Government of Bengal
Irrigation Department

Report on Rainfall and Floods in North Bengal 1870—1922

by

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Part I—Discussion of Rainfall and Floods
Part II—Description of Floods

(with Tables and Maps)

Part I

Discussion of Rainfall and Floods

RAINFALL AND FLOODS IN NORTH BENGAL, 1870—1922.

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RAINFALL AND FLOODS IN NORTH BENGAL, 1870—1922.

By P. C. Mahalanobis, I.E.S., Professor, Presidency College, and Meteorologist, Calcutta.

PART I.—SECTION I.—INTRODUCTION AND SUMMARY OF CONCLUSIONS.

1. The North Bengal Flood Committee[1] was appointed by the Government of Bengal in February 1923. The Committee co-opted me as a member, after the first two meetings of the Committee had already been held, and requested me to furnish the Committee with rainfall data and maps bearing on the question of occurrence of floods in North Bengal.

2. At this time a proposal had been placed before the Committee for the "control and regulation of the flood-water in the upper regions by the construction of flood absorption reservoirs and retardation basins, by means of which part of the flood of any particular basin or basins can be held back whilst the discharge from some other catchment is allowed to pass off and so reduce the volume of water coming upon the low areas at one time."

I learnt from Mr. G. T. Huntingford (Offg. Chief Secretary to the Government of Bengal, Public Works Department, and *ex-officio* Chairman of the North Bengal Flood Committee) that the Committee was then acutally considering a draft report recommending to Government "an investigation both from an engineering and from a financial point of view of the possibility of constructing such flood absorption reservoirs."[2]

I made a preliminary study of the rainfall data for the 1922 and the 1918 floods, which showed that the bulk of the rain had fallen in the near neighbourhood of the flooded areas, so that the advent of flood-water from "upper regions" was a factor of minor importance. I discussed those results with Mr. G. T. Huntingford, who asked me to prepare a series of maps showing the actual position and quantity of the rainfall immediately preceding some of the more important floods.

3. I prepared a set of such rainfall maps (for five important floods) and placed them before the third meeting of the Committee held on the 4th March 1924. The importance of the rainfall data was immediately recognised, and I was requested by the Committee to submit a report on the rainfall data for *all* important floods in North Bengal during as long a period as possible. The present report embodies the results of an analysis of the available rainfall data bearing on the question under discussion.

4. I found from the records of the Meteorological Office, Alipore, that reliable rainfall data for about 10 stations could be obtained from the year 1870. Some of them had been started earlier than 1870, but they were too few in number to be of any use. I therefore decided to start my work from the year 1870. A complete list of all the rainfall stations will be found in Table A (p. 7).

5. My first task was the compilation of a reliable list of all the important floods which had actually occurred in North Bengal during the period 1870—1922. I approached the Chairman of the North Bengal Flood Committee with a request to supply me with such information as would enable me to prepare a list of all important floods in North Bengal, area by area, and year by year, classified according to severity. Unfortunately this information was not available either in the Irrigation Department or in the Revenue Department of the Government of Bengal[3]. The Secretary to the North Bengal Flood Committee, however, addressed the Commissioner of the Rajshahi Division on this subject[4]. The Commissioner of the Rajshahi Division forwarded a short list of floods[5] obtained from the District Officers of Malda, Dinajpur, Rangpur and Rajshahi. He noted, however, that no systematic records had been kept and that the facts given were obtained in many cases from private

(1) Government of Bengal, Irrigation Department resolution No. 1, dated Calcutta, the 6th February 1923.
(2) Draft Report of the Committee circulated in March 1924, p. 8.
(3) Government of Bengal, Irrigation Department letter No. 6335 I., dated the 9th November 1923.
(4) See footnote (3).
(5) Office of the Commissioner of the Rajshahi Division, letter No. 5178, dated 8th December 1923.

individuals, and doubted whether the classification could be depended upon. The information supplied was very meagre and was not sufficient to enable me to start my work.

The Administration Reports of the Government of Bengal from 1870 to 1922, and the District Gazetteers for all the districts in Rajshahi were next systematically searched, and a provisional list of important floods was prepared and classified under four heads :—

(*a*) *Catastrophic*.—Involving considerable direct loss of human life; very great destruction of cattle and crops.

(*b*) *Severe*.—Small loss of human life; considerable destruction of crops and cattle.

(*c*) *Moderate*.—Considerable damage to crops and cattle, but no loss of human life.

(*d*) *Slight*.—Slight or moderate damage to crops, but no direct loss of cattle or human life.

6. A systematic search was then made among the old files of important newspapers and periodicals available in Calcutta. My best thanks are due to the authorities of the Imperial Library and the proprietors of a large number of newspapers (especially the proprietors of the *Amrita Bazar Patrika*) for facilities given to me in this connection. A list of the chief periodicals consulted is given below :—

(1) The *Amrita Bazar Patrika*,
(2) The *Bangabasi*,
(3) The *Hitabadi*,
(4) The *Bengalee*,
(5) The *Englishman*,
(6) The *Statesman*,
(7) The *Hindu Patriot*,
(8) The *Prabasi*, and
(9) The *Modern Review*.

The compilation of flood records was very carefully and conscientiously performed by Babu Pabitra Ranjan Kar, B.A., of the Meteorological Office, Alipore.

As regards the flood of September 1922, I am indebted to Sir P. C. Roy (President, North Bengal Flood Relief Committee) and Prof. Meghnad Saha, M.A., D.Sc. (now Professor of Physics, Allahabad University, then Publicity Officer, North Bengal Flood Relief Committee), for much valuable information. Mr. Rathindranath Tagore, B.Sc., very kindly placed at my disposal manuscript copies of weekly reports on weather and flood conditions preserved in the old files of the Tagore estate in North Bengal. These records refer to pargana Kaligram near Atrai, which is situated in the heart of the central flood-area. They proved very useful in checking the descriptions obtained from other sources.

7. It may be assumed as a working hypothesis that the normal drainage in any area is at least just sufficient to cope with the normal rainfall in that area. It is, of course, not true that the normal drainage is always sufficient to drain away the whole of the rainfall; for in many parts of North Bengal shallow floods and inundations are a regular feature of the rainy season, but I think it is true that, even with very heavy falls (provided they are normal or below normal), there would not ordinarily be any distress. It is the *excess* above normal which is important in causing abnormal flooding and consequent distress to the inhabitants.

8. Normal rainfall for each day of the year was available for only nine stations (Rampur Boalia, Malda, Dinajpur, Jalpaiguri, Cooch Behar, Kalimpong, Rangpur, Bogra and Sirajganj, which are daily reporting stations). It therefore became necessary to calculate the daily normal rainfall for the other 55 stations. The flood records showed that serious floods in North Bengal had usually occurred either in August or September[*]; that is, in the middle or towards the end of the rainy season. I therefore prepared the daily normal rainfall for all the stations, for each day of the two important flood months, August and September (given in Table A). The actual work of computation was supervised and systematically checked by my Assistant, Babu Devendranath Chakravarti, and I believe that the figures given in Table A are quite reliable. Normal rainfall for the month of July (as well as for certain selected days in July) and the normal rainfall for the whole of the flood period, July, August and September, were also directly computed. A short discussion of the normal rainfall will be found in Section II.

(*) Refer to article 6 above.

Rainfall figures were taken from the "Daily Rainfall of India" (published by the different Provincial Governments of India), which in many cases had to be checked and corrected from the original manuscript records of the Alipore Meteorological Office.

Accurate information about actual dates on which the floods occurred was lacking in most cases. A careful scrutiny of the original rainfall records and a method of approximation by successive stages had to be adopted to fix the limits of what may be called the "days of flood rainfall," that is the rainfall which probably acted as the direct cause of the flood in question.

For every flood, I first located approximately several possible periods of flood rainfall, by visual examination of the original records. The total rainfall as well as the excess percentages of each of these trial periods were then calculated and plotted on large scale (1" = 16 miles) working maps. I then compared these maps with the available description of the flood in question, and selected that particular rainfall period which corresponded most closely to the available flood description.

A large number of such trial periods (sometimes eight or ten for important floods) were worked out and examined. The final selection was thus made out of a large number of possible periods, and may therefore be taken as the most probable one.

9. When I first started work, I had intended to make a more comprehensive survey of the meteorological data than that given in the present report. My original project covered a systematic analysis of the monsoon rainfall, month by month, and by five-day periods, for every year (irrespective of the fact whether a flood had occurred or not), including a study of (*a*) the variability and the frequency distribution for different periods, (*b*) the correlation of rainfall between different days and different periods for the same station, and (*c*) the correlation of rainfall between different stations for the same day and the same period.

I had also intended to include the whole of Bengal, and certain adjoining areas, *i.e.*, portions of Assam, Bihar, Chota Nagpur and Orissa, in my study, and I actually collected a considerable amount of material (chiefly descriptions of previous floods) for this purpose.

The limited resources at my disposal (as regards time, trained clerks, and calculating appliances) compelled me, after some time, to curtail my programme very considerably. A good deal of work, however, was done before I gave up my original project. For example, the analysis of rainfall by five-day periods; the intra-class correlation and variabilities for one day, two, three, five and seven days (for 38 stations); the frequency constants (up to β_2 and β_1), and the correlation between different stations for the tri-monthly period July—September, etc., have been all determined. A great deal, however, still remains to be done, and in view of the unfinished state of the work as a whole, I have considered it advisable to leave them out from the present report.

10. Tabulation of daily normals, compilation of flood reports, and finally the analysis of relevant rainfall data were laborious tasks, and involved a very good deal of detailed work. Progress was necessarily slow, and more particularly so, as I could supervise the work only in my spare time, after discharging the duties of my dual office of Meteorologist, Calcutta, and Professor, Presidency College.

Contents of the Report.

11. The present report covers the administrative division of Rajshahi, better known as North Bengal, comprising the districts of Darjeeling, Jalpaiguri, Cooch Behar, Dinajpur, Rangpur, Malda, Rajshahi, Bogra and Pabna. It is situated between Lats. 23° 49′ and 27° 13′ N. and between Longs. 87° 48′ and 89° 53′ E. The area covers about 20,000 square miles and contains a population of nearly 10 millions. It is bounded on the north by the Himalayas, on the east by the river Sankosh (which separates the district of Jalpaiguri from the district of Goalpara in Assam) and the Brahmaputra, on the south by the Ganges and the Pudma, and on the west by the Purnea district.

12. My report consists of two parts —one general and the other descriptive. The actual description of each individual flood(together with all relevant rainfall data) has been given in Part II, the arrangement in which is strictly chronological. A summary list of all the floods discussed in this report will be found in Table B (p. 9).

13. Part I, which gives a general discussion, is divided into five sections.

Section I.—Introduction and summary of conclusions.

Section II.—Normal Rainfall and its Variability.—It contains a general account of the seasonal precipitation in North Bengal; normal rainfall for the three months July, August and September; the variability of rainfall from year to year; short notes on intra-class correlations for successive days; frequency of heavy rain; and fluctuations of rainfall from place to place.

Section III.—The Flood-areas of North Bengal.—For discussing the flood records, I have found it convenient to divide North Bengal into three main flood divisions with three subdivisions in each. The unit for discussion in the present section is each such subdivision.

A description of the drainage (including notes on the history of river channels) is given for each division, and the more important causes operating in each flood-area are discussed in detail.

Section IV.—Factors affecting the occurrence of Floods in North Bengal.—This section contains a discussion of the relative importance of the different factors—cyclonic downpours; general excess of rainfall: advent of water from adjoining areas; loss of water by evaporation and transpiration; level of drainage channels and notes on obstructions to drainage.

Section V.—Season and Frequency of Floods: Flood Prevention and Flood Warning.—Frequency of floods of different intensities in North Bengal have been compared with American and European data. This section also gives a short discussion of the different methods for flood prevention—erection of retardation basins, embankments; and improvement of drainage channels. It also contains a few notes on the issue of flood warnings.

Rainfall and Flood Maps.—Thirty-two maps accompany this report. Rainfall figures and lines are everywhere given in red, and flood areas and boundaries in black. Normal and actual rainfall are given in inches, while departures are shown as percentages of the normal. The intensity of a flood has been roughly indicated by the depth of shading.

A list of authors and books will be found in an appendix.

14. I am much indebted to Sir P. C. Ray, President, and Dr. Meghnad Saha, Publicity Officer of the North Bengal Flood Relief Committee (a non-official organisation), for information about the great flood of 1922; to Mr. Rathindranath Tagore for weekly weather reports from his estate in North Bengal, for the period 1882—1922; to Mr. G. H. Tipper of the Geological Survey of India for many valuable suggestions and information about the river system of North Bengal; to Babu S. tis Chandra Ghosh, Superintendent, Meteorological Office, Alipore, for supervision, Babu Prakriti Prasanna Chatterji, also of the Meteorological Office, and my own assistants, Babu Devendranath Chakravarti and Babu Sudhir Kumar Banerji, for the actual computation of the statistical work.

I am under a special debt of gratitude to Mr. C. Addams-Williams, President, and Mr. A. G. Maflin, Secretary to the North Bengal Flood Committee, for the facilities given to me for the present work. I also beg to acknowledge the ungrudging help I have received from Babu Pabitra Ranjan Kar, B.A., who worked as my assistant throughout the course of my enquiry.

15. I regret very much the great delay in submitting my report. This is partly due to constant interruptions by my departmental work in the Presidency College, and in the Meteorological Office, Alipore, and also to the fact that I was obliged to take leave during the course of my enquiry on account of ill-health.

16. For convenience of reference, I append herewith a short summary of conclusions.

April, 1926.

SUMMARY OF CONCLUSIONS.

I.—Normal Rainfall and its Variability.

1. .The effective rainfall (nearly 56 per cent. of the annual precipitation), so far as floods in North Bengal are concerned, is concentrated within the three months July, August and September, and is given entirely by the Bay current of the monsoon.

2. The normal rainfall is fairly steady (about 30″ in three months) in the south, but increases rapidly towards the north, under the influence of the Himalayas, to a value of about 90″ along

the foothills and outer regions of the Himalayas, and then falls off rapidly in the interior of the hilly country. The normal rainfall also increases slightly towards the east owing to the presence of the Garo hills.

3. The monsoon rainfall is pulsatory in character, and heavy falls are almost invariably brought about by cyclonic storms from the Bay. The tracks of these storms vary very considerably, and the actual region of the heaviest precipitation along any particular track also varies largely.

4. The variability of rainfall diminishes rapidly as the period (*i.e.*, number of days) under consideration is increased. The following theoretical expression for the variability for "*K*" days, was obtained on certain plausible assumptions:—

$$V_k^2 = \frac{V_1^2}{K}\left\{1 + (K-1)\,R_k\right\} \ldots\ldots (2{\cdot}1)$$

where V_1 is the observed variability for 1 day, and R_k the "intra-class" correlation for "K" successive days. Variabilities calculated from the above equation (2·1) were found to agree very well with directly observed variabilities.

5. The "intra-class correlation", R_k for "K" successive days, can be graduated by the empirical formula

$$R_k = 0{\cdot}588\ K^{-1} = (0{\cdot}6714 \cdot K)^{-1} \ldots\ldots (3)$$

The agreement with observed values of R_k was found to be satisfactory.

6. The observed seasonal variability of rainfall (for three months) is fairly steady, and is of the order of 25 or 30 per cent. of the normal precipitation. The calculated annual variability is about 17 per cent. The variability of rainfall in North Bengal is not excessive in comparison with other provinces of India, or other countries of the world.

7. The frequency distribution of rainfall is not "normal," that is, cannot be adequately described by the Gauss-Laplacian law of errors. It is definitely asymmetric, and the probability of very heavy falls is much greater than that given by the simple theory of normal probability.

8. The available data do not indicate any permanent increase (or decrease) of normal rainfall in North Bengal.

9. The actual site of heaviest precipitation fluctuates very irregularly during any particular season, and it is a matter of great uncertainty where the greatest rainfall would occur during the advance of a storm from the Bay.

10. Such fluctuations are, however, perfectly random, and the rainfall records do not reveal the existence of particular regions which are more likely to receive heavier falls than other regions.

II.—Floods in North Bengal.

1. North Bengal can be conveniently divided into several distinct flood areas:—

(A) Hilly districts and submontane country.

(B) Flat riparian tracts drained by the Tista, the Brahmaputra, and the Ganges.

(C) Country in the interior.

2. Sudden and torrential downpours caused by cyclonic storms from the Bay constitute the most important direct cause of floods in North Bengal, and have brought about all the great floods of North Bengal during the last 50 years.

3. Long-continued excess of general rainfall is also an important factor; and without it, a severe flood cannot last long in North Bengal. In area (A), and in the riparian tracts of the Brahmaputra and the Ganges, it acts as a predisposing factor, but cannot by itself cause serious flooding. In the plains of the Tista (B-1, vide Map No. 2) and in the interior of the country (C-3), it is, however, sufficient by itself to cause a slight or moderate flood.

4. Rainfall has usually been heaviest in the area in which the flood actually occurred. Water coming from adjoining areas has acted indirectly by swelling the rivers (and thus hampering the quick flowing away of the flood-water), but except to some extent in the submontane country, has done very little direct mischief.

