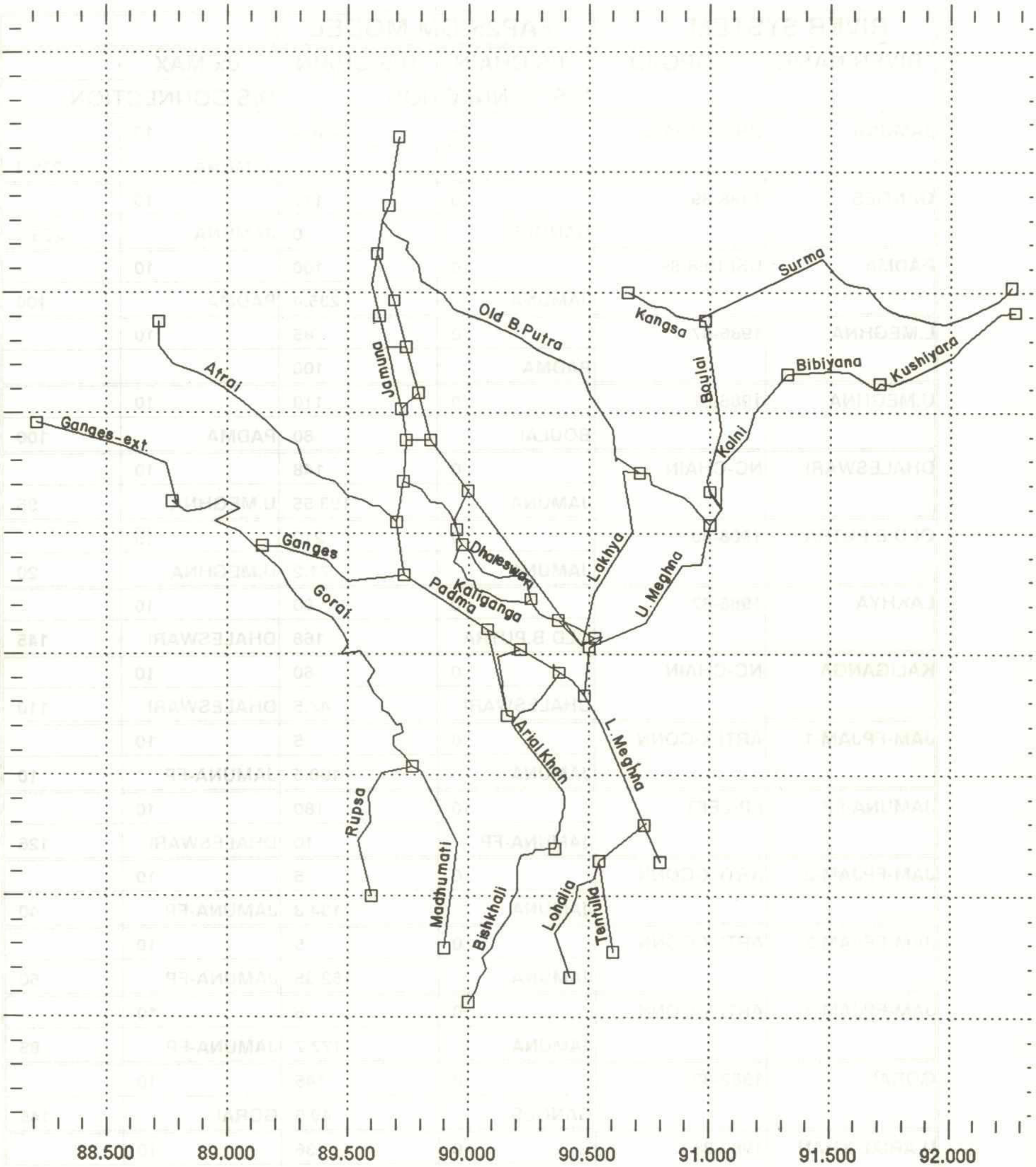
Appendix 8 provides on p. A.8-2 a graphical illustration of FAP 25 - FM Schematization. On p. A.8-3 to A.8-4 the river system is described in terms of upstream and downstream chainages of connections between the individual rivers.



FAP25-GM Schematization

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RIVER SYSTEM		FAP25-GM MODEL			
RIVER NAME	TOPO-ID	U/S CHAIN	D/S CHAIN	dx-MAX	
		U/S CONNECTION		D/S CONNECTION	
JAMUNA	BRTS-CHAIN	25	235.4	10	
				JAMUNA	235.4
GANGES	1988-89	0	117	10	
		GANGES	0	JAMUNA	235.4
PADMA	USED88-89	0	100	10	
		JAMUNA	235.4	PADMA	100
L.MEGHNA	1986-87	0	85	10	
		PADMA	100		
U.MEGHNA	1986-87	0	110	10	
		BOULAI	80	PADMA	100
DHALESWARI	NC-CHAIN	0	148	10	
		JAMUNA	193.55	U.MEGHNA	95
OLD B.PUTRA	1988-89	0	212	15	
		JAMUNA	71.2	U.MEGHNA	20
LAKHYA	1986-87	0	90	10	
		OLD B.PUTRA	168	DHALESWARI	145
KALIGANGA	NC-CHAIN	0	60	10	
		DHALESWARI	47.5	DHALESWARI	110
JAM-FPJAM-1	ARTI X-CONN	0	5	10	
		JAMUNA	100.5	JAMUNA-FP	10
JAMUNA-FP	FP-LEFT	10	180	10	
		JAMUNA-FP	10	DHALESWARI	126
JAM-FPJAM-2	ARTI X-CONN	0	5	10	
		JAMUNA	134.3	JAMUNA-FP	40
JAM-FPJAM-3	ARTI X-CONN	0	5	10	
		JAMUNA	162.35	JAMUNA-FP	60
JAM-FPJAM-4	ARTI X-CONN	0	5	10	
		JAMUNA	177.7	JAMUNA-FP	85
GORAI	1982-83	0	145	10	
		GANGES	49.5	GORAI	145
U ARIAL KHAN	1987-88	0	36	10	
		PADMA	60	ARIAL KHAN	36

RIVER SYSTEM		FAP25-GM MODEL			
RIVER NAME	TOPO-ID	U/S CHAIN	D/S CHAIN	dx-MAX	
		U/S CONNECTION		D/S CONNECTION	
ARIAL KHAN	1987-88	0	125	13	
		PADMA	80	BISHKHALI	0
SURMA	USED88-89	0	157	10	
				SURMA	157
KANGSHA	1986-87	0	60	10	
				SURMA	157
BOULAI	1986-87	0	80	10	
		SURMA	157	BOULAI	80
KUSHIYARA	1978-79	0	60	10	
				KUSHIYARA	60
BIBIYANA	1978-79	0	40	10	
		KUSHIYARA	60	KALNI	0
KALNI	1986-87	0	55	10	
		KALNI	0	BOULAI	80
ATRAI	1978-79	0	150	10	
				JAMUNA	213.4
RUPSA	1986-87	0	65	10	
		GORAI	145		
MADHUMATI	1982-83	0	100	10	
		GORAI	145		
BISHKHALI	1980-81	0	96	13	
		BISHKHALI	0		
TENTULIA	1986-87	0	70	10	
		L.MEGHNA	65		
LOHALIA	1986-87	0	60	10	
		TENTULIA	35		
PADMA-A.KHAN	SPILL-RIGHT	0	50	10	
		PADMA	43	A.KHAN	36
DHA-FPJAM-1	ARTI-CONN	0	5	10	
		DHALESWARI	36	JAMUNA-FP	115
GANGES-EXT	1988-89	0	97	10	
				GANGES	0

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APPENDIX 9

Safety Margin Analysis

1. INTRODUCTION

This appendix contains the results of the detailed analysis, which have lead to the recommended safety margin on design water levels, summarized in section 7.5 of the Main Report.