5. The rains during the first portion of the monsoon usually serve to replenish the "underground storage of water," to fill the river and other channels, and to saturate the soil. So that, it is only the rains in the latter part of the monsoon which are usually effective in causing floods in North Bengal.

6. At a very rough estimate, the maximum loss by interception, evaporation, and transpiration may be taken to vary from 0·3″ to 0·5″ per day during the monsoon in North Bengal. The normal daily rainfall is 0·54″. So that the excess of from 0·04″ to 0·24″ of rain per day must be carried off by the river channels under normal conditions.

7. The level of the river channels exercises a great influence on the occurrence of floods in certain areas. A high level of the Tista acts as a favourable condition for floods in the submontane country (A-2), and in the north-eastern plain (B-1), and may become directly operative by actual overflow. It also acts as a predisposing factor for floods in (B-2). A high level of the Brahmaputra is the dominating factor in (B-2), and may cause local floods even when the rainfall is not in excess; it can prolong a flood in the eastern portions of (C-3) but has practically no influence in the other areas. A high level of the Ganges can easily cause a flood in (B-3), can complicate the situation by pouring in water into the Chalan *bil* area, but on the whole, does not exert much direct influence on the occurrence of floods in the central or other areas of North Bengal.

8. Drainage is generally unsatisfactory over the greater part of North Bengal, and is peculiarly susceptible to even very slight changes of level. There is ample evidence to show that the ground level in the central area is being continually raised by the deposit of silt, and the river channels in the interior are steadily deteriorating.

Railway embankments (and possibly other obstructions) have helped in this process by acting as obstructions to the natural drainage of the area. Railway embankments have occasionally acted as barriers for holding up the flood-water, and have thus helped in prolonging the duration of floods.

9. In North Bengal the frequency of floods of some kind or other is 1 in 2¼ years, of moderate or severe floods 1 in 4 years, and of severe floods 1 in 7 years. Catastrophic floods occur about two or three times in a century. Severe floods appear to occur more frequently in North Bengal (about 14 per century) than in the U. S. A., or European countries (7 to 10 per century).

10. The river system in North Bengal has undergone profound changes during the last 150 years, especially in the central area, where important river channels have decayed, and the drainage has deteriorated considerably. The basic fact of the situation is that water cannot easily get out of the *bil* area owing to the extremely low level of the country. Even now the drainage is steadily getting worse, and if this process continues as it is doing at present, floods are likely to occur in future with greater frequency, and possibly with greater severity.

11. The flood of 1922 was caused by cyclonic rainfalls of practically unprecedented magnitude. The rainfall in the central area in one week was about 10 times the normal weekly precipitation, nearly three times the normal precipitation for the month of September, and approached the normal rainfall for the whole of three months, July, August and September. In other words, the flooded area received in one week practically as much rain as it would receive in certain years during the whole monsoon period. Railway embankments hampered quick draining away of the flood-water, and thus served to prolong the duration of the flood. But with such heavy falls, a flood of practically the same magnitude was bound to occur, even if there had not been a single railway line in existence.

12. Probability of occurrence of great floods diminishes very rapidly with the magnitude of the floods. The flood of 1922 was very exceptional, if not practically unprecedented, and a recurrence of a flood of such magnitude within a short time is extremely unlikely.

13. As the direct flow of water from the north is not a factor of importance (paragraph 4), and as the actual site of the heaviest precipitation always remains a matter of great uncertainty (paragraph 9), the erection of retarding basins is not likely to prove successful in preventing the occurrence of floods in North Bengal.

14. Embankments in the riparian tract may for a time prevent overflow from the rivers, but would tend to raise the bed of the rivers still further, and thus make the situation much worse in the long run. They are also of no use in the central area.

15. The essential problem in North Bengal is one of getting rid of the water quickly, and any improvement of the drainage channels is likely to exert a beneficial influence, either by preventing undue accumulation of water, or by helping in the quick draining away of the flood-water.

16. Owing to the low level of the *bil* area, floods are, however, likely to occur fairly frequently, until the level of the whole area is raised sufficiently to ensure the establishment of a stable hydrological regime

17. It is therefore necessary to advise and educate the inhabitants to adopt their life to the changing conditions; to build their houses on raised grounds, and to take other precautionary measures.

18. The issue of systematic flood warnings may also prove useful in mitigating the evils caused by floods, and would require—

(*a*) the inauguration and maintenance of a large number of river gauges on all the important river channels of North Bengal;

(*b*) a moderate increase in the number of rainfall stations;

(*c*) arrangements for telegraphic communication of gauge readings and rainfall information;

(*d*) systematic compilation and analysis of flood records, gauge readings, and rainfall data.

TABLE A.—NORMAL RAINFALL FOR JULY, AUGUST AND SEPTEMBER.

Serial No.	Station.	District.	Number of years' data used.	Monthly normal rainfall in inches.			Figures for three months.					
				July.	August.	September.	Normal rainfall in inches. (3 months).		Standard Deviation in inches (3 months).		Coefficient of variation (3 months).	
1	2	3	4	5	6	7	8		9		10	
1	Alipur Duars	Jalpaiguri	36	32·99	25·29	22·84	81·60	±1·92	17·09	±1·35	20·90	± 1·72
2	Atwari ..	Dinajpur	15	25·31	21·82	15·75	....		....		....	
3	Balurghat ..	Dinajpur	39	13·18	11·55	10·38	35·98	1·20	11·11	0·83	30·88	2·76
4	Bilmaria ..	Boalia ..	11	11·41	15·10	11·58	....		....		....	
5	Birganj ..	Dinajpur	20	17·03	14·18	12·03	43·83	2·09	13·84	1·47	31·58	3·66
6	Boalia ..	Boalia ..	52	10·81	11·23	10·27	33·01	0·94	9·99	0·66	30·26	2·17
7	Bogra ..	Bogra ..	51	13·06	12·83	11·26	37·52	0·96	10·19	0·68	27·16	1·94
8	Buxa ..	Jalpaiguri	52	50·36	43·67	31·04	124·57	2·66	28·42	1·88	22·81	1·51
9	Chanchal ..	Malda ..	44	13·83	12·38	10·61	38·30	1·01	9·97	0·71	25·85	1·98
10	Chaugram	Boalia ..	42	..	16·26	7·47	....		....		....	
11	Cooch Behar	Cooch Behar	50	28·11	23·07	25·00	75·80	2·54	26·64	1·79	35·15	2·64
12	Churamon ..	Dinajpur	42	13·87	13·09	11·52	39·04	1·34	12·87	0·94	32·97	2·67
13	Darjeeling ..	Darjeeling	52	32·31	25·42	19·60	75·38	1·50	16·08	1·06	21·33	1·46
14	Debiganj ..	Jalpaiguri	36	19·93	16·48	14·54	51·74	1·30	13·34	1·05	25·78	2·16
15	Dinajpur ..	Dinajpur	52	15·50	12·98	11·88	40·18	1·18	12·59	0·83	31·33	2·26
16	Dinhatta ..	Cooch Behar	43	19·97	17·65	19·46	57·53	1·51	14·72	1·07	25·59	1·97
17	Falakata ..	Jalpaiguri	46	28·43	22·79	18·40	70·92	1·86	18·74	1·31	26·42	1·98
18	Fulbaria ..	Cooch Behar	28	28·94	20·41	24·62	74·84	3·33	26·09	2·35	34·87	3·43
19	Gaibandha ..	Rangpur	50	13·15	11·71	12·05	37·64	1·37	10·77	0·72	28·61	2·08
20	Gangarampur	Dinajpur	17	15·60	14·31	11·97	40·31	1·67	10·22	1·18	25·35	3·11
21	Gaiol ..	Malda ..	37	13·60	13·20	11·40	37·87	1·03	12·32	0·96	32·63	2·79
22	Gobindganj	Rangpur	29	14·04	13·87	13·32	41·50	1·55	12·34	1·08	29·74	2·85
23	Gomastapur	Malda ..	18	12·02	10·57	7·91	30·21	1·53	9·62	1·08	31·84	3·90

Serial No.	Station.	District.	Number of years' data used.	Monthly normal rainfall in inches.			Figures for three months.		
				July.	August.	September.	Normal rainfall in inches (3 months).	Standard Deviation in inches (3 months).	Coefficient of variation (3 months).
1	2	3	4	5	6	7	8	9	10
24	Jalpaiguri ..	Jalpaiguri	52	31·28	24·77	21·42	76·83 ± 1·55	16·56 ± 1·09	21·55 ± 1·43
25	Kalchini ..	Jalpaiguri	22	35·36	31·47	20·65	87·96 2·26	15·70 1·59	17·85 1·86
26	Kalimpong	Darjeeling	32	23·90	19·06	12·79	55·33 1·76	14·75 1·24	26·66 2·39
27	Khetlal ..	Bogra ..	3	10·16	8·18	8·04	....	....	....
28	Kumargram	Jalpaiguri	16	43·20	30·99	25·54	....	....	....
29	Kurigaon ..	Rangpur	46	16·09	12·13	14·55	43·18 1·32	13·25 0·92	30·69 2·34
30	Kurseong ..	Darjeeling	33	43·60	35·11	25·07	104·39 1·93	16·42 1·36	15·73 1·33
31	Mahadevpur	Boalia ..	43	11·97	11·77	10·69	35·86 1·21	11·71 0·85	32·65 2·61
32	Malda ..	Malda ..	52	10·97	11·14	10·77	33·11 0·94	9·99 0·66	30·02 1·98
33	Manda ..	Boalia ..	35	12·38	10·39	9·80	31·94 1·45	12·72 1·02	39·82 3·79
34	Mathabhanga	Cooch Behar	43	26·23	21·74	19·93	69·12 1·84	17·85 1·29	25·82 1·99
35	Mickliganj ..	Cooch Behar	43	24·04	22·10	18·01	64·69 1·75	17·01 1·23	26·29 2·03
36	Mongpoo ..	Darjeeling	28	31·08	25·45	17·95	74·21 2·17	17·00 1·53	22·91 2·17
37	Nagrakata ..	Jalpaiguri	30	37·70	30·95	24·42	93·17 2·59	21·04 1·83	22·58 2·06
38	Nator ..	Boalia ..	52	12·22	11·54	10·52	34·62 0·84	9·00 0·59	26·00 1·83
39	Naugaon ..	Boalia ..	39	11·92	10·81	11·25	33·63 1·00	9·29 0·70	27·62 2·18
40	Nawabganj	Dinajpur	18	15·56	15·75	11·75	42·91 2·27	14·27 1·59	33·16 4·11
41	Nawabganj	Malda ..	18	11·10	11·40	7·90	30·93 1·57	9·89 1·11	31·98 3·94
42	Nilphamari	Rangpur	45	17·18	15·46	14·68	48·08 1·52	15·07 1·07	31·34 2·43
43	Nithpur ..	Dinajpur	20	12·25	12·93	11·09	33·14 1·45	9·62 1·02	29·03 3·33
44	Nowkhilla ..	Bogra ..	46	12·22	12·39	10·70	35·33 1·05	10·59 0·74	29·98 2·28
45	Pabna ..	Pabna ..	52	10·76	10·67	8·99	30·48 0·87	9·34 0·61	30·64 2·20
46	Panchbibi ..	Bogra ..	46	12·70	12·00	11·26	35·96 1·10	11·10 0·78	30·87 2·37
47	Parbatipur ..	Dinajpur	20	16·33	14·19	10·82	42·23 1·87	12·38 1·32	29·32 3·38
48	Pedong ..	Darjeeling	28	24·42	22·10	14·67	61·12 1·08	8·49 0·76	13·89 1·27
49	Pirganj ..	Rangpur	27	15·75	13·52	13·41	42·71 1·78	13·70 1·23	32·08 3·18
50	Raiganj ..	Dinajpur	46	14·75	13·98	10·72	39·85 1·16	11·69 0·82	29·36 2·23
51	Ramganj ..	Dinajpur	34	15·81	15·83	11·95	42·97 1·12	9·70 0·77	22·57 1·90
52	Rangpur ..	Rangpur	51	15·26	12·83	13·63	42·81 1·20	12·66 0·84	29·57 2·14
53	Saidpur ..	Rangpur	20	16·71	15·35	12·69	42·77 1·95	12·95 1·38	30·28 3·51
54	Sara ..	Pabna ..	12	9·52	10·98	8·55	....	....	....
55	Setabganj ..	Dinajpur	25	15·55	15·30	11·84	43·11 2·39	17·71 1·68	41·08 4·51
56	Shahzadpur	Pabna ..	9	10·49	12·49	8·35	....	....	....
57	Sherpur ..	Bogra ..	46	12·22	12·09	10·24	34·83 1·01	10·18 0·71	29·23 2·20
58	Sibganj ..	Malda ..	37	11·10	10·25	9·24	30·21 0·92	8·26 0·64	27·34 2·29
59	Siliguri ..	Darjeeling	39	33·40	27·18	21·39	82·66 2·22	20·55 1·56	24·86 2·00
60	Sirajganj ..	Pabna ..	52	11·49	11·59	9·93	32·46 0·82	8·71 0·57	26·83 1·89
61	Sunderganj	Rangpur	26	14·97	11·81	13·04	41·17 1·20	9·09 0·85	22·08 2·16
62	Tanor ..	Boalia ..	19	10·63	9·38	6·89	27·21 1·08	6·99 0·76	25·69 2·96
63	Thakurgaon	Dinajpur ..	34	19·95	16·26	14·57	51·82 1·35	11·66 0·93	22·50 1·89
64	Ulipur ..	Rangpur ..	35	14·09	13·01	13·92	41·86 1·28	11·20 0·90	26·76 2·39

TABLE 8.—LIST OF FLOODS IN NORTH BENGAL, 1870-1922.

Serial No.	Year.	Flood month.	Rainfall period.	Map No.	Affected.		Intensity of flood.	Extent of damage.	Remarks.
					District.	Area.			
1	1870	July and August.	July and August.	4, 5 ..	Rajshahi and Pabna.	B-2, B-3 ..	(c)—Moderate	Great damage to crops.	Overflow of the Ganges. High level of the Brahmaputra.
2	1871	End of August to second week of September.	September.	6 ..	Malda and Rajshahi (lower part).	B-2, B-3 C-1, C-2.	(b)—Severe and extensive.	Considerable loss of cattle.	Excess rainfall. Exceptionally high level of the Ganges.
3	1874	September.	29th August to 15th September.	7 ..	Rajshahi and Pabna.	B-3 ..	(c)—Moderate	Great damage to crops.	High level of the Ganges and of the Brahmaputra. Local excess of rainfall.
4	1875	August	.. ..		Pabna ..	....	(d)—Slight	Damage to crops	High level of the Ganges. Heavy local falls.
5	1879	August	.. ..		Rajshahi ..	....	(d)—Slight	Damage to crops	High level of the Ganges caused by heavy falls in the United Provinces and Bihar.
6	1885	September.	August and September.	8, 9 ..	Rajshahi, Malda and Dinajpur.	C-1, B-1 and B-4.	(b)—Severe	Considerable loss of human life and cattle and destruction of property.	Heavy local falls. Very high level of the Ganges.
7	1886	September.	6th to 11th September.	10 ..	Bogra, Malda, Rajshahi and Pabna.	B-3, B-4 and C-3.	(c)—Moderate	Destruction of houses and property.	Excess rainfall. High level of the Ganges and the Brahmaputra.
8	1890	August	.. ..		Pabna ..	....	(c)—Moderate	Roads seriously damaged.	Overflow of the Ganges.
9	1890	August	.. ..		Darjeeling ..	....	(d)—Slight	Roads seriously damaged.	High level of the Tista.
10	1892	July ..	1st to 8th July.	11, 12	Jalpaiguri, Darjeeling, Rangpur and Dinajpur.	A-2, A-3, B-1, C-1 and C-2.	(b)—Very severe.	Considerable loss of human life and destruction of cattle; great damage to roads and property.	Very heavy falls. High level of the Tista, Mahananda, Dharla and Atrai. Serious holding up of water in Dinajpur and Rangpur by the railway line.
11	1892	July ..	1st to 8th July.	11, 12	Pabna ..	B-2 ..	(d)—Slight	....	Overflow of the Ganges.
12	1898	September.	.. ..		Darjeeling ..	....	(c)—Moderate	Damage to crops	Local rainfall.
13	1899	September.	September.	12-1, 12-2.	Darjeeling ..	A-1, A-2	(a)—Very severe.	Destructive landslips, considerable loss of life and unprecedented damage to roads, bridges and buildings.	Very heavy rainfall on the 24th and 25th September.
14	1902	August	.. ..		Cooch Behar and Rangpur.	B-1, C-2	(d)—Slight	....	Excess of rainfall.
15	1902	September.	September.	12-3, 12-4.	Jalpaiguri ..	A-3 ..	(b)—Severe	Ten lives lost; damage to railways; serious loss of cattle.	Heavy falls in the hills. Overflow of the Tista.
16	1904	August	.. ..		Malda ..	....	(d)—Slight	....	Exceptionally high level of the Ganges.
17	1906	August and September.	27th July to 5th August; 27th July to 20th August.	13, 14 15, 16	Jalpaiguri, Cooch Behar and Darjeeling.	A-2, A-3 and B-1.	(b)—Severe	Extensive damage to crops and property.	Heavy rainfall.
18	1908	August and September.	27th July to 5th August; 20th July to 20th August.	13, 14 15, 16	Pabna, Rajshahi and Malda.	B-2, B-3 and C-3.	(d)—Slight	Famine conditions in Malda and Rajshahi.	Abnormal rise of the Brahmaputra.
19	1910	July ..	8th to 21st July.	17, 18	Cooch Behar and Jalpaiguri.	B-1 ..	(c)—Moderate	Several breaches in railway lines.	Excessive local rainfall.

Serial No.	Year.	Flood month.	Rainfall period.	Map No.	Affected.		Intensity of flood	Extent of damage.	Remarks.
					District.	Area.			
20	1910	July ..	8th to 31st July.	17, 18	Pabna ..	B-2 ..	(d)—Slight	....	Abnormally high level of the Brahmaputra.
21	1915	August	7th to 15th August.	19, 20	Duars ..	B-1 ..	(d)—Slight	Damage to crops	Heavy local rainfall.
22	1915	First week of September.	..	..	Pabna ..	B-2, B-3	(d)—Slight	Villages under water.	A high river level.
23	1918	End of August	18th to 27th August.	21, 22	Rajshahi, Bogra, Dinajpur, Rangpur, Pabna and Malda.	C-1, C-2, C-3, B-2 and B-3.	(b)—Severe	Several deaths and considerable damage to crops and property.	Heavy cyclonic rainfall on the 24th, 25th and 26th August.
24	1919	End of August and first week of September	..	..	Pabna ..	....	(d)—Slight	....	Overflow from the Ganges.
25	1922	Last week of September to middle of October.	Week ending 27th September.	23, 24, 25, 26, 27, 28.	400 sq. miles in Bogra, 1,200 sq. miles in Rajshahi and a small portion in Pabna and Dinajpur.	C-3 ..	(a)—Very severe and extensive.	Estimated loss of property worth 6 crores.	Exceptionally heavy cyclonic precipitation in the week ending 27th September.

SECTION II.—NORMAL RAINFALL AND VARIATION OF RAINFALL IN NORTH BENGAL.

It will be useful to give a brief summary of the seasonal change of weather in North Bengal, with special reference to rainfall.

Table 1—Monthly Normal Rainfall.

District.	Darjeeling.	Jalpaiguri.	Cooch Behar.	Rangpur.	Dinajpur.	Bogra.	Rampur-Boalia.	Pabna.	Malda.	Whole area.
Number of stations.	6	8	5	9	13	4	7	4	6	62
January ..	0·63″	0·48″	0·33″	0·27″	0·28″	0·40″	0·44″	0·20″	0·39″	0·37″
	(·52)	(·33)	(·27)	(·33)	(·39)	(·61)	(·77)	(·33)	(·71)	(·42)
February ..	0·99″	0·95″	0·71″	0·68″	0·75″	0·83″	0·71″	0·64″	0·88″	0·79″
	(·82)	(·68)	(·85)	(1·05)	(1·25)	(1·23)	(1·07)	(1·62)	(1·62)	(·90)
March ..	1·74″	1·93″	1·71″	1·25″	0·94″	1·14″	0·96″	1·36″	0·80″	1·28″
	(1·44)	(1·35)	(1·40)	(1·56)	(1·31)	(1·72)	(1·69)	(2·28)	(1·47)	(1·46)
April ..	3·99″	5·72″	4·88″	3·12″	1·87″	2·33″	1·66″	2·29″	1·19″	3·09″
	(3·31)	(4·00)	(3·55)	(3·90)	(2·61)	(3·52)	(2·92)	(3·02)	(2·19)	(3·42)
May	9·19″	14·37″	14·32″	11·11″	7·09″	8·37″	6·96″	7·39″	4·85″	9·17″
	(7·62)	(10·06)	(11·71)	(13·88)	(9·92)	(12·64)	(10·77)	(12·74)	(8·92)	(10·46)
June	23·41″	27·09″	27·60″	16·96″	14·65″	12·73″	11·06″	11·57″	10·55″	17·32″
	(19·40)	(18·96)	(22·60)	(21·20)	(20·50)	(19·20)	(19·46)	(19·42)	(19·40)	(19·71)
July	31·34″	34·06″	24·68″	14·64″	16·16″	12·70″	11·60″	11·10″	11·74″	18·68″
	(25·95)	(23·80)	(20·20)	(18·30)	(22·60)	(19·16)	(20·40)	(18·64)	(21·60)	(21·50)
August ..	26·30″	28·92″	21·25″	13·21″	14·31″	12·02″	10·43″	10·95″	11·11″	18·20″
	(21·80)	(20·22)	(17·40)	(16·52)	(20·00)	(18·14)	(18·34)	(18·40)	(20·45)	(20·75)
September ..	17·55″	21·93″	20·69″	13·14″	11·46″	10·84″	9·74″	8·19″	8·87″	13·68″
	(14·54)	(15·32)	(16·94)	(16·42)	(16·04)	(16·36)	(17·34)	(13·76)	(16·32)	(15·59)
October ..	4·52″	6·15″	5·62″	4·72″	3·47″	4·30″	3·59″	4·21″	3·41″	4·36″
	(3·74)	(4·30)	(4·60)	(5·90)	(4·85)	(6·49)	(6·32)	(7·07)	(5·27)	(4·99)
November ..	0·67″	0·53″	0·24″	0·33″	0·26″	0·52″	0·46″	0·43″	0·46″	0·41″
	(·55)	(·37)	(·19)	(·41)	(·36)	(·78)	(·81)	(·72)	(·84)	(·46)
December ..	0·31″	0·24″	0·12″	0·09″	0·07″	0·11″	0·09″	0·20″	0·10″	0·13″
	(·25)	(·16)	(·09)	(·11)	(·09)	(·16)	(·15)	(·33)	(·18)	(·14)
Whole year ..	120·64″	142·37″	122·15″	79·52″	71·31″	66·29″	56·80″	59·43″	54·35″	87·67″

Monthly averages.—North Bengal receives the greater part of its rainfall from the south-west monsoon. Table 1 gives the average monthly normal rainfall in each district. The figures have been taken from the "Monthly Rainfall of India, 1923," issued by the Meteorological Department. Figures within brackets give the monthly rainfall expressed, as percentage of the average normal annual precipitation.

Weather Conditions in North Bengal.

Winter rain.—During the cold weather months (December, January and February) fine weather prevails throughout North Bengal, barometric pressure decreases towards the south, from the belt of high pressure lying over the north-west of the Punjab to a belt of low pressure situated a little to the south of the equator. The air movement is generally from

the west, down the Gangetic plain, and recurving across Bengal, from north-north-west and north. Clear skies, fine dry weather, low humidity, and northerly or north-westerly winds are characteristic features of the weather in North Bengal during this period.

Rainfall is very scanty during December, January and February (less than 2 per cent. of the total annual precipitation), and is entirely caused by a succession of shallow depressions which pass eastwards from the north-west and west.

During March, April and May there is a rapid increase of temperature, accompanied by a continuous decrease of pressure over North India, which gradually becomes a low pressure area relative to the Indian Ocean. The depression is very slight at first but increases in intensity with the advance of the season. There is an increase in the indraught from the Bay of Bengal, which gives the characteristic south winds of the hot weather in Bengal.

Summer rain.—During day-time strong hot winds continue to blow down the Gangetic plain from the north-west; the interaction between these hot dry winds from the interior, and the damp sea-winds from the south, supplemented in North Bengal by the action of the hills in giving rise to a vigorous forced ascent, cause the characteristic thunderstorms (or nor'westers, as they are more popularly known) of the summer months.

These nor'westers, which often reach great violence and intensity, are however almost invariably small in extent, and the total rainfall due to them amounts to no more than 15 per cent. of the annual precipitation. Although important agriculturally, the rainfall during these months is thus much too small to be of any effect in causing floods.

Monsoon rain.—The next four months, June, July, August and September comprise the period of the south-west monsoon in North Bengal. More than three-fourths of the total annual rainfall (over 77 per cent.) is concentrated during these four months. For our present investigation this is the most important season. The amount and distribution of rainfall during this period in normal years, determines the prosperity of the whole of North Bengal, and in abnormal years, controls the occurrence of floods in the same region.

Advance of the south-west monsoon.—Accompanying the rapid increase of temperature in the land area in May, pressure generally decreases, so that, by the beginning of June the winter high-pressure area becomes replaced by a deep low-pressure area (usually called the monsoon trough), extending in India from Sind and Western Rajputana to Bengal.

A steady indraught of moisture-laden winds, from the oceanic area towards this low-pressure area in India, constitutes the south-westerly monsoon which continue to persist during the four months June to September.

The monsoon current in the south of the Bay of Bengal is from west-south-west of south-west, and is at this stage largely directed towards Burma and Tenasserim, and a considerable volume of this current proceeds to that area and crosses over the Tenasserim hills or passes up the Irawadi valley. The remaining portion advances up the Bay, and is deflected westwards by the action of the Aracan hills, with the result that, at the head of the Bay, the usual direction of the monsoon winds is from south-west or south. The advancing current crosses the coast between Chittagong and Puri, and comes almost immediately under the influence of the Assam hills and the Eastern Himalayas. That portion of the current which passes into the narrow valley between the Assam and the Chittagong hills, is forced upwards, and gives very heavy rain to the south face of the Assam hills. The remaining portion enters Bengal and is deflected practically westwards, owing largely to the action of the lofty barrier of the Himalayas.

This is a very effective rain distributing current. It contributes, as I have mentioned, the greater part of the rainfall in Bengal, as it advances up the broad flat river plains, the elevation of which remains practically constant or increases very slowly with distance from the sea.

Bay storms.—The front of an advancing current of the monsoon in the Bay of Bengal is usually an area of disturbed weather, strong winds and rain squalls. A characteristic feature is the formation of a cyclonic storm in the Bay of Bengal, which advances landwards and usually strikes the Bengal or the Orissa coast, and moving in directions between north and west, give more or less general rain. In ordinary years the monsoon is usually established by the middle of June, and for the next three

or four months continues to flow as a deep broad horizontal current of air across the Gangetic plain, with irregular movements accompanying rainfall.

Breaks in the monsoon.—The monsoon period is, however, not one of continuous rainfall in North Bengal. More or less general rain is received during periods varying very considerably in length, with intervals of fine weather and passing clouds. During a break, a cyclonic storm would often form in the Bay, and advancing northwards give another burst of heavy rain. The monsoon rainfall is thus pulsatory in character, with bursts of general rain alternating with breaks, partial or general, as the case may be.

The majority of the storms which form in the Bay of Bengal during the monsoon period are usually of slight or moderate intensity, but are remarkable for the very heavy rain which they distribute along their paths. The pulsatory character of the monsoon, caused by the spasmodic advance of these storms from the Bay, however, introduces large local variations in heavy rainfall, and thus plays an important part in causing floods in North Bengal.

Transition stage.—Towards the end of September the transition from the wet to the dry season commences, but is usually not completed until the middle or third week of December. The area as well as the frequency and intensity of rainfall gradually decreases. The total rainfall in October and November amounts to only about 6 per cent. of the annual precipitation and has little bearing on the question of floods.

Normal Rainfall during July, August and September.

The possibility of a flood occurring comes about only when the actual rainfall is in excess of the normal, so that the ordinary drainage is unable to carry away the excess amount of water. It is, therefore, not so much the *actual* rainfall but the *excess above normal* which is of importance in our present investigation. A careful study of the normal rainfall is thus essential for our purpose.

Normal Rainfall Map.—Map No. 1 gives the normal rainfall in North Bengal for the three months July, August and September[1]. The normals are based on records for 64 stations, fairly well distributed over the area. The length of the records is not very great; 11 extend over 50 years, 15 between 40 and 50, 14 between 30 and 40, and 12 between 20 and 30, giving a total of 52 stations with records of 20 years or more and 12 stations with records of less than 20 years. The reliability of the normals (for records extending over 20 years or more) may be taken to vary from 3 per cent. to 5 per cent., depending on the length of the records and the variability of the normal. Probable errors of the normal for each station are given in column (8), Table A.

The tri-monthly normal rainfall is fairly steady in the south and increases slowly towards the north from a value of about 30″, to a value of 40″, in a distance of 80 to 90 miles in the Gangetic plain. In the next thirty miles or so, in the submontane district, it increases more rapidly to 50″. The normal rainfall then begins to increase very rapidly, under the influence of the Himalayas, and attains a value of over 100″ at Kurseong and Buxa, which are situated well up in the hills. It begins to fall off again, also very rapidly, as the interior of the hill is approached, and decreases to about 60″ at Pedong. The normal rainfall also increases towards the east, under the influence of the Garo hills but not to the same extent as towards the north.

Aerial precipitation.—I have found it convenient to divide North Bengal into several distinct flood-areas (*see* Section III). I plotted these flood-divisions together with the isohyetal lines (*i.e.*, lines of equal rainfall given in Map No. 1 for the three months July, August and September, on squared paper, and by direct measurement computed the total normal precipitation

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([1]) In Table A, column (1) gives the serial number; column (2) the name of the station; column (3) the administrative district; column (4) the number of years of records used in the present analysis. Columns (5) to (7) give normal rainfall in inches during the three months—July, August and September. Column (8) gives the mean rainfall in inches (together with the probable error of the mean) for three months; column (9) the standard deviation in inches (together with its probable error foot-note); column (10) gives V, the co-efficient of variation, expressed as a percentage [footnote (7) p. 15] together with its probable error.

([2]) The probable error is a quantity which measures the reliability of the normal. It gives the limits within which, it is even chance, that the normal really lies. Thus for Alipur (Dooars) the normal is given as 81·60″ ± 1·92″, where 1·92″ is the probable error of the mean. It implies that, it is even chance, that the true normal lies between 83·52″ and 79·68″.

The probable error is calculated from the formula : $P = \cdot 6745\sigma/\sqrt{N}$ where "σ" is the standard deviation [footnote (6), p. 15], and N is the total number of years on which the normal is based.

in each area[3]. The figures are given below in column (4), Table 2, in units of million cubic feet. Column (5) of the same table gives the average precipitation in inches, obtained from the aerial estimate, while column (6) gives the same quantity but derived from the figures for individual stations.

Table 2—Aerial Precipitation (July, August and September).

Flood area.	No. of stations.	Areas in square miles.	Rainfall in million cubic feet.	Mean rainfall.	
				Aerial estimates.	Individual stations.
1	2	3	4	5	6
A-1 ..	5	906	166,581	79·1"	80·1"
A-2 ..	4	1,378	291,261	90·3"	90·9"
A-3 ..	3	983	140,122	61·3"	64·4"
B-1 ..	9	3,816	535,130	63·7"	64·4"
B-2 ..	2	1,045	87,416	36·0"	33·6"
B-3 ..	6	2,381	176,985	32·5"	32·0"
C-1 ..	13	3,480	333,243	41·2"	38·6"
C-2 ..	5	1,642	184,103	48·2"	45·5"
C-3 ..	15	5,129	438,302	36·1"	36·3"
Total ..	62	20,560	2,353,143	49·0"	49·5"

Accuracy of aerial estimates.—According to Sir John Benton[4], the number of stations (N) required for reliable estimates of rainfall over an area A (in square miles) is given by $N = 1 + \sqrt{A}/5$. For North Bengal, A = 20,000 square miles, and N is therefore about 30. The actual number used in this report is 57, and is thus quite adequate.

R. E. Horton[5] has given the following formula for the percentage error of an aerial estimate of rainfall:—

$$d = \frac{14 \cdot 7\, R}{P\sqrt{N}}$$

Where d = per cent. error R = difference between the greatest and least rainfall amounts within the area, P = approximate mean aerial rainfall, and N = number of stations.

For North Bengal, for the period July, August and September, R = (124·6" − 27·2") = 97·4 inches, and P = 50 inches, N = 62.

Thus $d = \frac{14 \cdot 7 \times 97 \cdot 4}{50\sqrt{62}} = 3 \cdot 7$ per cent. approximately.

Taking into consideration the errors of estimating areas (about 2 per cent.), the figures in the above table may be considered accurate to about 5 or 6 per cent. The difference between columns (4) and (5) is usually of this order or less. Thus as a first approximation, we shall be justified in using the average of individual stations for finding the mean aerial precipitation in North Bengal.

The general character of the rainfall during the flood months may, therefore, be summed up as follows. There is very heavy rain along the outer regions and foot-hills of the Himalayas. On reaching the plains, the normal rainfall decreases rapidly at first and then very gradually, towards the south, until in the extreme south the normal rainfall is practically constant over a very large area.

Variability of the Rainfall.

The normal rainfall however does not give any idea about the magnitude of the fluctuations which occur from year to year. For this we want a different quantity, namely, the variability of the rainfall from year to year.

Average deviation.—The difference between the actual rainfall at any station in any particular year and the normal rainfall for that station, will be called the deviation (from normal) for that particular year. These deviations will sometimes be positive and sometimes negative. But if we ignore the sign of these deviations and take their actual magnitude for all available years, add them up, and divide by the number of years, we get the "average deviation." This "average deviation" will obviously give a measure of the variability of the rainfall.