As discussed in Chapter 5 of the Main Report substantial shifts in rating curves from one year to the other are observed for various discharge stations. Such changes are likely caused by morphological processes, in particular gradual changes of bedforms and cross-sectional shapes. The mechanisms of these phenomena is not yet well understood, but the impression is that the last years flood may well have a distinct impact on the rating curve to be adopted for the next year. Hence, this phenomenon causes an additional variation of annual maximum flood levels above the variation related to the particular shape of each flood hydrograph, as would occur in a river with a "fixed bed".

The GM presumes indeed a "fixed bed" of the river with a unique relation between levels and bottom roughness coefficients. This appendix therefore addresses the question to what extent design water levels, as calculated with the "fixed bed" model, should be adjusted to take into account the effect of apparently more or less at random shifting rating curves.

2. METHODOLOGY FOR ASSESSMENT OF SAFETY MARGINS

Variations in water levels for a fixed discharge, due to shifts in rating curves caused by morphological processes, can likely be represented by a normal distribution with zero mean and a standard deviation in the order of 25 cm (20 to 30 cm; see section 5.3.2 of the Main Report). For future annual flood peaks such variations must be considered to be fully statistically independent from the actual floods itself. Hence, its randomness adds up to the standard deviation of the probability distribution of annual maximum water levels, as determined on the basis of simulations with a 'fixed bed' General Model. In other words, if an infinitely large number of flood events is simulated with a "movable bed" model, a larger variance of the annual maximum flood level would be found than it would be the case if the same events are simulated with a "fixed bed" model; the difference being the variance due to morphological processes.

The updating of the GM (January 1992) is likely to produce a close match of the probability distributions of simulated and observed annual maximum water levels for all key-stations. Even then a substantial random error in individually simulated extremes may occur, with a close to zero mean and a standard deviation in the order of 25 cm (section 7.4.1 of the Main Report). It is impossible to determine to what extent such errors are affected by the above discussed morphological phenomena, and to what extent they are due to other errors, e.g. modelling errors, errors in boundary conditions or errors in observed water levels. It is therefore recommended to take the random effects of morphological phenomena separately into account, in addition to the standard errors as derived from simulated and observed maximum water levels. As a consequence, the total safety margin to be added to design water levels consists of:

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- a margin to account for the effects of random morphological processes, as displayed through annual shifts in rating curves;

- a margin to account for possible errors in model calibration, boundary conditions and observed water levels;

- a margin to account for probable underestimation of extreme events due to the shortness of the available record of observations;

- free board to account for wind set-up, wave run-up and other safety requirements.

The last component is left to the judgement of design engineers. The others are discussed in detail in the following.

3. STATISTICAL CHARACTERISTICS OF EXTREME WATER LEVELS

The calculation of safety margins requires the combination of probability distributions of annual maximum water levels, modelling errors and shifts in rating curves. The normal distribution can be applied for the latter two types of errors.

In Appendix 5 various distributions were tested for annual extreme water levels and the log-normal distribution was recommended. However, it was also shown that in the range of design return periods adopted for the FAP, nearly all tested distributions produced more or less the same results. To ease the present analysis, the Gumbel distribution of annual maximum water levels is therefore used here, defined as:

$$P = \exp\{-\exp(-t)\}$$

where:

$$t = (x - U)/B$$

and:

P = probability of non-exceedance
t = reduced Gumbel variate
x = Gumbel distributed variable
U = location parameter
B = scale parameter

The approach is to establish a total safety margin, which can be applied for the whole main river system in Bangladesh. Fortunately, standard modelling errors, see Table 7.2 of the Main Report, and standard deviations of shifts in rating curves , see Table 5.5 of the Main Report, appear to be fairly uniform in space, both in the order of 25 cm.

Variations in annual maximum water levels exhibit a similar uniformity along the main system. Standard deviations are generally in the order of 45 cm, which corresponds to a scale parameter B = 0.35 m for the Gumbel distribution. For the present analysis a Gumbel distribution with zero mean (location parameter U = - 0.20 m) and scale parameter B = 0.35 m is adopted as a uniform probability distribution of annual maximum water levels on the main rivers.

For the elaborations in the following chapters, it is convenient to summarize here a few characteristic data for specific return periods T of the above Gumbel distribution, given a number of observations N = 24.

P	T	t	Xp	Sxp
0.99	100	4.60	1.41	0.29
0.98	50	3.90	1.17	0.25
0.95	20	2.97	1.84	0.20
0.90	10	2.25	.59	0.17
0.57	2.3	.57	0.0 (*)	0.09

(*): the average is set at zero as reference level

The standard deviation Sxp of the estimate Xp reads for the maximum likelihood estimates of the Gumbel distribution parameters:

Sxp = B * SQRT((1.109 + 0.514 t + 0.608 t^2) / N)

Confidence intervals (95%) for the estimates Xp are generally set at about twice the value of Sxp.

4. SAFETY MARGIN FOR MODEL ERRORS AND RANDOM MORPHOLOGICAL PROCESSES

Modelling errors and errors due to the effects of random morphological phenomena are independent random normal processes, which can be treated as a single random normal process by adding the variances of both sources of errors. For maximum flood levels both types of errors have a uniform standard deviation in the order of 25 cm, thus the resulting joint standard deviation will be about SS = 35 cm. This normal distribution should then be combined with the fitted Gumbel distribution of the annual extreme water levels, with a uniform standard deviation in the order of S = 0.45 m, see Chapter 3.

The analysis would be simple in the event of a normal distribution of annual maximum levels to be combined with a random normal error. The result would be that the annual maximum levels remain to be normally distributed, leaving the mean annual maxima unaffected, while the standard deviation of the annual maxima would increase from S to S*, as follows:

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S* = SQRT(S^2 + SS^2)

i.e. from 0.45 to 0.57 m. As a result, the estimated T years annual maximum level should then be increased with a safety margin dXp, accounting for modelling errors and variations due to random morphological processes, equal to:

dXp = tp * (0.57 - 0.45) = 0.12 * tp

where tp represents the standard normal variate, as follows:

P	T	tp	dXp
0.99	100	2.33	0.28
0.98	50	2.05	0.25
0.95	20	1.65	0.20
0.90	10	1.28	0.15

The extent to which this analysis is also valid for a Gumbel distributed annual maximum water level has been tested thoroughly with Monte Carlo simulation technique in a spreadsheet, as follows:

- generation of a random sample of 1,000 Gumbel distributed variates, with location parameter -0.2 and shape parameter 0.35 (standard deviation 0.45), representing the probability distribution of annual maximum water levels;
- generation of a random sample of 1,000 normal distributed variates, with zero mean and standard deviation 0.35, representing random errors due to model errors and random morphological processes;
- summation of both random samples and ranking of the sum in ascending order;
- ranking of the original Gumbel distributed sample in ascending order;
- calculation of the difference between events with a specific return period in both ranked series.