Standard deviation.—For certain theoretical reasons, it is, however, more convenient to take the squares of the deviations (thus automatically getting rid of the difference in signs), and extracting the square root of the average,

(3) The measurements have been carefully checked with a planimeter by Mr. Sudhir Kumar Bhose, B.Sc., and Mr. S. Sultan, B. Sc., of the Presidency College, Calcutta. Individual readings were found to agree within 2 per cent.
(4) *Buckley Irrigation Pocketbook, 1920, 324.*
(5) *Monthly Weather Review (U. S. A.), 1923, July, 348.*

compute a number called the " standard deviation." [6] This " standard deviation " is, from the mathematical point of view, a very convenient measure of the variability of the normal. The greater the " standard deviation," the greater will be the variability of rainfall.

Coefficient of variation.—The normal rainfall, however, differs considerably from place to place. For purposes of comparison it is, therefore, more convenient to consider not the absolute variability (as measured by the standard deviation), but the proportional variability, obtained by dividing the " standard deviation " by the " normal rainfall." This quantity is called the " co efficient of variation." [7]

Variability for three months—July, August and September.—Map No. 5 gives a plot of this relative variability (coefficient of variation) of the normal rainfall in the three months—July, August and September—for each station for which the data extend over 20 years or more.

It will be noticed that within a considerable area in the central districts, and also in a certain area along the bank of the Ganges in the extreme south, the relative variability is approximately constant, and is nearly 30 per cent. The variability is more than 25 per cent. over the greater part of North Bengal, while the variability is of the order of 20 per cent. within a small region in the hills. It is interesting to note that although rainfall is very heavy in the hills, the relative variability is actually lower than that in the central area.

Variability for other Periods.—I have calculated the variability for a number of other periods, for 38 stations for which records of 30 years or more were available. I do not propose to discuss here the results in detail, but I am giving below the average values for the different flood-areas.[8]

Table 3—Observed Variabilities for different Periods.

Flood areas.	Variabilities.					
	1 day.	2 days.	3 days.	5 days.	7 days.	92 days.
A-1 ..	114·1	82·8	76·28	60·03	53·54	21·2
A-2 ..	140·8	110·0	118·20	101·26	89·12	21·8
A-3 ..	159·1	145·0	112·0	95·30	81·31	24·6
B-1 ..	175·8	143·9	127·3	109·85	93·98	27·2
B-2 ..	181·2	135·3	128·3	104·93	92·12	28·6
B-3 ..	151·8	130·3	96·12	88·06	76·95	30·4
C-1 ..	171·7	147·8	116·6	100·1	81·40	28·5
C-2 ..	195·9	158·6	125·5	108·1	95·54	30·8
C-3 ..	173·6	137·9	112·6	97·20	85·60	30·3
Whole area ..	165·1	134·6	113·9	98·03	84·11	27·58

Annual variability.—The coefficient of variation for one year has not been directly calculated, but has been derived as explained below from the coefficient of variation for a quarter (July, August and September).

Let m_1, m_{k-1}, m_k; s_1, s_{k-1}, s_k and $V_1=100\ s_1/m_1$, $V_{k-1}=100\ s_{k-1}/m_{k-1}$, $V_k=100\ s_k/m_k$, be the mean, the S. D., and the co-efficient of variation for one quarter, for $(k-1)$ quarters, and " k " quarters respectively. For one year $k=4$.

We now make one assumption, namely, that the rainfall in the quarter July, August and September is not correlated with the rainfall in the remaining portion of the year. The correlation in any case is small, and large errors cannot be introduced by treating it as zero. If in addition we substitute average values in the variance it can be easily shown that

$$m_k=m_{k-1}+m_1 \quad \ldots\ldots\ldots (1\cdot1)$$

$$s^2_k=s^2_{k-1}+s^2_1 \quad \ldots\ldots\ldots (1\cdot2)$$

$$V^2_{k-1}=V^2_1/(k-1) \quad \ldots\ldots\ldots (1\cdot3)$$

(6) The formula for " s, " the standard deviation, is simple and can be expressed as follows :—

Let M be the normal rainfall at any station. Let m_1, m_2, m_3, ... be actual rainfall in individual years. Then corresponding deviations are $M-m_1=d_1$, $M-m_2=d_2$, etc. If the total number of years for which records are available is N, and " s " is the standard deviation (S. D.), then

$$N.\ s^2=d_1^2+d_2^2+d_3^2+\ldots\ldots\ldots=\Sigma(M-m)^2.$$

(7) It is customary to define V as 100 s/M where " s " is the standard deviation, and M is the Mean. Multiplication by the constant 100 is purely conventional, and is adopted to give the final result the form of a percentage.

(8) The value for one day is the average of seven separate daily values, and the value for two days the average of two separate sets.

Now writing $m_k = c.m_1 = c.m_{k-1}/(c-1)$, and dividing (1·1) by m^2_k,

we get $V^2_k = \frac{V^2_1}{c^2}\left\{1 + \frac{(c-1)^2}{k-1}\right\}$ ....(2).

For North Bengal, $V_1 = 27{\cdot}58$, $c = 87{\cdot}57''/50{\cdot}74'' = 1{\cdot}726$, and $K = 4$, we therefore get from equation (2), the coefficient of variation for 1 year as 17·12 per cent

For periods lower than a quarter, the assumption made above is not strictly justified, as the rainfall correlation between successive periods do not vanish and equation (2) cannot be used as it stands. I have therefore, used the " intra-class correlation " to measure the deviations from this equation. If R_k is the " intra-class correlation "[9] for rainfall on R successive periods (in this case, K days), then[10].

$$V^2_k = \frac{V^2_1}{k}\left\{1 + (k-1)R_k\right\} \quad \ldots\ldots(2{\cdot}1).$$

This equation reduces to (2) when $R_k = 0$ since C (for daily periods) then becomes equal to K. Taking North Bengal as a whole, and using the value of V_k given in Table 3. I derived the intra-class correlations R_k given in column (2), Table 4, with the help of equation (2·1). These correlations were also computed directly for each individual station for the period 1st to 7th August. Average values of such directly observed correlation R′ for each area are given in column (3), Table 4.

I further found that the computed correlations in column (2) could be graduated fairly well by the following formula:—

$$R_k = 0{\cdot}538k^{-1} = \left(\frac{0{\cdot}4926}{k}\right)^1 = (0{\cdot}6714k)^{-1} \quad \ldots\ldots(3)$$

where R_k is the intra-class correlation for "K" successive days.

Graduated values of R″ obtained from equation (3) are given in column (4) of Table 4.

Using Fisher's transformation[11], namely,

$$Z = \tfrac{1}{2}\log_e\left\{\frac{1+(k-1)R}{1-R}\right\}$$

$$s^2 = k/2(k-1)(N-2)$$

where s is the S. D. of Z, and N is the total number of years' record used. I have calculated values of Z, Z′ (corresponding to R and R′) and s given in columns (5) and (6) and (8), respectively.

Table 4—Intra-class Correlations.

1	2	3	4	5	6	7	8
Period (days).	R (K).	R′ (K)	R″ (K)	Z.	Z′.	Z-Z′.	s.
2	0·3293	0·2135	0·3324	0·3420	·2168	·1252	·0326
3	0·2139	0·1919	0·2450	0·2975	·2694	·0281	·0274
5	0·1907	0·1602	0·1670	0·3892	·3349	·0543	·0254
7	0·1361	0·1040	0·1298	0·1858	·1487	·0371	·0242
92	0·0172	..	·0188	..	..	..	..

The differences between Z and Z′ given in column (7) compared to the S. D. given in column (8) are thus not significant (except perhaps in the case of the two days period) and the use of equation (2·1) is justified. The agreement between R and R″ is also quite satisfactory. We may, therefore, use equation (3) for deriving R_K for different periods, and then use equation (2·1) for determining the corresponding variabilities.

Using equations (3) and (2·1) successively I obtain the following table for average R_K and average variability V_K (for North Bengal as a whole), for different periods. Observed values, where available, are given in column (4) for comparison. It will be noticed that the agreement between computed and observed values is excellent.

(9) J. A. Harris, *Biometrika, IX, 1913, 446-450.* It can be easily shown that R^k measures the average correlation for an interval of (K+1)/3 days.
(10) Substituting the average daily mean and the average daily S. D
(11) " Statistical Methods for Research Workers " by R. A. Fisher (London, 1925), p. 185.

Table 5—Variabilities for different Periods (North Bengal).

K days.	Intra-class correlation R_k.	Coefficient of variation V_k	
		Computed.	Observed.
1 ..	....	....	165·07
2 ..	0·33 24	134·70	134·63
3 ..	·24 50	116·40	113·94
5 ..	·16 70	95·36	98·03
6 ..	·14 58	88·53	....
7 ..	·12 98	83·22	84·11
8 ..	·11 74	80·49	....
9 ..	·19 75	75·08	....
10 ..	·09 93	71·85	....
12 ..	·08 86	66·96	....
18 ..	·06 39	56·21	....
24 ..	·05 15	49·80	....
25 ..	·04 99	48·75	....
30 ..	·04 36	45·36	40·77[18]
31 ..	·04 25	44·70	....
60 ..	·02 59	33·88	....
61 ..	·02 56	33·64	....
62 ..	·02 53	33·43	....
92 ..	·01 88	28·21	27·58
1 yr.	0	17·12	....

Variability of Rainfall in other Provinces of India.—In "The Rainfall of India" (Indian Meteorological Memoirs, Volume III, 1888) H. F. Blanford has compared the mean variability (derived from the average deviation, and not the standard deviation) of different rainfall provinces of India, based on about 20 years' records. The nearest division was Lower Bengal, which, however, covered a much larger area than our North Bengal. It included 25 stations (Mem., p. 41) from all over the present-day administrative province of Bengal, out of which only seven stations belonged to North Bengal proper. The mean variability of Lower Bengal is given as 10 per cent. (Mem., p. 129). The coefficient of variation (which is based on the S. D. and not on the average deviation) will be a little higher. By direct calculation from the data given on p. 149 of the same Memoir, I found the coefficient of variation to be 12·41 per cent. Considering the large differences in the two areas concerned, our value of 17·28 per cent. for North Bengal alone is quite possible.

For convenience of comparison I reproduce below relevant portions of Blanford's Table given on p. 129 of his Memoir. I have added in column (6) the coefficient of variation obtained from the average variation[19] by multiplying the latter by the constant factor 1·2533.

Table 6—Annual Variabilities from Blanford.

1	2	3	4	5	6
Province.	Number of stations.	Years.	Mean rainfall.	Average variation per cent.	Coefficient of variation.
1. Punjab Plains	29	20	21·5"	13	16·3
2. N.-W. P. and Oudh.	30-41	20	37·1"	23	28·9
3. Behar ..	3-13	20	43·4"	18	22·6
4. Lower Bengal	11-29	20	66·7"	10	12·5
5. Rajputana ..	4-19	20	27·9"	13	16·3
6. Central Indian States.	8-21	20	41·3"	15	18·8
7. Western Bengal	4-10	16	49·6"	7	8·8
8. Assam and East Bengal.	7-17	20	95·2"	5	6·3
9. Orissa and Northern Circles.	10-16	20	47·8"	12	15·1
10. Central Provinces, South.	7-19	20	49·9"	10	12·5
11. Khandesh and Berar.	7-11	20	34·7"	20	25·1
12. Guzerat ..	6-10	20	35·6"	15	18·8
13. Sind and Cutch	7-10	20	8·8"	37	46·5
14. North Deccan	10-14	20	9·5"	15	18·8
15. Hyderabad ..	3-19	14	31·8"	17	21·3
16. Mysore ..	7-16	20	28·8"	15	18·8
17. Konkan and Ghats.	9-12	20	143·2"	12	15·1
18. Malabar and Ghats.	6-8	20	115·0"	12	15·1
19. Carnatic ..	27-40	20	34·2"	15	18·8
20. Arakan ..	2- 6	20	155·0"	8	10·1
21. Pegu ..	5- 7	14	73·1"	9	11·3
22. Tenasserim ..	2- 4	20	172·0"	8	10·1
North Bengal (for comparison).	38	43	49·8"	..	17·12

It will be noticed that the variability of the annual precipitation in North Bengal is not excessive in comparison with the other provinces of India.

(18) The mean coefficient of variation for 12 stations for the month of July was found to be 40·77 with S. D. = 2·38. The computed value for 38 stations given in Table 5 is 45·05. The difference from the observed value is 5·72, which is not significant in comparison with a S. D. of 2·36 (apart from the fact that the two variabilities refer to different number of stations).

(19) On the assumption of a normal distribution.

Variability of Rainfall in other Countries.—For British Isles[14] as a whole, the annual variation (based on 54 years of record) is 11 per cent., and is thus nearly 50 per cent. less than the annual variation of North Bengal.

For England East, I find by direct computation from the data given in R. A. Hooker's paper on "The Weather and Crops in Eastern England, 1885—1921"[15] that the average variability for eight weeks is 35·15, for one quarter 27·9 and for 40 weeks 13·25.

In central and Western Europe[16] the average departure has been stated to be 13 per cent. of the annual precipitation, that is, to have a coefficient of variation of 16·3, which is slightly less than North Bengal.

In California[17], the average annual variation is 25·7 per cent., which is considerably higher than North Bengal.

Probability of Excessive Rainfall.

Using the variabilities given in the Table 5, it is a simple matter to calculate, with the help of a table of the Probability Integral[18], the probability of any given excess occurring in any given period.

I give below a short table of such probabilities for a few selected values of percentage excess[19]. The S. D. for each period is given within brackets at the head of each column.

Table 7—Probability of given excess. (Number of occasions in 100 years.)

Excess per cent.	1 day (0·6057).	27 days (1·2016).	24 days (2·0088).	30 days (2·2045).	61 days (2·9726).
25	5365·6	649·2	153·8	120·3	45·74
50	4648·2	465·8	78·75	54·0	13·72
75	3977·2	312·3	32·95	19·64	2·56
100	3322·1	195·0	11·10	5·48	·296
125	2762·1	113·1	3·00	1·189	·296
150	2230·2	60·70	·6556	·1897	·207
200	1376·2	13·77	·1030	·0021	..
250	807·6	2·210	·0015	..	..
300	422·1	·2653	..	..	..
400	92·7	·0013	..	..	..
500	14·7	·0001	..	..	..

Frequency of very heavy rain.—The probability of very large excesses cannot, however, be accurately obtained from the above table, which is based on the normal distribution. The distribution of total rainfall (in a given period) is asymmetric, and shows greater frequencies for heavy excess. I have calculated the frequency-constants (up to β_1 and β_2) for 38 stations for the tri-monthly period, but as they have not yet been checked, I refrain from reproducing (or using) them here.

We can, however, look at the question from a slightly different point of view. Very high excesses are controlled by a comparatively small number of exceptionally heavy falls of 3 inches more in a day, and the frequency distribution of such heavy falls would give us some idea about the probability of very large excesses occurring in any particular place. The frequency of heavy rain in India has been given in the Memoirs of the Indian Meteorological Department Volume XXIII, Part VIII, 1923. I have prepared my summary Table 8 from the data given in this Memoir.

The information given in the original Memoir is based on observations recorded during the period of 30 years extending from 1891 to 1920. The period of record, however, varies from station to station, and the frequency number for different stations are not comparable with one another, without an allowance being made for the number of years of observation from which the data have been extracted. To facilitate comparison, I have, therefore, expressed all figures as frequencies in 100 years, and have taken the average for each area.

(14) Q. J. Met. Soc., 1923, Oct., 215.
(15) Q. J. Met. Soc., 1922, April, 115—138.
(16) Hann. "Lehrbuch der Meteorologie," 1915, 110—113, (*M. W. R., U. S., 1925, April, 149*).
(17) B. M. Varney "Seasonal Precipitation in California and its Variability"—(*M. W. R., U. S., 1925, April*).
For individual towns in America, the mean annual variability varies from 9 per cent. in New York to 25 per cent. in San Francisko—(*M. W. R., U. S., 1919, September, 631*).
(18) Table II, Tables for Statisticians and Biometricians.
(19) I have restricted the total "population" to the four rainy months—June, July, August and September. For example for seven days, and for an excess of 100 per cent., the probability is 0·11476. Now about 17 weeks will occur in each year during the four possible months—June to September—or altogether 1,700 weeks in 100 years. Thus multiplying 0·11476 by 1,700 we get 195·0 approximately, as the number of occasions on which the weekly excess is likely to exceed 100 per cent. in 100 years.

Table 8—Mean Frequency of Heavy Rain. (Number of occasions in 100 years for each station).

Area.	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3	Whole area.	
Number of stations ..	5	5	3	9	4	4	14	4	11	Observed.	Computed.
Daily rainfall ..	0·8600	0·9814	0·6662	0·6923	0·3915	0·3480	0·4479	0·5239	0·3926	0·5280	..
Daily S. D.	1·418	1·619	1·099	1·142	0·645	0·555	0·739	0·864	0·648	0·8937	..
3"-4"	323·8	587·1	308·3	409·4	169·8	104·8	161·7	240·7	174·4	262·1	105·5
4"-5"	138·1	331·5	181·1	222·8	48·2	44·5	59·1	114·5	66·1	123·5	1·98
5"-6"	76·3	182·3	108·3	140·5	29·9	38·9	27·0	34·5	29·0	67·5	Less than ·000036
6"-7"	43·5	91·4	37·7	68·1	8·2	20·8	13·2	31·9	14·0	33·6	
7"-8"	21·3	59·4	17·2	32·1	6·5	4·7	8·6	18·6	11·0	18·6	
8"-9"	15·3	29·5	7·2	11·2	3·3	0·8	2·4	5·8	6·0	8·3	
9"-10"	8·6	21·5	4·4	8·1	3·3	..	2·4	2·4	0·3	5·1	
10"-11"	1·9	11·3	..	5·2	0·8	..	1·0	3·8	1·5	2·8	
11"-12"	3·2	5·3	2·6	1·1	..	..	0·7	0·8	1·1	1·5	
12"-13"	1·3	3·3	..	1·5	0·8	..	0·2	1·2	0·5	1·1	
13"-14"	..	..	..	0·4	..	..	0·3	..	..	..	
14"-15"	..	1·9	..	0·4	0·8	..	..	1·6	..	..	
15"-16"	0·6	..	1·1	..	..	..	0·2	..	0·3	1·1	
16"-17"	..	0·6	..	..	..	..	..	..	..	..	..
17"-18"	..	..	..	..	..	..	0·3	..	..	..	..
19"-20"	0·6	..	..	..	..	..	..	..	..	..	..
24"-25"	..	..	..	0·4	..	..	..	..	..	..	..

The last column gives the theoretical frequencies. It will be noticed that the observed frequencies are far more numerous than those given by the probability integral (which is based on the normal distribution). For example, for the whole area, a fall of 3 inches given an excess of 2·46″ (with a daily mean of 0·54″), which divided by the S.D. = 0·893″, gives a deviation of 2·755. From a table of probability integral, I find that the probability for falls of 3″ or more is ·0029350. The probability of falls of 4″ or more is ·0000533. Thus, the probability for falls between 3″ and 4″ is ·0028817. Multiplying this by 365 × 100, we get 105 as the theoretical frequency in 100 years. Similarly, the computed frequency for falls between 4″ and 5″ is 1·98, and beyond 5″ only ·000036, which is practically zero.

We conclude, therefore, that the likelihood of very heavy falls occurring in North Bengal is actually much greater than that given by the simple theory of normal probability.

This is important, as it indicates that, although the average variability as measured by the coefficient or variation is not exceptionally high in North Bengal, the actual chance of floods being caused by very heavy rains is really great.

Fluctuations from place to place.

Rainfall in North Bengal shows great fluctuations in a totally different sense. During the same period, or even on the same day, certain stations may get heavy falls while other stations in the neighbourhood have very little. Even when heavy general rainfall occurs over a particular area, the actual site of the heaviest precipitation fluctuate very irregularly, and it is a matter of great uncertainty where the exceptionally heavy rains would actually fall[*]. This patchy or fluctuating character of very heavy rainfall is a feature which one would expect from the nature of the causes which bring about such precipitation. As I have already mentioned,

([*]) For example, in the week ending 27th September 1922, 49·95″ of rain fell at Balurghat, and 27·20″ at Pirganj, while Nawabganj (situated about half-way between those two stations) had only 8·70″. During the same week, Tanor had 20·61″, and Nator 27·75″, while Rampur Boalia (which is situated at a distance of about 16 and 25 miles, respectively, from the above stations) had 9·98″.

A. T. Henry ("The Distribution of Rainfall Over Restricted Areas", *M. W. R., U. S., 1921, July, 401*) found that seven gauges situated within an area of 60 square miles in New Orleans, La., (U. S. A.), showed catches varying from 11·94″ to 19·55″ in one single month, giving a range of fluctuation of 47 per cent. of the mean of the seven gauges.

the heaviest precipitations are usually brought about by cyclonic storms coming up from the Bay. Not only do the tracks of these storms vary very considerably, but the actual region of heaviest precipitation along any particular track also varies largely.

These fluctuations in heavy falls are however, random in character, so that no particular region is more favourably situated than others for such heavy falls. This is borne out by the fact that both the maps for normal rainfall and for variability show perfectly continuous gradation, and do not reveal the existence of regions especially susceptible to heavy falls.

Changes of Normal Rainfall.

Without entering into a detail examination of the question, I may mention here that the available data do not indicate any permanent increase (or decrease) of normal rainfall in North Bengal. There is no definite evidence of such changes having occurred in recent years in other parts of the world also. In fact it is now generally recognised that changes brought about by human agencies have practically no effect on the normal rainfall of a country. For example, increase of cultivation[11], or increase of drainage[12], have been definitely shown to have no appreciable effect[13].

([11]) J. Warren Smith, "Cultivation does not Increase the Rainfall"—(*M. W. R., U. S., 1919, Dec., 858*).

([12]) E. V. Willard, "Rainfall and Drainage Operation"—(*M. W. R., U. S., 1924, Sept., 419*).

([13]) Sir Gilbert T. Walker's memoir "On the meteorological evidence for supposed changes of climate in India" (*Ind. Met. Mem. Vol. XXI, Part 1, 1910*) gives a general discussion of the question.

SECTION III.—THE FLOOD AREAS OF NORTH BENGAL.

North Bengal may be conveniently divided into three distinct natural divisions with three subdivisions[1] in each :—

(A)—Hilly districts and submontane country including—

(1) hilly district of Darjeeling,

(2) submontane country running parallel to the foothills of the Himalayas,

(3) south-easterly projection on the west bank of the Tista, in district Jalpaiguri.

(B)—The flat riparian tracts drained by the three great rivers of North Bengal comprising—

(1) the north-eastern basin of the Tista,

(2) the low-lying country on the right (west) bank of the Brahmaputra,

(3) the spill area on the left (north) bank of the Ganges.

(C)—The country in the interior consisting of—

(1) and (2) uplifted plains in the north-west and the north, and

(3) the central low-lying area covered with marshy depressions.

(A)—Hilly districts and submontane country.

In the north of the area lie the foothills (which rise abruptly to a height of over 10,000 feet above sea-level) and the deep valleys of the Lower Himalayas. These spurs and valleys are heavily forested and mountain torrents rush down on every side.

Next comes a tract of submontane country consisting of the low-lying belt of the Terai and the Dooars, at a height of 300 feet above sea-level, and running from west to east along the foot of the Himalayas in the district of Darjeeling, Jalpaiguri and Cooch Behar. This tract is traversed by numerous rivers rushing down from the hills, and was formerly covered by dense jungles[2], but has been now extensively cleared for ordinary cultivation and tea gardens.[3]

The Tista drains Sikkim, eastern portions of the Darjeeling district, and also the central submontane area. A number of mountain streams (*e.g.*, the great and the little Rangit, Ghish, Dharla, Jaldhaka, Daina, Duduya, Torsa, Dima, Raidhak, etc.) suddenly debouch from the hills and bring down a considerable volume of water in the submontane area, and ultimately flow into the Tista or the Brahmaputra.

Drainage.—We have seen that normal rainfall is high in the hilly districts and in the submontane country. Owing to the mountainous character of the good drainage offered by a large number of hill streams and broad rivers, water however, flows away quickly.

Flood areas.—This area may be divided into three flood divisions—(A-1) comprising the hilly districts (A-2) the submontane country running from west to east along the foothills of the Himalayas; and (A-3) the raised plain on the right (west) bank of the Tista.

The following table gives a list of floods in area (A-1) graded according to their intensity[4] :—

Table 9—Flood List for Area (A-1).

Year.	Month.	District affected.	Nature.	Map No.
1886	September	Darjeeling ..	(c)—moderate	10.
1890	August ..	.. ..	(c)— "	
1892	July ..	.. ..	(b)—very severe.	11, 12.
1898	September	.. ..	(c)—moderate	
1899	..	.. ..	(a)—catastrophic.	12-1, 12-2.
1906	August and September.	.. ..	(c)—moderate	13, 14, 15, 16.

(1) Shown in Map No. 2. The area (B-4) shown in the map was finally incorporated with area (B-3), (after the maps had already been printed).

(2) T. H. Burkill, "A note on the Terai Forest, etc." : "The natural vegetation of the Terai between the Gandak and the Teesta is forest."—*J. A. S. B., 1916, 267.*

(3) Burkill : "The little variety in the woody vegetation over these wide tracts is evidence of periodic and severe firing at no very remote date, whereby the forest was destroyed first to a savannah, and then to what remains now, through such a state as we see at the present time on the great gravel bank of the Eastern Duars towards Nagrakata. • • • • • • • • • • • • In the eighteenth century, Northern Purneah emerged into a transition phase between forest and cultivation, such as we can see in the Eastern Duars at the present time. • • • • • • • • • In the process nearly all the formerly existing tree growth was burned off, and although we find now that the landscape is full of trees, they are bamboos and mango trees whose planting is certainly very recent."—*J. A. S. B., 1916, 271-272.*

(4) As explained in section 1, paragraph 5, page 2, floods have been classified in accordance with the following scheme :—

(*a*) *Catastrophic* : involving considerable direct loss of human life ; also great destruction of crops and cattle.
(*b*) *Severe* : small loss of human life ; considerable loss of crops and of cattle.
(*c*) *Moderate* : considerable loss of crops and of cattle but no direct loss of human life.
(*d*) *Slight* : slight or moderate damage to crops, but no loss of cattle or human life.

In the hilly districts small landslips causing slight or moderate damage to roads and bridges, occur almost every year during the rainy season, and have not been taken into consideration in compiling the flood list given above.

More extensive landslips and greater damage to roads, bridges and houses are caused by moderate or heavy rainfall continuing for a long period, which does mischief by gradual loosening of the soil, rather than by sudden flooding. For example, in 1886, unusually heavy rain fell throughout June, July, August and September, and caused serious landslips and considerable damage to roads and bridges. In 1890, heavy rain fell during practically the whole of July, and in 1898, throughout September, and caused great damage to hill roads, and interrupted communications for a long time. In all these cases the rainfall was distributed over a long period, and the damage done was general and more or less gradual.

More severe and occasionally catastrophic floods (*e.g.*, in September, 1899) are also sometimes caused by very heavy rainfall occurring within a short period. In 1892, exceptionally heavy rain fell in the first week of July (the excess for that week being over 150 per cent. in certain places), which led to a torrential flood, and did considerable damage to roads, bridges and houses. In 1899, although heavy rain had fallen for many days in September, the great disaster was directly caused by the exceptionally heavy falls on the 23rd, 24th and the 25th September, which were given by a cyclonic storm from the Bay. At Darjeeling 19·40" of rain fell in a single day (25th) and the excess for three days amounted to from 800 per cent. to 1,500 per cent. (8 to 15 times the normal rainfall). The water rushed down in torrents and caused disastrous landslips with considerable destruction of life and property. In 1906, another flood of the same type was caused in the first week of August, by exceptionally heavy precipitation given by storms from the Bay.

We thus see that floods in this area are invariably caused by heavy local rainfall. They are either due to continued rainfall over a long period (*e.g.*, 1886, 1890 and 1898) or to sudden and torrential rain occurring within a short time (*e.g.*, 1892, 1899 and 1906).

Table 10—Flood List for Area (A-2).

Year.	Month.	District affected.	Nature.	Map No.
1886	September	Jalpaiguri ..	(d)—slight ..	10.
1892	July ..	" ..	(b)—very severe.	11, 12.
1898	September	Doors ..	(d)—slight ..	....
1899	"	Jalpaiguri ..	(b)—severe	12-1, 12-2.
1906	August and September.	" ..	(b)— "	13, 14, 15, 16.

Drainage.—The general slope in the strip of submontane country running parallel to the foot-hills of the Himalayas, is from north to south, and is fairly good, and the drainage of the country, which is traversed by numerous streams running down from the hills, is also generally satisfactory.

Floods.—Heavy rainfall in the hills would ordinarily cause a certain amount of damage in the submontane area (*e.g.*, in September 1886 and 1898); but would not give rise to serious floods unless accompanied by heavy local rainfall. For example, in September 1899, the unprecedented rainfall in the hills did not cause any serious damage in the Jalpaiguri district, evidently because local rainfall in Jalpaiguri itself was not excessive. Severe floods may also occur without heavy rainfall in the hills, as in 1902, when great damage was done by the overflowing of the Tista caused by excessive local rainfall.

Heavy local rainfall, if continued for any length of time, may by itself, give rise to general flooding, as in the year 1890. The situation would be further aggravated if, owing to heavy falls in the hills, the rivers also rise high, as in 1892, or actually overflow their banks, as in 1906.

Owing to the good drainage offered by the general slope of the country, floods in this area are, however, quickly drained away, and are usually of short duration.

Table 11—Flood List for Area (A-3).

Year.	Month.	District affected.	Nature.	Map. No.
1892	July ..	Jalpaiguri ..	(b)—severe	11, 12.
1899	September	" ..	(c)—moderate	12-1, 12-2.
1902	"	" ..	(b)—severe	12-3, 12-4.
1906	August and September.	Jalpaiguri and Cooch Behar.	(b)—extremely severe.	13, 14, 15, 16.

Drainage.—This area is practically a south-easterly projection of the submontane country[1].

[1] It is bounded on the north by the submontane country; on the west by the district Dinajpur; on the south by a line following roughly the 300 feet contour and by the water-shed separating the Ghaghat from the Tista; on the east by the Tista.

The ground slopes down about 100 feet in a distance of 40 or 50 miles and is drained by the Tista[6], the Karatoya and the Ghoramara[7].

Floods.—Floods are of rare occurrence but when they occur they are usually severe in character and are almost invariably caused by cyclonic downpours as in July 1892, September 1902 and August 1906. In all these years, heavy rain had fallen in the hills and in the submontane country, and water from the north swelled the rivers considerably, and thus aggravated the situation. In 1906 the Tista actually overflowed.

Heavy rain in area (A-1—hilly districts) or in area (A-2—submontane country) cannot, however, by itself produce a flood in area (A-3), as may be easily gathered from the rainfall analyses for 1870, 1874, 1898, 1899, 1910, 1915 and 1918, years in which heavy rain had fallen in the north, but had not caused any flooding in (A-3).

The Tista acts as a very effective barrier and completely isolates area (A-3) from area (B-1); so that (unless the Tista itself overflows its western banks), floods cannot be caused in (A-3), by any amount of heavy rain falling to the east of the Tista[8].

In 1892 and 1906 the level of the Brahmaputra rose exceptionally high (over 24 feet at the Gauhati gauge in 1892, and generally over 27 feet in August 1906). This naturally hampered drainage and added to the severity of the floods. A high level of the Brahmaputra, by itself, cannot however cause a flood in (A-3).

It would thus appear that severe floods in area (A-3) can be brought about only by the conjunction of heavy local rainfall, heavy rainfall in the north, and a high river level, while the factors occurring singly may remain ineffective.

Area (B-1)—North-eastern Plain.

Drainage.—East of the Tista lies the flat river plain of the western Dooars, Cooch Behar and Rungpur[9]. It is drained by numerous rivers and hill-streams, by the Dharla[10], the Tista, the Brahmaputra, and their tributaries.

Owing to the flatness of the country (the average slope of the ground is about 100 feet in a distance of 90 or 100 miles and is considerably less towards the extreme south-east), drainage is not satisfactory. The tributaries of the Tista bring down a considerable amount of sand and debris from the hills which is continually raising the beds of the rivers, and is gradually making their current sluggish.

Table 12—Flood List for Area (B-1).

Year.	Month.	District affected.	Nature.	Map No.
1890	August ..	Dooars ..	(c)—moderate	....
1892	July ..	Dooars and Rungpur.	(b)—severe ..	11, 12.
1902	August ..	Cooch Behar	(d)—slight ..	12-3, 12-4.
1906	August and September.	,, ..	(b)—very severe.	13, 14, 15, 16.
1910	July ..	,, ..	(c)—moderate	17, 18.
1915	August ..	Dooars ..	(d)—slight ..	19, 20.

Severe floods have been caused almost always by cyclonic downpours occurring at the end of a period of excessive general rain. For example, heavy falls during the first week of July 1892, at the end

(*6*) The river channels in this part of the country have changed very considerably during the course of the last 150 years. The Tista used to flow into the Ganges, and was also connected with the Karatoya. In 1765 Major Rennell noticed a river Sanafkotta, which he described " as a branch of the Teesta, comes out of that river above Allygunge, and as we are informed runs into the Coretya " (Karatoya). " Journals of Major James Rennell " edited by T. H. De-Latouche ; *Memoir, Asiat. Soc. Bengal, Vol. III, 1910.*

(*7*) Rennell (*Mem., p. 68, 1766*) described the country as " fine and well-cultivated " with wheat, sugarcane and tobacco. " We proceeded about 3½ miles along the west bank of the Teesta and then struck off to the NW, and within a mile of the Teesta and then crossed the Curume or Ponjah River which is deep and rapid. Four miles NWBN from hence we crossed the Guramarra another deep and rapid river which joins the Corto and Curume some miles to the southward and all fall into the Teesta." The " Curume " was probably an old channel of the Tista, and the " Corto " is a corruption of the name Karatoya. Further west he met three small rivers Corto, Soan and Doank (modern Dank)—" neither of them is more than 90 yards broad or more than 2 foot deep at this time " (February, 1766, p. 69).