The above sequence of calculations was repeated a number of times and the average difference between events with a specific return period, with and without the effect of random errors, was calculated. Results indicated that the values of dXp, as given in the above table, are only slightly overestimated for return periods of 20 years and higher.

5. SAFETY MARGIN FOR STATISTICAL UNCERTAINTY

Another consideration has been whether a safety margin to account for probable underestimation of extreme events due to the shortness of the available record of observations should be added. Two approaches are considered here.

5.1 Confidence Intervals

To illustrate the issue, it is noted that the 90% confidence interval (1.65 * Sxp ; see Chapter 3) for the 100 year annual maximum level usually ranges from + 45 cm to - 45 cm around the expected level, while in reality there is still a small chance that the expected 100 year annual maximum level turns out to be the 30 year annual maximum. A safety margin of some 25 cm for the 100 year flood maximum and of 15 cm for the 10 year flood maximum (equivalent to the standard deviation of the estimate, Sxp, see Chapter 3) could be taken as a choice for this safety component. This ensures that the adopted 100-year annual maximum proves to be in reality at least not lower than the actual 50 year flood maximum.

A particular issue which has to be considered in this respect is how to use the benefits of the acquired historical information on flood levels, rainfall and river flow data prior to the period of model simulations. In Chapter 6 of the Main Report it is demonstrated that maximum flood levels observed during the last 25 years are at least representative for a period of say 75 years, where statistics for the last 25 years may lead to slightly conservative designs. Confidence intervals around the Gumbel distributions derived from model simulations for the latter period should then be adjusted accordingly, by reducing the standard deviations Sxp of the estimates Xp with a factor SQRT(75/25) = 1.73. This would then reduce the safety margin for statistical uncertainty for the 100 year annual maximum to 15 cm and for the 10 year annual maximum to less than 10 cm.

5.2 Expected Probability

Another approach to account for a probable underestimation of extreme events due to the shortness of the available records is pointed out by various authors. While conventional flood frequency analysis is concerned with providing an unbiased estimate of the magnitude of the design flood level or flow exceeded with a certain probability, sampling properties imply that such estimates will on average be exceeded more frequently. For example, for samples of 24 years the estimated 100-year event will actually be exceeded once in 60 years.

The flood level estimate, computed for a given sample and for a specific return period, is approximately the median of all possible estimates. In other words, there is an approximately equal chance that the true magnitude will be either above or below the estimated magnitude. However, the probability distribution of the estimate is positively skewed, so the average of the magnitudes computed from many samples is larger than the median.

The consequence of the discrepancy between the median and the mean flood estimate is that, if a very large number of estimates of flood magnitude could be made over a region, based on an corresponding number of samples, on average more 100-year floods

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would occur than expected. The expected probability of occurrence of flood events in any year can be estimated for events of nominal return period T by the formulas, from Ref. 1, in Table A.9.1, where N denotes the number of observations. These equations are derived for the normal distribution and apply approximately to the Pearson Type III distribution. The latter produces for Bangladeshi conditions nearly identical results as the log-normal distribution, which is recommended in Chapter 6 of the Main Report for annual extreme water levels.

Table A.9.1: Expected Probability of Occurence of Flood Events in Any Year.

T(Years)	Exceedance Probability	Expected Probability
1000	0.001	0.001 + 0.28/N^1.55
100	0.01	0.01 + 0.26/N^1.16
20	0.05	0.05 + 0.30/N^1.04
10	0.10	0.10 + 0.30/N^1.04
3.33	0.30	0.30 + 0.138/N^.925

To correct for this bias the above equations must be applied in reverse direction. The result is (with some interpolation) that the 180, 80, 25, 11-year flood events in conventional flood frequency analysis should in fact be used to estimate respectively the real 100, 50, 20 and 10-year events.

For conditions along the main rivers in Bangladesh, the above results in upward corrections of design levels of respectively 21, 17, 8 and 4 cm for the above design return periods. Given the representativeness of the last 25 years for the longer term, there may be some reason to reduce these values slightly.

6. RECOMMENDED SAFETY MARGINS

The total safety margin, accounting for model errors, the effects of random morphological processes and the likely underestimation of extreme events, due to the shortness of available records of observations, should be added. For the latter component a margin dH, based on the difference between expected probability and exceedence probability is used.

The results are summarized in Table A.9.2. The recommended total safety margins are denoted with dHmax. In view of the representativeness of the last 25 years for the long term and the slight overestimation of the margin dXp (see Chapter 4), some reduction of the sum of dXp and dH has been applied.

Table A.9.2: Recommended Total Safety Margin, dHmax, for Different Return Periods.

P	T	dXp	dH	sum	dHmax
0.99	100	0.28	0.21	0.49	0.40
0.98	50	0.25	0.17	0.42	0.35
0.95	20	0.20	0.08	0.28	0.25
0.90	10	0.15	0.04	0.19	0.20

The above safety margin dHmax has to be considered within the overall safety requirements including freeboard, cf. Chapter 2.

It is recommended that FPCO takes a decision on this issue at short notice, considering the importance of a unified approach in all FAPs for the assessment of design criteria.

7. REFERENCES

Ref.1 Chow, V.T, Maidment D.R., and Mays, L.W.
Applied Hydrology. McGraw-Hill Book Company. 1988

APPENDIX 10

Model Boundary Data Needed by Regional Studies from FAP 25

Appendix 10 gives a list of stations and sections along the major rivers and important distributaries from which FAP 25-GM data are required by the Regional Studies. The lists are presented from page A.10-2 to A.10-7.

FAP-1 BOUNDARY CONDITIONS

DISCHARGES

POSITION	RIVER	CHAINAGE
Hardinge Bridge	GANGES	35.75
Bahadurabad	JAMUNA	FAP25-GM Jamuna inflow
Bhairab Bazar	MEGHNA	15
Kaunia	TEESTA	FAP25-GM Teesta inflow

WATER LEVEL

POSITION	RIVER	CHAINAGE
Gorai	GORAI	7
Madaripur	ARIAL-KHAN	36
Chandpur	MEGHNA	19.167

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FAP-2 BOUNDARY CONDITIONS

WATER LEVEL		
POSITION	**CROSS SECTION**	**CHAINAGE**
JAMUNA		
Dudhumar outfalls	Out of the General Model	
Dharla outfalls	J-17	25
Teesta outfalls	J-15-1 and J-16	46.6 and 39.4
Gaibanda	J-13	76.6
Phulchari	J-12	91
Sariakhandi	J-11	105.4
Hurasaghar outfalls	J-3 and J-3-1	213.4 and 205.0
GANGES		
Eusupfur		13
Hardinge Bridge		32.5
GANGES EXTENSION		
Mohananda outfalls		18
Rampurboalia		45

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FAP-3 BOUNDARY CONDITIONS

WATER LEVEL		
POSITION	CROSS SECTION	CHAINAGE
PADMA		
	P-0-1	93.25
	P-2-1	60
	P-4-1	36
	P-7	0
JAMUNA		
	J-2	227.8
	J-3	213.4
	J-4-1	188.2
	J-7-1	152.2
	J-9	130.6
	J-11-1	98.2
	J-13-1	71.8
	J-14	64.6
	J-15-1	46.6

27.8

FAP-3.1 BOUNDARY CONDITIONS

WATER LEVEL AND DISCHARGE		
POSITION	CROSS SECTION	CHAINAGE
JAMUNA	J-7 TO J-14-1	64.6 to 188.2
OLD BRAHMAPUTRA	OB-1 TO OB-16	0.0 to 156

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FAP-4 BOUNDARY CONDITIONS

WATER LEVEL AND DISCHARGES		
POSITION	CHAINAGES FOR WATER LEVEL	CHAINAGES FOR DISCHARGES
GANGES	32.5 to 117.0	35.75
PADMA	0.0 to 100.0	11.125
UPPER MEGHNA		0.0 to 110.0
LOWER MEGHNA	0.0 to 85.0	
GORAI	7.0 and 78.0	3.5 and 80.5
ARIAL KHAN	36.0	36.5
RUPSA	0.0, 40.0 and 65.0	3.25, 36.5 and 60.0
BISHKHALI	60.0	57.0

FAP-5 BOUNDARY CONDITIONS

WATER LEVEL AND DISCHARGES		
POSITION	CHAINAGES FOR WATER LEVEL	CHAINAGES FOR DISCHARGES
UPPER MEGHNA		
Bhairab Bazar	20	15
Daudkandi (1)	80	83.75
Satnal	110	106.25
LOWER MEGHNA		
Chandpur	19.167	23.75
Rahmatkhali	65	42
Ramgati (2)	85	80

(1) : Assumed to correspond to Meghna Ferry Ghat.
(2) : Chainage 85 km is Daulat-Khan.
Ramgati is situated 20 km donwstream.

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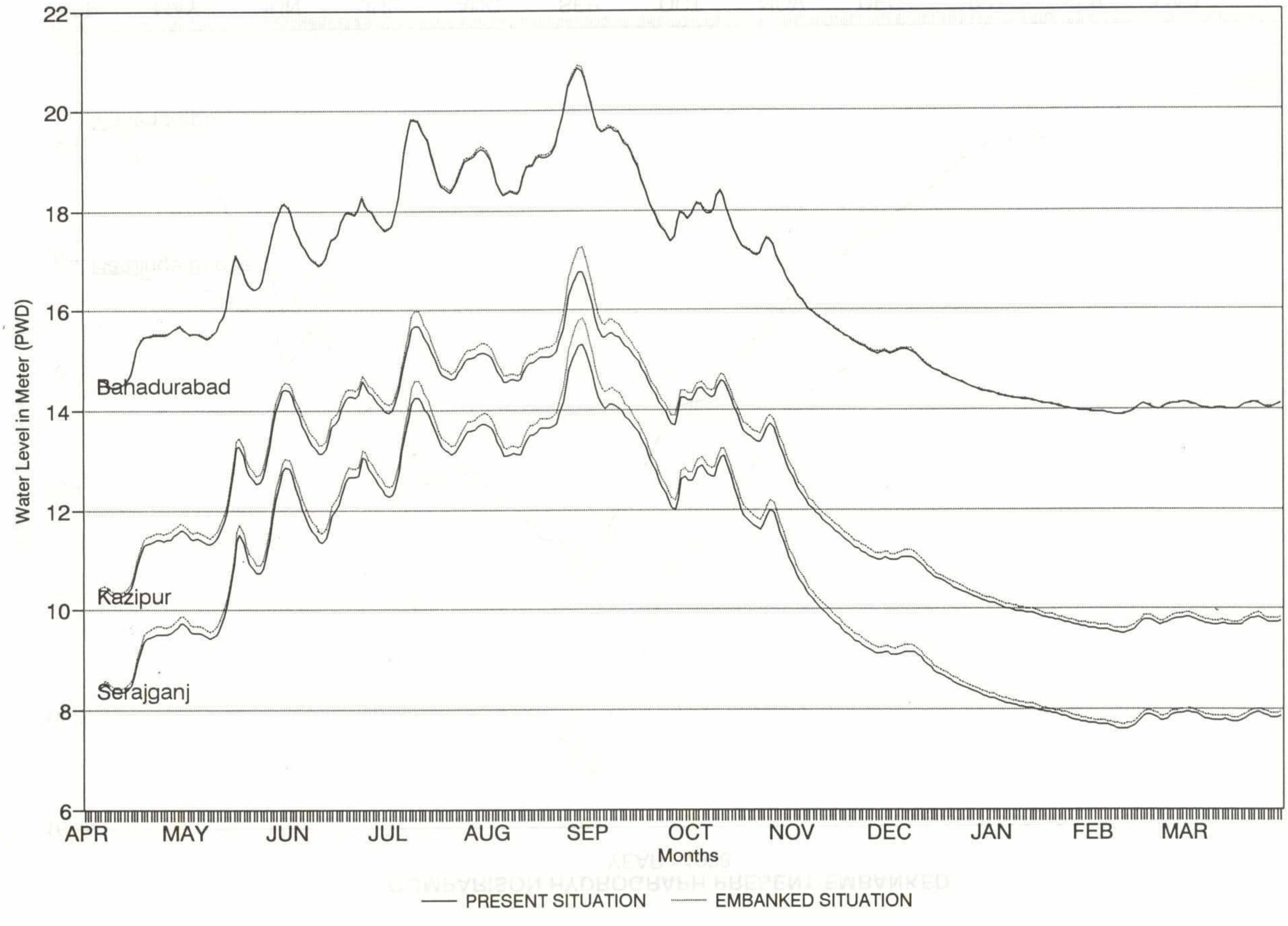
APPENDIX 11