(*8*) Before the diversion of the Tista in 1787, there was, however, no such isolation. In fact in 1765-66, Major Rennell found that the Tista, the Gaghat, the Dharla and the Punarbhava were all interconnected. After crossing the Manash Creek (a branch of the Tista), and proceeding to " Dammo-Choculo six miles ESE from Rangpur, crossed Allykury Creek, which is another branch of the Teesta and about 2 feet deep at this time (November, 1765).

The whole country appears to be very well watered, being everywhere intersected by small creeks . . . . . The Goggot Creek (modern Gaghat) comes within three-quarters of a mile of the west part of town (Rungpur) . . . . is navigable for boats of 150 maunds till the month of January, . . . and . . . . is said to be a branch of the Purnabubah river which has its source in the kingdom of Boutan (modern Bhutan)." A little later, Rennell mentions that the Dharla has likewise its source in the Boutan, and in the wet season has a communication with the Purnabubah (Mem., 54 - 55).

(*9*) It is bounded on the north by the submontane country on the east by the Goalpara district and the Brahmaputra ; on the south and the west by the Tista.

(*10*) In 1765 Rennell described the Dharla as from 350 yards to a quarter of a mile broad and navigable all the year round for boats of 2,000 maunds between Gurygong (Kurigram) and the conflux with the Brahmaputra (*Mem., 55*). Rennell (writing in December-January 1765-66) found the current " excessively rapid," and estimated the average flow to be seven miles per hour.

of a very rainy season (general excess of 100 per cent. for the whole month), heavy falls on the 26th and 27th September 1902 (general excess of 100 per cent. for the whole month); cyclonic falls during the first week of August 1906 (general excess of from 50 to 100 per cent. in July and from 100 per cent. to 200 per cent. from 27th July to 20th August) caused very severe floods, which washed away roads and bridges, and made extensive breaches in embankments and railway lines.

Heavy precipitation within a short period (for example, that occurring in the second week of August 1915), if not accompanied by a general excess, will not ordinarily give rise to severe floods. A long continued general excess of rainfall (amounting to from 50 per cent. to 100 per cent. in three or four weeks), even if not accompanied by cyclonic downpours, may, on the other hand, give rise to slight or moderate floods, especially if the level of the Brahmaputra is high. This happened in August 1890, when the level of the Brahmaputra rose abnormally high (the reading at the Gauhati gauge exceeded 27 feet on the 5th August), and again in July 1910 (Gauhati gauge 24·4 feet on the 12th July, rising to 30·2 feet on the 31st), or in 1918 (Gauhati gauge from 26 to 29 feet).

In fact, in this area, the level of the Brahmaputra is a factor of very great importance. With a low level of this river, even a considerable excess of local rainfall in September 1898 and 1899 did not give rise to floods. On the other hand a high level of the Brahmaputra added to the severity of the floods in 1892, in 1902, and particularly in 1906 (when the Gauhati gauge rose to 32 feet), and prolonged considerably the duration of the slight or moderate floods of 1890, 1910, 1915 and 1918, by hampering quick draining away of the water.

Heavy precipitation in the hills and in the submontane country can affect area (B-1) in two ways; by a direct onrush of water, or indirectly, by a swelling of the Tista and other hill streams leading to their overflow. The Dharla in 1892, the Tista in 1902, both the Tista and the Dharla in 1906, and the Torsa in 1910 overflowed their banks, owing to heavy rain in the hills, and caused great damage. So long as the rivers did not overflow a direct onrush of water from the hills (due to heavy rain in that area, as in 1886) can, however, do very little damage in the plains.

Area (B-2)—Spill Area of the Brahmaputra.

The level of the country in the east of districts Rungpur, Bogra and Pabna is very low and the greater part of this area is inundated every year during the rainy season, by the overflow of the Brahmaputra[11].

Drainage.—The slope is extremely small and amounts to only about 50 feet in a distance of 100 miles[12]. The drainage is roughly from north to south, but sets away from the Brahmaputra, slightly towards the south-east.

The Gaghat (the upper part of which is approximately parallel to the Tista), used to be a very important river in

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(11) I have taken the following description of the Brahmaputra from Mr. G. H. Reaks' Report (Appendix II, Hooghly River and its Head-waters, Government of Bengal, 1919, Volume I). "The Brahmaputra is 1,800 miles in length and has a drainage area of 361,200 square miles over country with a heavy rainfall, the average in the Assam Valley being about 88 inches. After traversing Tibet in the easterly course as the Tsan Po, it emerged into Assam under the name of Dihong and flows south-westward through an alluvial plain in the Assam valley, 450 miles in length with an average breadth of 50 miles, receiving various tributaries on both banks, draining the Himalayan slopes on the north and northern slopes of the Assam hills from the south. The Brahmaputra curves round the western spurs of the Garo hills where it receives the Tista on its right bank and under the name of Jamuna, flows due south to join the Ganges at Goalundo, receiving the Baral-Atrai combination on the right bank and throwing off the Dhaleswari distributary about 44 miles above Goalundo. The latter river, the upper portion of which has deteriorated runs south-eastwards, splitting into two branches, one of which the Buri Ganga flows past Dacca and then combining again with the other branch enters the Meghna at Narayanganj. An old silted-up course of the Brahmaputra branches off from the present main stream, opposite the old mouth of the Tista, and continuing the curve round the Garo hill spur, drains south-eastward past Mymensingh and into the Meghna."

"The low water discharge of the Brahmaputra is about 150,000 cusecs; no reliable figures are available for the flood discharge, which is probably greater than the Ganges. The river level at Gauhati commences to rise in March and small flood of about ten days' duration usually occurs at the beginning of May, owing to early rains. The river then rises steadily till the middle of July, remains at its highest level for two months and then falls gradually from the middle of September to its lowest stage in the middle of February."

"The silt charge from experiments made at Gauhati was 1 to 3,260 by weight in April, increasing to 1 to 1,500 in July and is probably greater when the river is in full flood; in the Padma at Goalundo, the proportion by-weight was 1 to 446 in August 1909. The sand here is very fine, practically all passing through a sieve with 90 threads to the inch."—*Reaks* (*p.* 30).

(12) "The slope of the Brahmaputra, which is 16 inches to the mile at Dibrugarh at the head of the Assam Valley, decreases to six inches at Tezpur in the middle of the valley, and then to 4¾ inches and 4¼ inches at Dhubri where it commences to flow south. At Goalundo, where it joins the Ganges, the slope as mentioned before is 4¼ to 4¼ inches to the mile during the dry and flood seasons respectively."—(*Reaks*, *p.* 30).

former days[13], and used to get a considerable volume of water from the Tista through an off-take at Nahali. It has now decayed and in its upper portions is merely a drainage channel of local importance. Below Gaibandha it flows in a southerly direction, roughly parallel to the channel of the Brahmaputra, and near the boundary of district Bogra, is joined by the Guzaria a considerable channel which separates itself from the Tista, shortly before that river falls into the Brahmaputra. The united streams, under the name Bangali continues to flow in a southerly direction, bifurcates into the Halhalia, is joined by the Karatoya on the right (east) bank, changes its name to Phuljhor, and receives several off-takes of the Brahmaputra (Kajipur and Ichamati No. 2), and finally falls into the Hurasagar, which is an important off-shoot of the Brahmaputra in the district Pabna. The united rivers under the name Hurasagar then receives the Baral (near Shahzadpur), and Ichamati No. 1 (near Bera), and finally flows into the Brahmaputra[14].

Table 13—Flood List for Area (B-2).

Year.	Month.	District affected.	Nature.	Map No.
1870	July and August.	Pabna ..	(c)—moderate	4, 5.
1886	September	Bogra ..	(d)—slight	10.
1892	July ..	Pabna ..	(d)— ..	11, 12.
1906	August and September.	.. ..	(c)—moderate	13, 14, 15, 16.
1910	July ..	.. ..	(b)—slight ..	17, 18.
1915	August and September.	.. ..	(d)— ..	19, 20.
1918	August ..	Pabna and Rungpur.	(d)— ..	21, 22.

The level of the Brahmaputra is a very important factor. If the gauge reading at Gauhati rises above 25 feet, then even a slight or moderate excess of local rainfall may easily give rise to local floods. Heavy rain in the north particularly in area (B-1), acts as a contributory cause, but becomes operative through a rise in the level of the Brahmaputra. For example, sympathetic floods occurred in (B-2) in 1892, 1906, 1910, 1915 and 1918, a few days after floods had occurred in area (B-1).

In these years, local rainfall in (B-2) was also usually above normal; but in 1915, a slight flood had actually occurred without any local excess of rainfall, and was probably caused mainly by the exceptionally high level of the Brahmaputra (Gauhati gauge, fluctuated between 28 feet and 31 feet).

In fact, heavy rainfall in the north or a high level of the Brahmaputra would not, by itself, and in the absence of excessive local rainfall, ordinarily give rise to floods in this area. For example, in 1874 (Gauhati gauge, 27 feet), 1879 (Gauhati gauge, 30 feet), 1890 (Gauhati gauge, 27 feet) or in 1898 and 1899, water from the north flowed away smoothly without causing floods.

Severe floods in this area would, of course, be brought about by a concatenation of all three factors; heavy rainfall in the north, a high level of the Brahmaputra and an excessive local rainfall in the area affected.

Heavy rainfall in (C-3), that is, in the central area, cannot also, by itself, produce a flood in (B-2); 1922 is a striking example. In spite of a catastrophic precipitation and a disastrous flood in the central area (B-2) was left practically unaffected, mainly because the drainage capacity of the Brahmaputra remained unimpaired; the Gauhati gauge reading was below 23 feet during the whole of September, and below 18 feet towards the end of the month.

([13]) Rennell: "The Gaggot Creek (modern Gaghat) comes within ½ of a mile of the west part of the town (i.e., Rungpur). It is navigable for boats of 150 maunds till the month of January. This creek is said to be a branch of the Punarbubah River, which has its source in the Kingdom of Boutan (Bhutan), and runs by way of Reagunge Denospour (Dinajpur) and Bulla; afterwards joining the Ganges by several branches, the chief of which are those of Mahananda, Surda and Jaffiergunge" (*Mem., 54-55, 1765*).

([14]) The face of the whole country was changed within the last 100 or 150 years by a change in the course of the Brahmaputra, T. H. D. LaTouche, in his paper on "Relics of the Great Ice Age in the Plains of Northern India" (*Geological Magazine, New Series, Decade V, Volume VII*, 1910), has put forward the view that the Brahmaputra was originally a much smaller stream than at present. The Dihong, one of the main tributaries of the Brahmaputra, cut back into the valley of the Dihong, in recent times, until it beheaded the Tsan Po, which formerly flowed westward, and either issued through the northern Himalayas or lost itself in the deserts of Tibet. With the accession of the Tsan Po, the Brahmaputra became a very great river, and began to carry down large quantities of silt, and commenced delta-building activities on a large scale. When the Tista broke into it in 1787, the Brahmaputra deserted its old south-easterly course, and forced a passage south through the Jenai and Konai into the Ganges at Jaffarganj. This change carried it from the eastern to the western side of the Madhupur jungle, and probably took place gradually between 1750 and 1830.

In Rennell's time (1765) a continuous line of *Jhills* extended north-westwards from the place where Brahmaputra now joins the Ganges at Goalundo, along what was then the course of the eastern branch of the Atrai, or lower Teesta. The main stream of the Brahmaputra has broken across this low ground. (*Mem. 81, also footnote by La Touche*).

Area (B-3)—Riparian Tract of the Ganges.

The riparian tract on the left (north) bank of the Ganges may be divided into two divisions, one comprising the southern portion of Malda[15], and the other the southern portions of Rajshahi and Pabna[16].

The country in the south of the district Malda is low-lying and extremely flat [17]. The slope is from north-west to south-east and does not amount to more than 20 or 30 feet in 60 or 70 miles. North of the Kalindri lies the Tal land which floods deeply as the river rises and drains into swamps. South of the Kalindri, the country is seemed by old courses of the Ganges[18], and is full of swamps (*bils*) extending on the right (west) bank of the Mahananda[19], from its junction with the Kalindri, to Nawabganj. During the rainy season, the

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([15]) I had originally intended to consider it as a separate flood division (B—4), but finally decided to incorporate both under one division (B—3). Map No. 2 had been printed before I gave up my intention of discussing the two areas separately.

([16]) The following general description of the Ganges is taken from Reaks' Report. "It runs in a generally easterly direction along the southern side of its central valley, skirting the northern edge of peninsular India, and receiving successively as affluents on its left bank the rivers Gumati and Gandak, draining the Himalayan southern slopes, and on its right bank the Tonge and the important Sone river. Just above Sahebganj, the Kosi joins it from the north, and the Ganges then sharply rounding the outlying fringes of the Rajmahal hills, follows a general south-easterly course. Shortly after passing Rajmahal, it enters on its deltaic career, giving off its first effluent the Bhagirathi, at Geria, about 34 miles above Rampur-Boalia. A few miles further down the Ganges receives its last tributary, the Mahananda. After passing Rampur-Boalia, the Baral river is thrown off from the left bank and this stream flowing through the Chalan Jhil and combining with the Atrai from near Jalpaiguri, joins the Brahmaputra above Goalundo."

"About 19 miles below Rampur-Boalia and the same distance above Sara, the Matabhanga takes off from the Ganges at the old Jalangi entrance and, flowing in a south-westerly direction enters the Hooghly near Chakdaha under the name of the Churni."

"The Ganges passes Sara 19 miles after throwing off the Matabhanga, and above Kushtia, or about 12 miles below Sara, it gives off the Garia effluent which lower down under the name of the Madhumati, flows into the Bay through the Baleswar and Haringhata estuary. The Ganges meets the Brahmaputra at Goalundo, about 59 miles below Sara"—(*Reaks, p. 29*).

"The Ganges has a length of 1,540 miles and a catchment area of 397,5000 square miles with an average rainfall of 42 inches. From February to May, its average discharge at Sara just below the Nadia off-shoots is probably below 50,000 cusecs. This begins to increase in May and rises to an average maximum of 1,500,000 cusecs at the end of August, or the beginning of the September. The greatest discharge ever measured was 1,926,080 cubic feet per second on the 22nd August 1910, and the probable maximum discharge at extreme high flood level would be 2,500,000 cusecs. The river level is consequently lowest in April and May. It begins to rise in the latter month and then more sharply early in June, attaining its maximum height about the end of August ; there is usually a subsidiary freshet which maintains the flood level in the first half of September and it then falls gradually to its lowest stage, the flood being imperceptible by the end of November".

"From experiments at Rampur-Boalia at the height of the flood season in August 1909, the Ganges was estimated to carry an average proportion of dry silt by weight of 1 to 473, or about 924 grains to the cubic foot. In September 1903 the proportion measured at Sara was 1 to 527, or 830 grains to the cubic foot. In August and September, the proportion is estimated at 1 to 760 or 575 grains, at the head of the Ganges canal. The sand found in the river at Sara is very fine, all passing through a sieve with 75 threads to inch and only 58 per cent. being stopped by a No. 100 sieve"—(*Reaks, p. 30*)

([17]) It comprised part of the ancient divisions of *Pundra* and *Gauda*. I have taken the following extracts from Monomohan Chakravarti's "Notes on the Geography of Old Bengal" (*J. A. S. B., IV, 1908*) :—

"The province was thus evidently bounded on the west by the Ganges with the Mahananda, and on the east by the Karatoya. The land (Pundra) was low and moist and crops were abundant." (p. 271).

"In Todarmal's rent-roll Gauda tract · · · (had) on the east the streams Punarbhava and Mahanda, on the west the old Kosi and the hills of Sontal parganas, on the south North Murshidabad and North Birbhum and on the north an ill-defined limit of Puraniya and Dinajpur districts, Debikoti being included in the extreme north-east" (p. 280).

"*Gauda*.—The land was low and moist, farming operations regular, with abundant flowers and fruits" (p. 274).

([18]) The history of Gaur furnishes ample evidence about changes of course of the Ganges and other rivers in this part of the country. Monomohan Chakravarty in his "Notes on Gaur and other old places in Bengal" (*J. A. S. B., V., 1909*) has put forward the view that Laksmanavati, a town situated on the south bank of the Kalindi, was the capital of Gaur from at least the 8th century A. D. Chakravarty has adduced evidence to show that the old course of the Ganges flowed through the Kalindi at that time. "The Ganges after flowing through the Kalindi would pass through the lowest sections of the present Mahananda bed ; and thus the formation of the extensive marshes and depressions on its both banks could be accounted for, as they could have originated only from the action of some deep and broad stream carrying enormous loads of silt like the Ganges" (p. 200).