Comparison of Hydrographs under Embanked and Present Situation

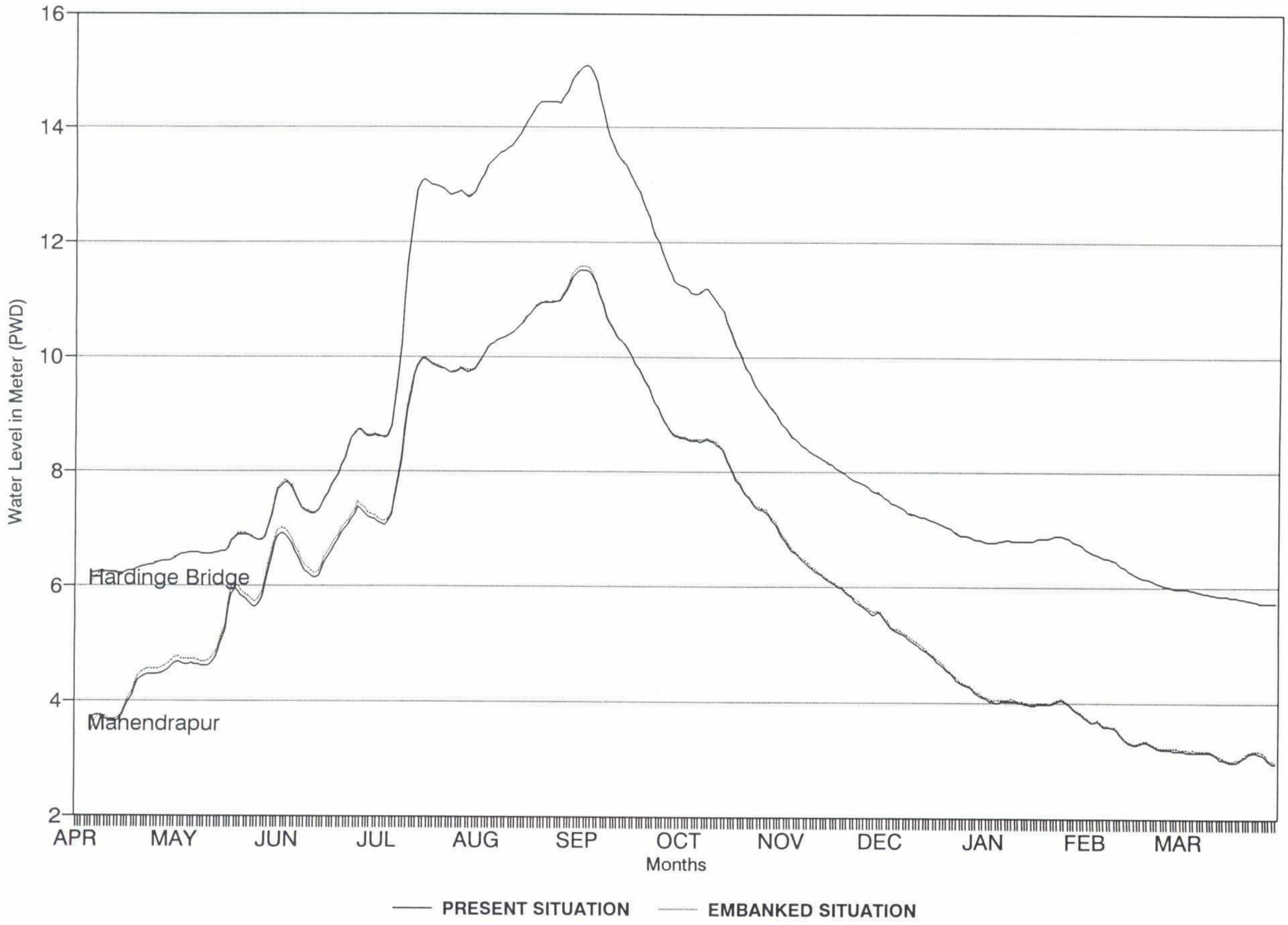
Appendix 11 presents a few plots comparing water level and discharges for important stations under embanked condition along the left bank of Jamuna from the offtake of Old Brahmaputra from Bahadurabad to Kalatia along Dhaleswari-Kaliganga with the present situation of 1988. Water level comparisons are available in pages A.11-2 to A.11-5 and discharge comparison hydrographs are shown in pages A.11-6 to A.11-8.

EFFECT OF EMBANKMENT ON WATER LEVEL

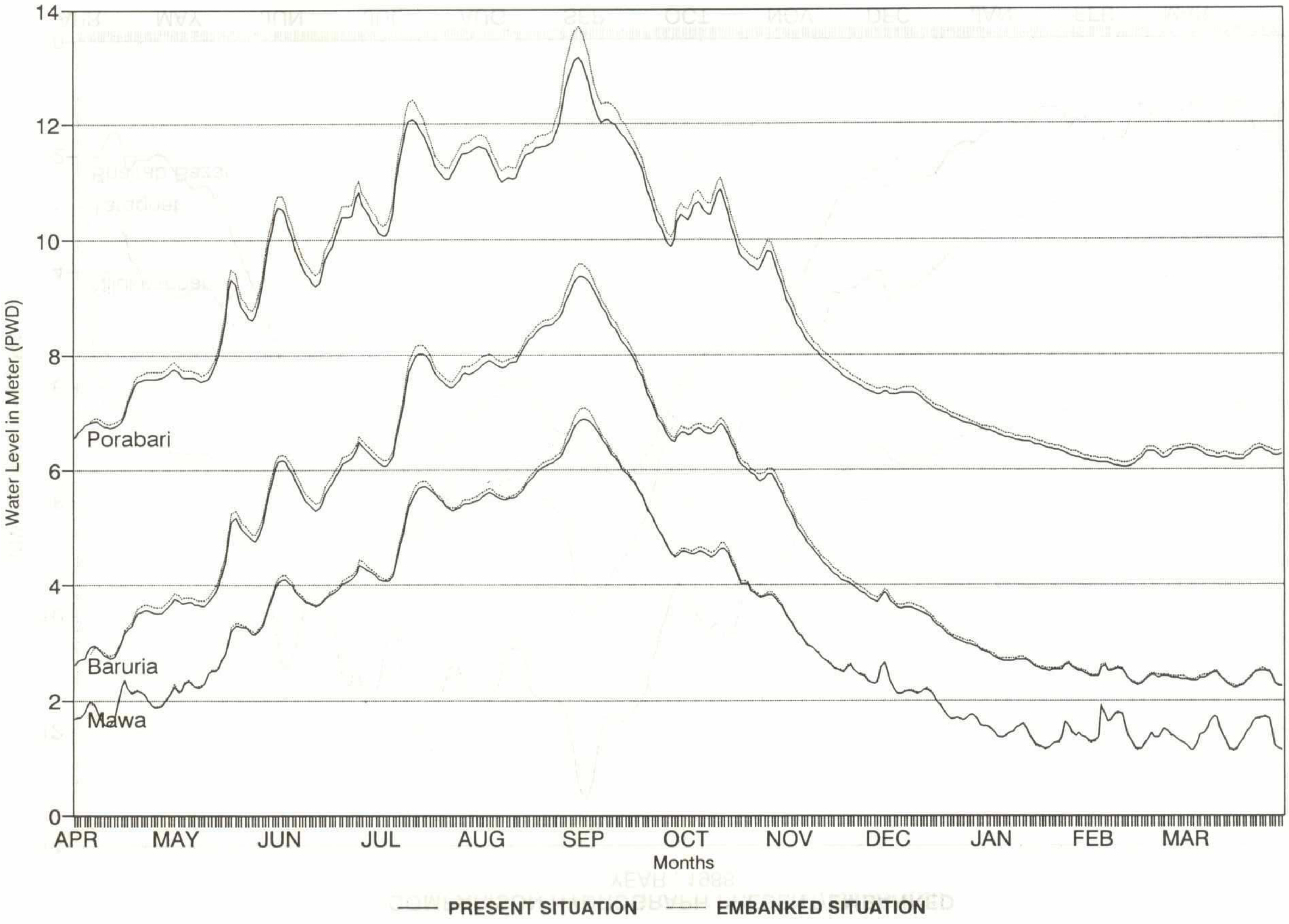
COMPARISON HYDROGRAPH PRESENT/EMBANKED
YEAR : 1988