Laksmanavati was made the seat of the government about 1200 A. D. under the early Muhammadan rulers. The capital was transferred to Pandua about 1334 A. D. This removal "was obviously connected with the changes in the river-courses, making Lakhnauti unhealthy and uninhabitable" (*Chakravarti, 204*). Probably about 1453, the capital was removed back to Gaur. This transfer was also largely connected with the physical changes of the locality, "after much fluctuations, the Ganges seems to have found a comparatively stable course on the west of the city and its floods probably raised the level of the city on its eastern part" (p. 205). In the earlier part of the 16th century, a Portuguese visitor, De Barros, described Gaur as a magnificent city with 2,000,000 inhabitants and situated on the banks of the Ganges (p. 210). The capital was, however, again removed from Lakhnauti to Pandua, "not merely because the former had become uninhabitable from the diversions of the river, but also because the latter had considerable facility of water communications"—(*J. A. S. B., V, 1909, 217*).

Tanda became the capital about 1566-67 A.D., but the seat of government was removed to Rajmahal about 1596-97 A. D. "The fluctuations in the river course, no doubt, brought on this transfer to Rajmahal. Already in 1588 Ralph Fitch had noticed that the river had receded a league off the city" . . .

The place appears in a map of Valentyn (1726) as "thandah," and in Rennell's atlas (1779-81) as "Tarrah." It has now disappeared, having been destroyed by floods about 1826 A.D.—(*J. A. S. B., V, 1909, 231*).

Old Malda, seven miles south of Pandua, was at one time situated at the confluence of the Mahananda and the Kalindi. The following description of the Town is taken from "the Malda Diary and Consultations" edited by W. K. Firminger (*J. A. S. B., XIV, 1918, 2*) :—

"The Towne is small, but conveniently seated on a branch of the Ganges and a small river from Morung (modern Nepal) which Joyne a little above the Towne, which is of great resort, being the staple of cloth, etc., for that part of the countrey, and comes in from all parts within thirty or forty miles." (Extract dated December 6th, 1676).

([19]) These swamps are very old. The country surrounding the old city Lakhanor was described about 1205-6 A.D. as being filled with mud-swamps and morasses—(*J. A. S. B., V, 1909, 214*).

level of the Ganges rises and the discharge of the Mahananda diminishes, the Tangan and the Purnabhava bank up and flow backwards, expanding into huge lakes, while the slackened speed of the Kalindri causes a similar phenomenon in Tal land.

In Rajshahi and Pabna also, the Ganges flows through a country which is extremely flat, the average slope from west-north-west to east-south-east being only 30 or 40 feet in 100 miles[20]. During the rainy season, the level of the Ganges often rises higher than the level of the rivers which are connected with it on the north. This fact was noted by Major Rennell so early as 1765. Since then the situation has become further aggravated by the continual deposit of silt and the consequent raising of the bed of the Ganges. The bank of the Ganges is also being raised at the same time [21]; so that it is now actually situated at a higher level than the country lying immediately to its north[22]. The Ganges below Rampur-Boalia sends several branches to the east[23]. The most important off-shoot at present is the Baral, which in its turn throws off several smaller branches (such as Musakhan, Nandakuja, Narad etc.) and through them carries, during the rainy season, a considerable volume of Ganges water into the *bil* area. The Ichamati[24] is another important branch which takes off from the Ganges (Pudma) below Bajitpur Ghat; and flowing in a tortuous course through the southern portion of Pabna, joins the Hurasagar in the east of the district.

As may be easily gathered, the drainage of the whole area depends entirely on the level of the Ganges. When the level of the Ganges is low, water would find its way into that river, but during the rainy season, when the river level rises high, the Ganges would fail to function as a drainage channel. In fact, the drainage sets away from it, towards the north and the north-east, and when the river level rises high, water would actually overflow its bank and spread over the adjoining country.

Table 14—Flood List for Area (B-3).

Year.	Month.	District affected.	Nature.	Map No.
1870	July and August.	Rajshahi and Pabna.	(*c*)—moderate	4, 5.
1871	August to October.	Rajshahi and Malda.	(*b*)—severe and extensive.	6.
1874	September	Rajshahi and Pabna.	(*c*)—moderate	7.
1875	August ..	Pabna ..	(*d*)—slight ..	....
1879	.. ..	Rajshahi ..	(*d*)— ..	....
1885	September	Rajshahi and Malda.	(*b*)—very severe.	8, 9.
1886	..	Rajshahi ..	(*c*)—moderate	10.
1890	August ..	Pabna ..	(*c*)— ..	....
1904	.. ..	Malda ..	(*d*)—slight ..	....
1906	August and September.	Pabna ..	(*c*)—moderate	13-16.
		Rajshahi and Malda.	(*d*)—slight ..	....
1915	September	Pabna ..	(*d*)—	19, 20.
1918	August ..	Malda and Pabna.	(*d*)—	21, 22.
1919	August and September.	Pabna ..	(*d*)—	....

A high river level and an excessive local rainfall are practically the only two factors of importance in this area.

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(20) "From Sahebganj to Sara the average slope is 3·36 inches to the mile in the dry season and three inches to the mile in flood. At Goalundo, at the confluence of the Ganges and Brahmaputra the fall is 4·15 inches in the dry season and 4·50 inches to the mile in the flood season. The slope of the river, of course, varies naturally at different points according to conditions, and at Sara where conditions are abnormal, it was found, when the river was in high flood, to vary at points a short distance apart, from as little as 3½ inches to the mile, to as much as 15 inches to the mile, changing at one point just below Sara, from 9 to 15 inches to the mile as the river rose from the low to its high stage"—(*Reaks, 30*).

(21) W. A. Inglis in his "Problems set us by the Rivers of Bengal" (*J. A. S. B., V, 1909, 398*) notes: "In the plains of Bengal, the rivers are, as a rule, of a deltaic character and we find the highest ground along their margins. That is, the streams in its natural condition is already to some extent embanked. This is due to the deposit of silt from the water flowing out of the stream over its sides."

(22) About 400 years ago the main volume of the Ganges used to flow through the Bhagirathi, which however gradually silted up. The Mathabhanga and the Garai became in turn the main stream, but the Ganges continually tended eastwards, until it broke through and joined the Brahmaputra near Goalundo. At one time the Ganges "probably followed the course defined by Rennell and Sherwill past Rampur-Boalia through the Chalan Jhil, Dhaleswari and Buri Ganga rivers past Dacca into the Meghna. In course of time the Ganges opened out other channels to the south until it reached its present course and in Rennell's time, before the Brahmaputra joined it, flowed through the Arialkhan river and its branches to the eastward, to the sea"—(*Reaks, 31*).

The main stream of the Ganges having in the course of ages raised the land surface on the extreme western side of the delta may, by this very process, have been naturally diverted gradually into the comparatively less developed regions to the eastward. It may have been further influenced in this direction by the change of course of the Kosi, which gradually carried that river westward until it discharged into the Ganges above Rajmahal"—(*Reaks, 34*).

(23) "After the great change in the course of the Brahmaputra channel during the latter half of the 18th century when it entered the Ganges at Jaffarganj near Goalundo, the latter river endeavoured to avoid the conflict by forcing a new passage to the sea through the middle of the delta. As Ferguson points out, the Ganges was fordable at several places above the junction with the Brahmaputra in 1838." It was also fordable in 1857 according to Sherwill. The Garai river which offered the most convenient passage, increased in width at its off-stake, from 600 feet in 1838 to 1,908 feet in 1863, and the lower reaches of the Madhumati opened out considerably. Sherwill and Ferguson in 1857 and 1863 anticipated, if the process continued, that the great outlets of the Ganges to the sea would be through the Garai, Upper Kumar and Chandana rivers. The Ganges between Khushtia and Goalundo could then be expected to silt up and become a huge *jhil*. Those anticipations were, however, never realised; the combined Ganges and Brahmaputra having apparently failed to make the Arialkhan, or the contiguous eastern branch, the main outlet, has, since Rennell's time, broke into the Meghna, south of Rajabari, and thus became and remains the main channel of the Padma" (*Reaks, 32*).

(24) Also *see* C. Addams—Williams' "Note on Deltai rivers" (*Hooghly river, Appendix IV, 140-142*). The Ichamati was described by Rennell in 1764 (under the name Pabna Creek), as coming out of the Ganges from the north side, and again falling into it at "Rattingunge"—(*Mem. 15*, June 1764).

The normal drainage in this area is barely sufficient to cope with the normal rainfall. A moderate excess of local rainfall with a normal river level, or an abnormal rise of the river with a normal rainfall, is sufficient to cause local floods; while excessive rainfall with a high river level is almost sure to lead to severe inundations. In 1871 and 1885, this critical balancing between rainfall and drainage was clearly shown by the fact that the height of the flood diminished immediately after a temporary break in the rainfall, and again increased immediately after a fresh onset of rain. On the other hand, in 1870, 1875, and 1890, the local rainfall was by no means excessive (in fact, in 1870 was actually below normal over a large area), and yet floods had occurred, chiefly owing to the very high level of the Ganges and the Brahmaputra (the Rajshahi gauge exceeded 25 feet and the Gauhati gauge 27 feet in August 1875 and 1890, respectively).

Floods never occur in this area with a low level of the Ganges, *i.e.*, so long as the drainage of the country remains unimpared; for example, in spite of a considerable excess of local rainfall a flood did not occur in 1902, evidently because the level of the Ganges was lower than usual, and the rain water could flow away without accumulation.

Heavy rainfall in the north, or in the central area, has very little influence on the occurrence of floods in area (B-3). Excessive precipitation in the north in 1898 and 1899, or in the central area in 1892 and 1918, did not produce floods in (B-3). Even the catastrophic rainfall of 1922 had no effect, which showed conclusively that water coming from the north was a negligible factor, so far as its direct effect was concerned. Whatever little influence such rainfall in the north, or in the central area, may exert, becomes operative in an indirect way, by raising the level of the Ganges or of the Brahmaputra.

Area (C)—Country in the Interior.

This area forms part of the great Gangetic plain, in which two distinct tracts may be distinguished. The greater portion consists of recent alluvium, seamed by numerous old courses of moribund rivers, and full of *bils* and water-logged depressions; while in certain portions (particularly in Malda and Dinajpur) there occurs an outcrop of an older and more elevated alluvial formation known as Barind land[25] with a stiff red clay or quasilaterite soil.

Area (C-1)—North-western highlands.

This area which comprises the greater portion of district Dinajpur and the northern portion of district Malda constitutes the western highlands, and is situated at a slightly higher level than the rest of the Gangetic plain[26].

Drainage.—The rivers flow from north to south. The Mahananda[27] rises in the Darjeeling district near Kurseong and flowing through western Jalpaiguri, Purnea and Malda falls into the Ganges in Rajshahi. The Nagar (which rises just north of Atwari[28]) and forms the boundary between districts Purnea and Dinajpur) with a number of tributaries (*e.g.*, Kulik, Gamar, etc.); the Chiramati (rising near Pirganj); the Tangan[29], with its tributary Tulai; and the Punarbhaba (which rises near Thakurgaon), all flow into the Mahananda and thus ultimately find their way into the Ganges.

The river channels are well-marked and fairly constant, and the river beds are on the whole below the level of the surrounding country; it is only in exceptional years that the rivers overflow their banks to any great extent. The main rivers carry a considerable volume of water during the rainy season, but become very shallow in the dry season.

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(25) "Varendra : . . . The eastern boundary was evidently the Karatoya river, and the southern the Padma . . . . Varendra is described as lying east of Padmavati, and containing towns ; Pudila near the Narada river ; Natari (modern Natore) ; Capala on the Varala ; Kakamari ; and Syamataka on the Calana Bil." Monmohan Chakravarti, "Notes on the Geography of Old Bengal"—*J. A. S. B., IV, 1908, 288.*

(26) It is bounded on the north by the submontane country ; on the east by a line running from north to south, and following roughly the watershed separating the Dhepa and the Punarbhaba (on the west) from the Atrai (on the east) ; on the south, by the Kalindri and the Mahananda, down to Gomastapur ; and on the west by the Purnea district.

(27) In 1766, Rennell gave the following description : "The course of the Mahanada is in general about S. W. and it is increased very considerably by several small rivers that fall into it between Sanashygotta and MahaRaage-Gunge (modern Krishnagunge)" (*Mem., 70*).

(28) "The Nagoor (modern Nagar) River separates the Provinces of Purranya & Denospour. The river is small and fordable. Its course is from the NNE. and must of course be one of the rivers that we crossed between the Teesta and Mahananda, tho' called there by a different name. The country here is well cultivated and had a pleasant appearance "—(Rennell, Feb., 1766, *Mem., 71*).

(29) "Thirteen miles east from Seebgunge crossed the Tangally River (modern Tangan River) near Currumka : This river is small and fordable and has its course from the northward. The country on both sides of it is pleasant and well cultivated "—(Rennell, Feb., 1766), (*Mem., 71*).

They are, however, now gradually decaying through the silting up of their beds and their current is getting sluggish in character.

Table 15—Flood List for Area (C-1).

Year.	Month.	District affected.	Nature.	Map No.
1885	September	Dinajpur ..	(*d*)—slight ..	8, 9.
1892	July ..	,, ..	(*b*)—very severe.	11, 12.
1918	August ..	,, ..	(*b*)—severe ..	21, 22.

The drainage in this area is satisfactory and consequently floods are of rare occurrence. They are almost always brought about by heavy local rainfall given by cyclonic storms. For example, cyclonic downpours occurred over a large part of this area, at the end of a very wet season, and caused a great flood in 1892. In 1918 also, heavy rain fell during the period 18th to 27th August, and caused another severe flood.

In both these years (more particularly in 1892), the situation was very much aggravated by the serious holding up of the water by the railway line from Katihar to Parbatipur, which runs from west to east and thus cuts right across the general direction of the drainage channels. In 1885, a slight flood occurred near Dinajpur and was due to excessive local rainfall, probably also partly aided by the holding up of water by the railway line.

In 1892 and 1918 heavy rain had also fallen in the hills and in the submontane country in the north, and a considerable volume of water came down from there, swelling the rivers and streams in area (C-1). But water coming from the north is never sufficient by itself, and in the absence of heavy local precipitation, to cause a serious flood. For example, in 1874 (29th August to 15th September), 1879 (August), 1890, 1898, 1902, 1910, and 1915, heavy rain had fallen in the north, which, however, flowed away without giving rise to any floods in (C-1). Even the catastrophic rainfall of 1899 in the Darjeeling hills, or the heavy precipitation of 1906, when the country lying immediately to the north-east of (C-1) was severely flooded, did not produce floods in this area.

A moderate excess of local rainfall, amounting to 200 per cent. or 300 per cent. above normal in one week (for example, from 6th to 11th September 1886) can apparently be carried away safely from this area. It is only when the general rainfall is considerably heavier, and is also accompanied by cyclonic downpours, that a flood can occur.

Area (C-2).

This is a portion of raised country lying immediately to the south of area (A-3), and lying on the west bank of the Tista.[30]

The general slope of the country is from north-west to south-west, and the level falls about 120 feet in 50 or 60 miles. The drainage is on the whole satisfactory and water flows away fairly quickly.

Table 16—Flood List for Area (C-2).

Year.	Month.	District affected.	Nature.	Map No.
1892	July ..	Dinajpur ..	(*b*)—very severe.	11, 12.
1902	August ..	Rangpur ..	(*d*)—slight ..	12-3, 12-4.
1918	,, ..	Dinajpur ..	(*b*)—severe ..	21, 22.

Floods are of rare occurrence, and much the same remarks apply to this area as to area (C-1). The two severe floods of 1892 and 1918 were brought about in this area, by exactly the same causes which were effective in area (C-1), namely, heavy cyclonic precipitation, serious obstruction of drainage by the Katihar-Kaunia railway line and the swelling of drainage channels by water coming from the north. In 1902 a slight flood occurred near Rungpur (similar in character to the one near Dinajpur, in 1885) which was caused by excessive local rainfall, aggravated probaly to some extent, by the holding up of water by the railway line. It does not, however, call for any special remarks.

Just like area (A-3), this area also is effectively segregated by the Tista from area (B-1), and is not affected by even very heavy precipitations on the east of the Tista.

Area (C-3)—Central Low-lying Country.

The central area is extremely flat and is seamed with the old courses of great rivers which have decayed or are even now decaying rapidly.

Drainage.—The key to the drainage situation in this area is given by the history of the Karatoya and the Tista.

The Karatoya was at one time a mighty river, and was specially noted for its sanctity in the Mahabharata[31]. The

(30) It is bounded on the east by the Tista ; on the south by a line roughly following the 100 feet contour and running parallel to the Katihar-Kaunia railway line, on its south, at a distance of from 10 to 15 miles ; and on the west by the area (C-1).

(31) Bhisma-Parva, IX, 35 ; Vana-Parva, LXXXV, 3, quoted in *J. A. S. B., V. 1909, 269.*

Amarkosha (the famous Sanskrit lexicon) gives it the synonym *sadanira, i.e.*, always with water, or unfordable [32]. It it believed to have been famous in the time of the Chinese traveller Hiuen Tsiang (Yuan-chwang, about 640 A.D.), who described the country through which it flowed as "low and moist "[33]. It has been identified with the river which Bucktiyar Khilji described about 1203 A.D., as a river "thrice as great as the river Ganges." It was marked as a large river, connected with the Brahmaputra, in the Map of Bengal prepared by Van den Broucke in 1660, and also in Major Rennell's Map[34].

In 1810, Dr. Buchanan-Hamilton described it as a very considerable river, and mentioned that its upper part was then known as the Tista. A sudden change in its channel was, however, caused by a big flood which occurred in 1820. Since then the river has been rapidly silting up, has changed its course very frequently, and is fast becoming moribund. The present channels of the Jabuneswari, the Karta, and other minor local streams represent old channels of the Karatoya.

In Rennell's time, the Tista ran down from the Sikkim Himalayas past Jalpaiguri and flowing south communicated with the Karatoya and Atrai rivers and passed into the Ganges near Goalundo. One branch, the Punarbhaba, joined the Mahananda near the latter's confluence with the Ganges[35].

In 1787 A.D., a catastrophic flood occurred, and the Tista forced its way and opened out the present channel to the south-east[36].

([32]) Amarkosha, Kanda 1, Vargga X, Verse 33.

([33]) *J. A. S. B., IV., 1908, 271.*

([34]) "Eight Miles more ENE. crossed the Corto or Coretya River. This River is 150 yards broad & very rapid tho' fordable in most places. It receives the Guramarra & Curume Rivers a little farther down & afterwards falls into the Teesta. Nabobgunge lies about 2 miles NE. from the place where we crossed the Corto. The country is here most waste interspersed with Groves of Betel Trees "—(Rennell, Feb., 1766, *Mem., 71*).

([35]) In January 1766, Major Rennell gave the following description: "About 3 miles NWBW. from Dewangunge, we came to the Eastern Bank of the Tista a large river from Boutan (modern Bhutan). The bed of this River is from a mile to a mile and quarter in breadth, but the channel at this time is not more than 300 yards over and from 3 to 7 cubits deep; the stream is not very rapid and the water extremely clear. The bottom is sand and pebbles. It course is here from N. to S. running as we are informed by Ragge Gunge and Denospur (modern Dinajpur) and emptying itself into the Ganges by several channels "—(*Mem., 67*).

([36]) The Tista appears to have alternated, at different periods, between the two main rivers, the Ganges and the Brahmaputra. It continually deposited its silt in the country through which it flowed, and when the level of the land was sufficiently raised, changed its course, and joined the other river. In this way, by its wanderings, it has succeeded in practically filling up the land lying between the two main streams.

The following description has been taken from F. C. Hirst's article on the Kosi river: "The land lying in the rectangle formed by Latitude 24 to 26·20"N.,and Longitude 88 and 90 E., is therefore liable to vary between the plain of the Ganges and its feeders, and that of the Brahmaputra and its tributaries, the main agent which causes a variation being a high flood. We have seen that the Brahmaputra, during that time, thanks to an unprecedented flood of the Tista, robbed the Ganges of the water of the Tista River. This piracy is very probably not the first of which the Tista has been the victim; it has, in all probability, in bygone days, alternated, at different periods, between the two master streams "—(*J. A. S. B., IV, 1908 476*).

T. H. D. LaTouche in his "Relics of the Great Ice Age in the Plains of Northern India" has observed that "the effect of this (diversion of the Tista) was not at first noticeable but it is probable that the silt brought down by the Teesta was too much for the Brahmaputra to deal with, hampered as it was already by the damming back of its waters by the Meghna as the latter slowly raised the levels of Sylhet and that the two allied rivers were compelled to find a new channel. The insignificant Jennsi offered the means of escape and its bed was occupied about one hundred years ago."

"The struggle that then began between the Brahmaputra and the Ganges is still in progress and issue was joined so recently, almost within the memory of men now living, that we cannot suppose that it has yet been fought to a finish, or that developments may not take place that will have far-reaching effects upon the future history of Bengal. The Brahmaputra, being the more powerful river is not likely to rest content with the advantage it has already gained. Up to the present time, indeed, it has not been able to exert its full strength, for it cannot do so until, it has brought the level of the Assam valley to the state in which it would have been had the valley been originally excavated by a river of the size and power of the present Brahmaputra. As it is, much of the force of the river when in flood is spent in the low ground flanking its course, but when this has been brought to the 'true regimen,' there is no doubt but that the river will be able to show its real strength with more effect in its lower course."

Even in 1838 it had succeeded in damming back the Ganges to such an extent near the confluence that the latter was fordable at several places above Goalundo, and was compelled to seek for a new exit to the sea. The Garai, which leaves the Ganges at Kushtia, was enlarged from a mere creek unable to float a vessel drawing more than a foot or two of water as Rennell found it in 1764, to a broad and deep river, now the principal steamer-route from Calcutta to the Upper Ganges. What further development may take place we cannot predict, but it is possible that their influence may be felt still higher up the Ganges, and may even extend to the Jalangi or Bhagirathi, and so affect the welfare of Calcutta. The mitigation of any evil effects these changes may have is a matter for the consideration of engineers. If they become acute something might be done to assist the Ganges by inducing the Tista to return to its old allegiance; but the forces exerted by such vast bodies of moving water are so prodigious that it is unsafe to speculate without a complete knowledge of the facts "—(*Geological Magazine, New Series, Decade V, Vol. VII, 1910*).

Fergusson has suggested that the new course of the Tista was along an old bed of the river, since Rennell shows a "Tista Creek" passing south of Ulipur above the position of its present junction with the Brahmaputra, and a series of pools along this course. The mouth of the river has however worked downstream considerably since that time—(*Reaks, 33*).

After the catastrophic change of 1787, it took a long time for conditions to settle down. F. D. Ascoli in his article on "the Rivers of the Delta" has made the following observations: "It was by the opening up of this Calliganga River, that the Ganges had by the year 1818 found for itself a new exit into the Meghna. The new stream was called the Kirtinassa (the Destroyer of Glories). That the consummation of this change required a period of 30 years from the date that the Tista and Brahmaputra commenced sending the bulk of their water down the Jenai River to meet the Ganges at Jaffierganj above Rajanagar, is not a matter of surprise. It is true that the flood of 1787 was sudden and severe; it spread its ravage even so far south as Rennell's Baugebary (Bansgari); but it is equally certain that the Brahmaputra acquiesced in its new course down the Jenai slowly, almost imperceptibly. Even so late as 1840, the old river to the north of Dacca was still known as the main stream of the Brahmaputra. Changes in the lower deltaic plains do not show themselves by sudden outbursts, but by a process whereby the river shifts by cutting its own banks or by gradually entering into and opening out the banks of some smaller stream. The period of 30 years is not surprising "—(*J. A. S. B., VI, 1910, 547*).

In 1789-90 Government spent two lakhs of rupees and employed 12,000 men in an attempt to restore [37] the Tista to its old channel, but without any success. In 1809, when Dr. Buchanan-Hamilton compiled his notes, he found that near Madargaj, a little below Jalpaiguri, the Tista sent off, to the south, a branch known as the Buri or old Tista, and then turned eastwards and entered Cooch Behar. Since then the old channel of the Tista had decayed much further and is now represented by the partly moribund channels of the Atrai, the Jamuna and the Nagar.

It is probable that the Karatoya and the Tista united at a spot, marked at the present time by the Chalan Bil, and flowed into the Brahmaputra, through the country now occupied by the numerous *bils* or low-lying swamps and depressions which cover a large area in districts Rajshahi and Pabna and partly also in Bogra[38]. These *bils* or marshy depressions dry up during the hot weather, but expand into swallow sheets of water during the rainy season[39]. In some cases, as already noted, they represent the remains of great rivers, *i.e.*, the Karatoya and the Tista. In other cases they have arisen mainly by the action of rivers, which by silt deposit have raised their beds above the level of the surrounding country; so that the land lying between two parallel rivers form a kind of trough, the drainage of which cannot be discharged into the adjoining rivers.

The Atrai, which occupies the old channel of the Tista, with its different branches (the Gur, Mara Atrai, Baralai) and a number of tributaries flow into the Chalan Bil, which is probably the oldest[40] as well as the biggest *bil* in size, and measures, at the present time, over 140 square miles. The Nagar (which is a branch of the Karatoya, and joins Atrai near Singra), and the Jumna (which rises in the Jalpaiguri hills and flows through Dinajpur and Bogra, and is joined by the Chiri Nadi and the Tulsiganga), also fall into the Atrai and thus ultimately pass into the Chalan Bil. The accumulated water of the above rivers is slowly carried off through the Baral (which is an off-shoot of the Ganges), and ultimately drains into the Brahmaputra.

As has been already noted, with a rise of the Ganges, a considerable volume of water from that river would usually find its way into the Chalan Bil, and thus complicate the situation still further[41]. If, in addition, the level of the Brahmaputra also rises high, the current of the Baral would be actually held back, and the water in the Chalan Bil would be kept pent up until the Brahmaputra falls again.

The incursion of silt-laden water from the Ganges into the *bil* area has also caused, and is still causing, rapid silting up and consequent raising up of the level of the surrounding country[42]. The capacity of the *bil* area for holding flood-water is thus rapidly diminishing. The water, therefore, can now spread over a far larger area than before, and can thus give rise to floods which are more widespread in character and cause

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([37]) *District Gazetteer, Rangpur (1911), p. 5*

([38]) In Rennell's time the Karatoya, the Tista, the Atrai and a number of other channels were all mixed up in this area. For example, Rennell mentions a river near " Cullum " (modern Chalan), at the head of the Chalan Bil, which " mixes with ye Jeels or separates into several streams. . . Above Cullum it is in general 200 or 220 yards broad and deep enough for the largest boats. The stream is not rapid. . . This river has a great many names given it, the people of every district giving it a particular name. Between Boutan (modern Bhutan) and Ragge Gunge (near modern Dinajpur) it is named the Tista, from thence to Bandegotta, the Attri (modern Atrai), between that and Cullum (modern Chalan) the Golenuddy; and afterwards the several names Baganuddy, Ballaser and Curramjar. . . . At Baumanpara the river is 300 yards broad and sufficiently deep. About 12 miles below this place the river changes its general course from South to S. E., and at the same time separates into 2 channells, and the northmost of these again into several others. By the waters being divided into so many streams it happens that none of them are navigable for boats of 2 cubits draught of water. . . . the country round this place is an entire swamp "—(*Mem., 84-85*, Dec., 1766). Rennell also mentions another " branch of it, which turns off to the Eastward near Chatmol and receives the Gorregott (modern Gaghat) and Rungpour (modern Karatoya) rivers "—(*Mem., 86*, Dec., 1766).

([39]) Rennell gives the following description : " Immediately above the head of the Currumjar River the great Jeels begin. These jeels in ye wet Season are joined together, & form a prodigous Lake which extends from the Western parts of Dacca to Nattour, a tract of about 80 English miles. In the dry season they form several distinct Lakes. The Denosour River runs thro' the Western Part of these Jells, frequently losing itself for several Miles, & dividing into a number of Branches. On the skirts of the Jeels are several considerable Villages particularly, those of Sajatpour, Hurriol, Chatmol, Cullum & Nattour. In the shallow parts of the Jeels a prodigious number of tame Buffaloes are kept, by which means this part of the Radshy Countrey furnished the neighbouring Provinces with Ghee. The Country is incapable of any other Improvements for as it lies very low, the neighbouring Jeels make it a perfect swamp "—(Rennell, *Mem., 82*, Dec., 1768, 82).

([40]) Mentioned in the Bhavisyat Purana, *Indian Antiquary, XX, p. 420.*

([41]) The Kosi according to Fergusson, who quotes from Buchanan-Hamilton, originally combined with the Mahananda and flowed through the Baral-Atrai rivers into the Brahmaputra. Rennell recorded about 1779 that the Kosi at no distant date had flowed past Purneah and joined the Ganges 45 miles below its present mouth.—(*Reaks, 33*).

It is also not improbable that one time the Ganges itself had flown through the Chalan Bil area.

([42]) The Chalan Bil is said to have extended not very long ago, over an area of 420 square miles. In 1909 it was found to have shrunk to 142 square miles, of which only 33 square miles remained under water throughout the year. It was calculated at that time that about 170 million cubic feet of silt was deposited annually over 142 square miles causing a rise of the level at the rate of about half an inch every year. In 1913 it was found that only 12 or 13 square miles remained under water all the year—(*Dist. Gaz., Rajshahi, 1916, pp. 8-9*).

greater distress. The raising of the level is also causing a further and more rapid decay of existing channels in this area.

Table 17—Flood List for Area (C-3).

Year.	Month.	District affected.	Nature.	Map No.
1886	September	Bogra ..	(d)—slight ..	10.
1906	August and September.	Pabna ..	(d)—slight ..	13, 16.
1918	August ..	Rajshahi, Bogra and Dinajpur.	(b)—very severe.	21, 22.
1922	September	Rajshahi, Bogra Pabna and Dinajpur.	(a)—catastrophic.	23—28.

Floods.—Excessive local rainfall is practically the only direct cause which gives rise to floods (which are of rare occurrence) in the central area.

In the slight or moderate flood of 1886, for example, very heavy rain had fallen, in the last week of September, within the central area itself. In 1906 another slight flood occurred in the south-east corner of this area, and was again due to excessive local rainfall.

In 1918 and 1922 the controlling factor was the unusually heavy local precipitations. Within the central area itself water flowed in a south-easterly direction, and the actual position of the area of the highest flood was situated some distance to the south-east of the area of heaviest precipitation. In both these years, the level of the Ganges was not very high, and did not add materially to the difficulties of the situation. The high level of the Brahmaputra in 1918, however, held up the water in the east of the flooded districts, and prolonged the duration of the flood for a long time.

A study of the earlier-flood years clearly shows that water from the north is not a factor of any importance. In 1870 (July), 1874, 1879, 1890, 1898, 1899, 1902, 1910 and 1915, exceptionally heavy rain had fallen in the north, but did not produce floods in the central area.

In 1871, 1874, 1879 and 1885 very heavy rain had also fallen within the central area itself, without however producing any floods in this area. A study of the rainfall maps of these years leaves the impression that the water could then flow away smoothly towards the south-east without undue accumulation.

The new railway line from Sara to Parbatipur was constructed in 1877-78, but the waterways were then much more extensive. The Santahar-Bogra line was constructed in 1899 and the Sara-Sirajganj line in 1915. It seems probable, therefore, that before the construction of the railway lines, particularly of the west-east lines, the natural drainage of the central area was better able to cope with even a considerable excess of local rainfall.

At the same time it should be clearly realised that severe floods in this area are inevitable with catastrophic local precipitations like that of 1922. There cannot be any doubt that a great flood would have occurred in 1922, even if all the railway lines in North Bengal had not been in existence. It is, however, not improbable that the flood would have subsided more quickly than it actually did, if the drainage had been less obstructed.

SECTION IV.—FACTORS AFFECTING THE OCCURRENCE OF FLOODS IN NORTH BENGAL.

It scarcely needs mentioning that rainfall, having regard for its intensity, duration, and geographic distribution, is the sole cause of occurrence and maintenance of floods of whatever magnitude.

The occurrence of a flood in any particular area is determined by the amount of excess of (A) the total inflow of water, over (B) the total outflow from that area, either by evaporation, soakage into soil, or by drainage.

Under (A) we have—

(1) the actual rainfall within the area under consideration;

(2) water coming from adjoining areas, the amount of which depends on the relative situation of the areas concerned

As regards (B), the total water entering any given area may be divided into several portions—

(1) the portion intercepted by trees, bushes and other obstacles, and evaporated before reaching the ground;

(2) evaporation from the surface of the soil before penetrating to an appreciable depth;

(3) evaporation from the soil below the surface, and transpiration by plants and vegetation;

(4) portion which replenishes the underground storage of water;

(5) surface and sub-surface drainage, as determined by the nature, shape and size of the catchment area;

(6) drainage by rivers and other channels; and

(7) artificial obstructions to drainage, such as railway lines, roads or embankments.

In this section I have given only a "first" study of the factors under (A)—(1) cyclonic downpours and general excess of rainfall, and (2) water coming from adjoining areas, together with certain general observations about the factors under (B), and also a few notes on artificial obstructions to drainage[1].

(A)—Inflow of Water.

(1) Cyclonic rainfall.—With cyclonic downpour (*i.e.*, heavy precipitation within a very short time, usually brought about by depressions or cyclonic storms from the Bay) a sudden congestion of the normal drainage is inevitable and a flood of some kind or other is bound to occur.

A familiar (but trivial) example is given by the occasional flooding of Calcutta streets, during the rainy season, caused by very heavy downpours lasting sometimes only for a few hours. These floods of course subside quickly, and although they give rise to a certain amount of inconvenience, do not cause any distress. At the other extremity stand the great floods of North Bengal (like that of 1922), which cover hundreds or thousands of square miles and cause enormous damage and distress. The street floods of Calcutta and the great floods of North Bengal, however, have this in common, that they are brought about by the same cause, namely, the failure of the normal drainage to carry away sudden and torrential precipitations.

Such sudden and heavy downpours constitute the most important factor[2] in the causation of floods in all the different areas of North Bengal. Heavy cyclonic rainfall, within or in the near neighbourhood of the flood area, has acted as the direct cause in bringing about all the great floods of North Bengal during the last 50 years, *e.g.*, the severe floods of 1885, 1892, 1902 and 1