COMPARISON HYDROGRAPH PRESENT/EMBANKED
YEAR : 1988



COMPARISON HYDROGRAPH PRESENT/EMBANKED
YEAR : 1988



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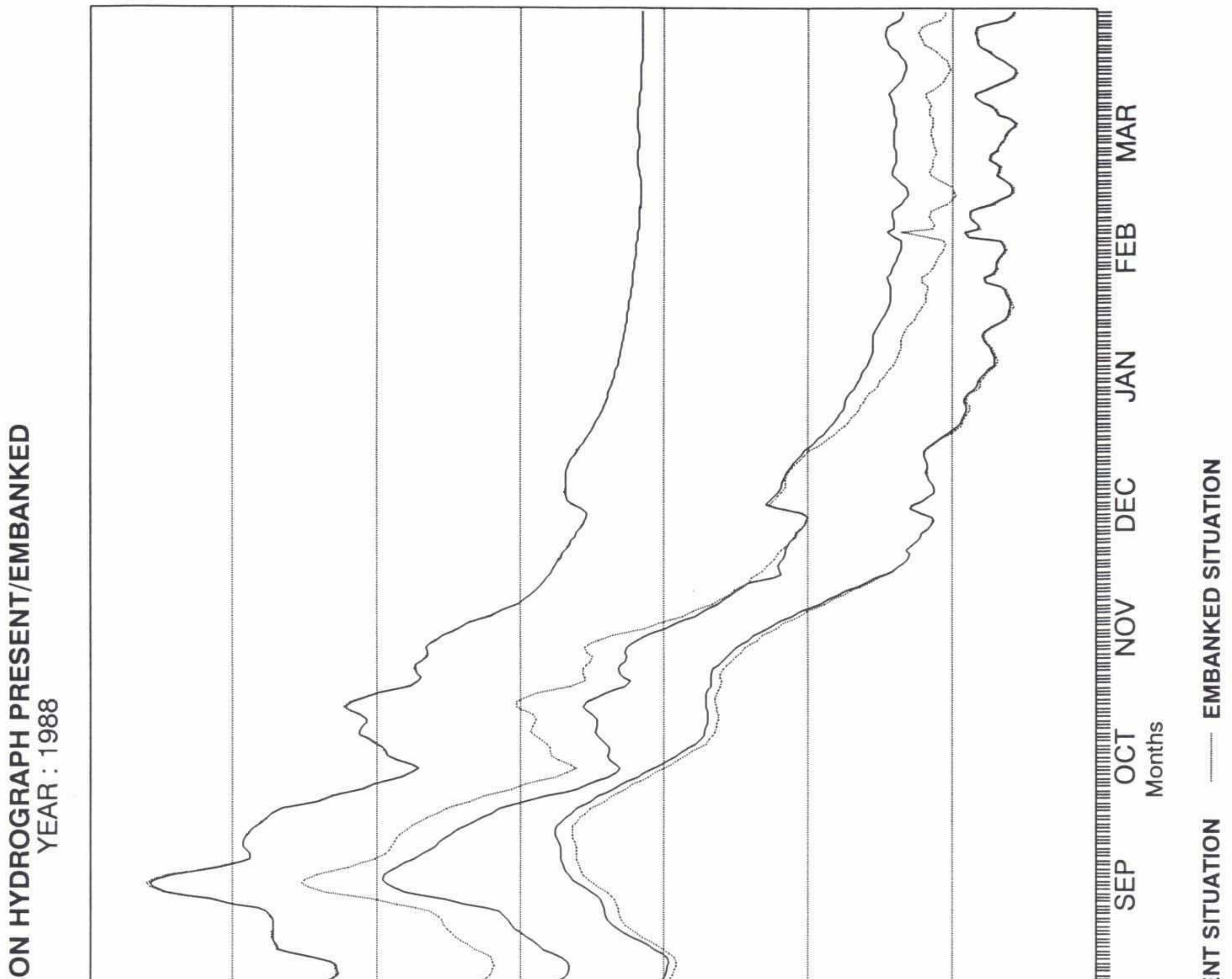

COMPARISON HYDROGRAPH PRESENT/EMBANKED
YEAR : 1988
Water Level in Meter (PWD)
0
2
4
6
8
10
12
14
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
Months
Nilukhirchar
Taraghat
Bhairab Bazar
PRESENT SITUATION
EMBANKED SITUATION

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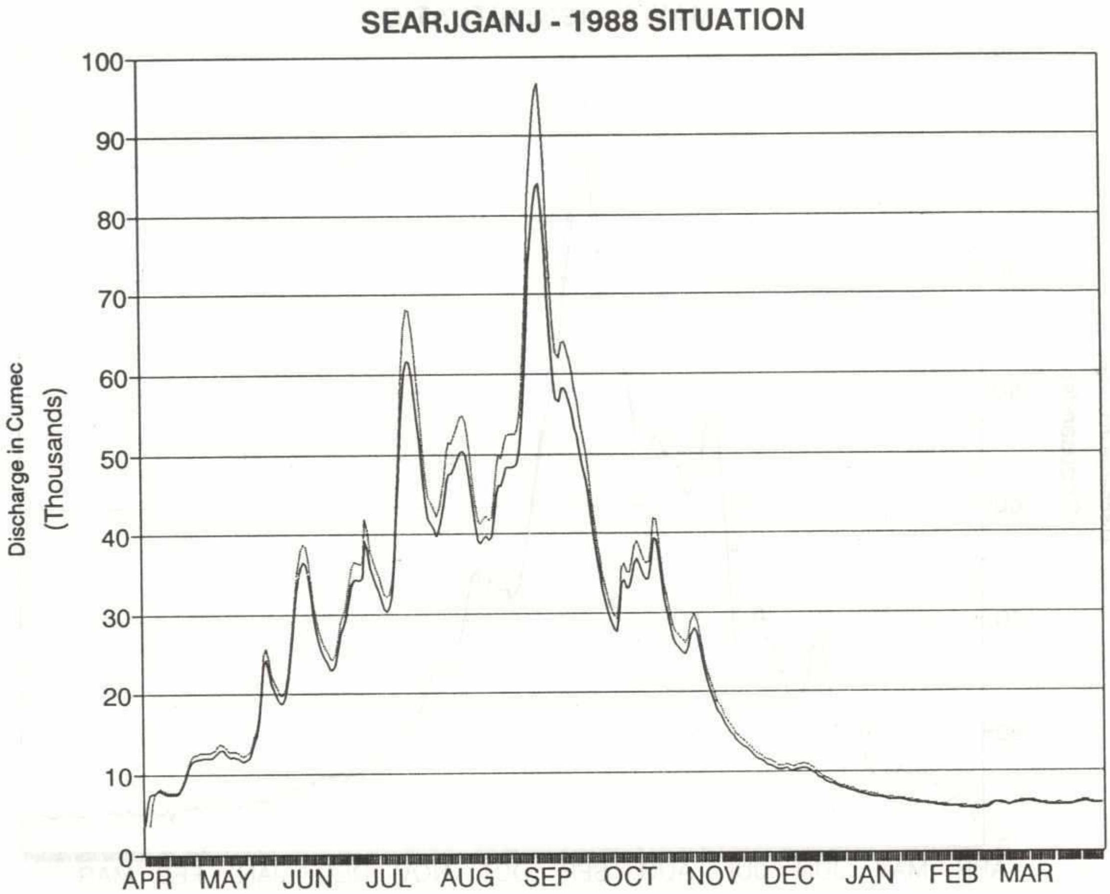
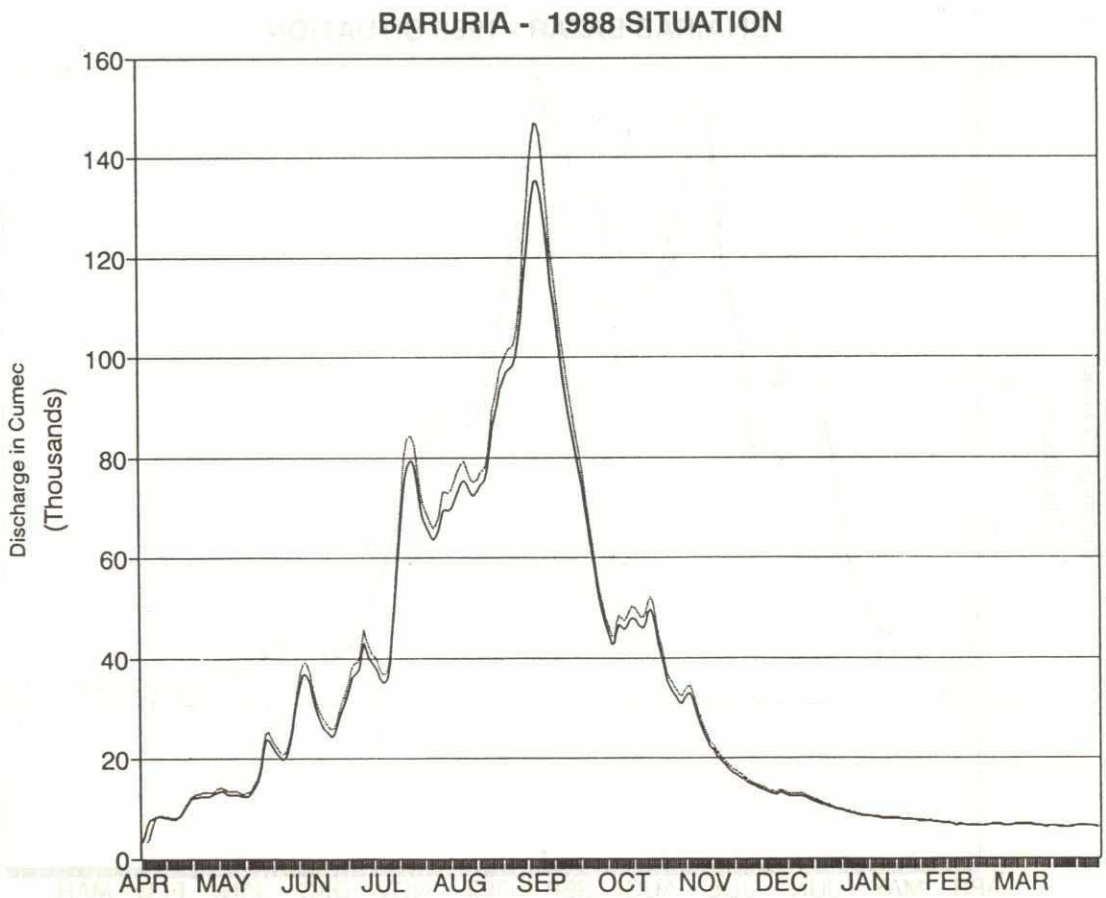
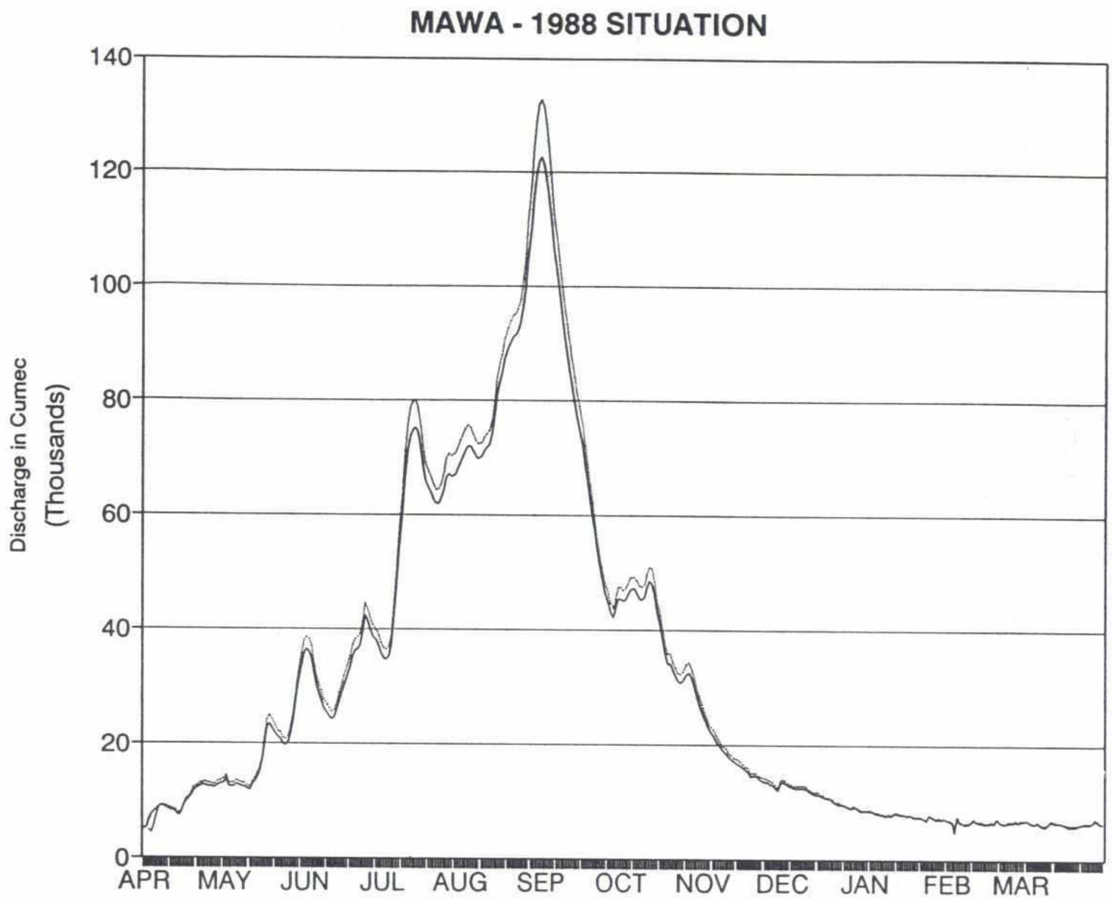
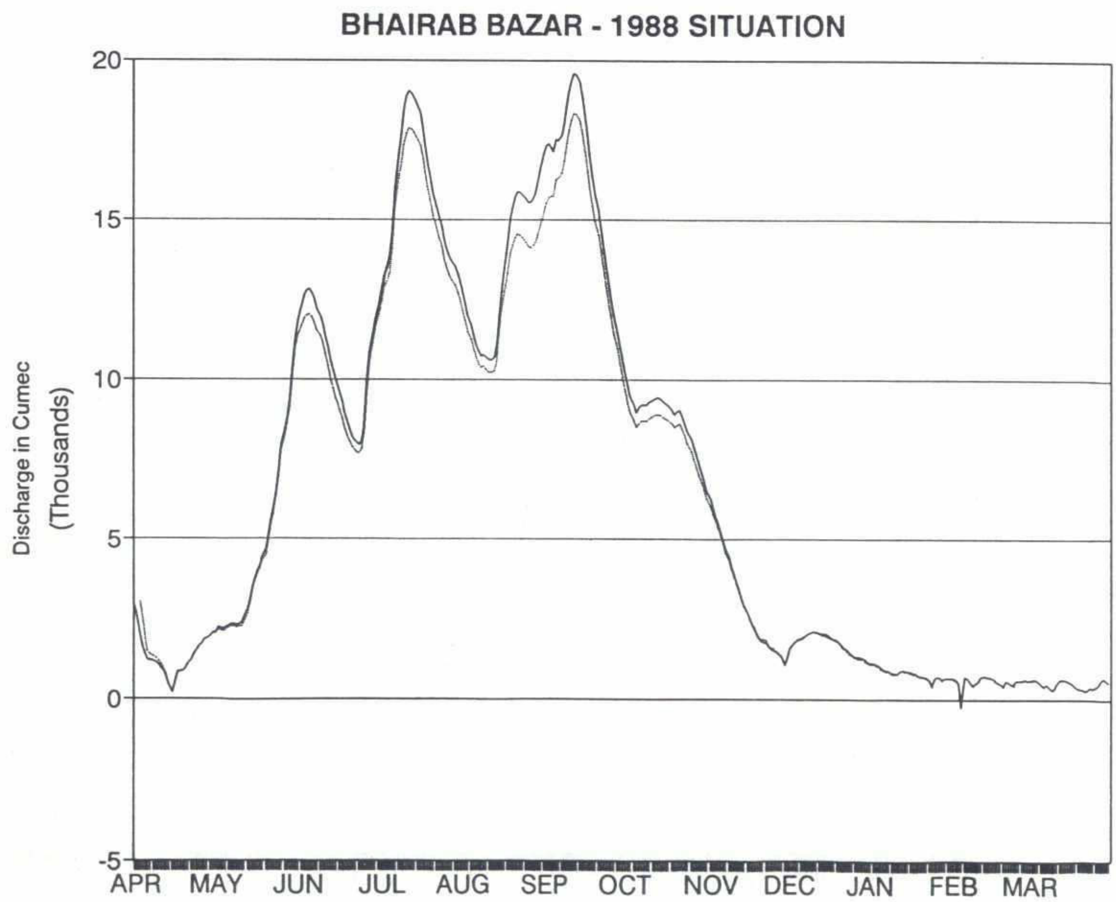
EFFECT OF EMBANKMENT ON DISCHARGE

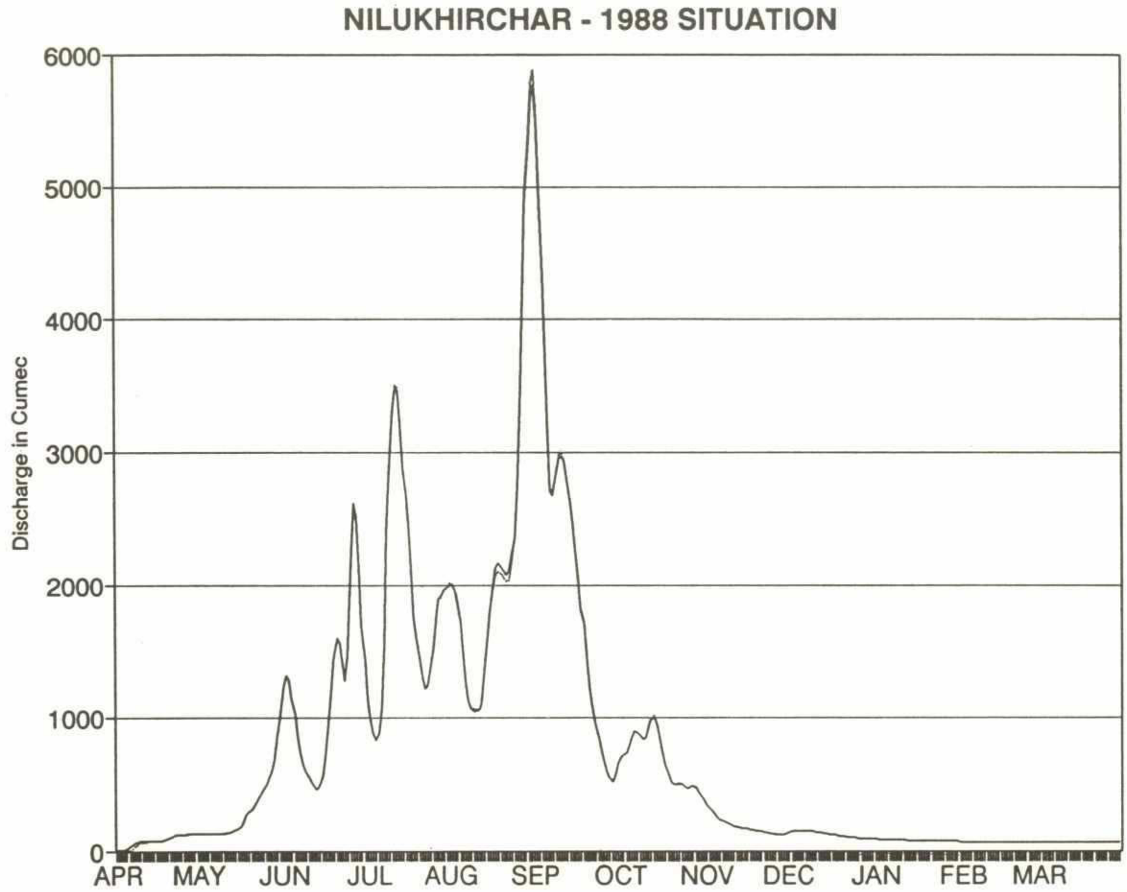
2b0


SEARJGANJ - 1988 SITUATION
Discharge in Cumec
(Thousands)
100
90
80
70
60
50
40
30
20
10
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR


BARURIA - 1988 SITUATION
Discharge in Cumec
(Thousands)
160
140
120
100
80
60
40
20
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR


MAWA - 1988 SITUATION
Discharge in Cumec (Thousands)
140
120
100
80
60
40
20
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR


BHAIRAB BAZAR - 1988 SITUATION
Discharge in Cumec (Thousands)
20
15
10
5
0
-5
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR


NILUKHIRCHAR - 1988 SITUATION
Discharge in Cumec
6000
5000
4000
3000
2000
1000
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR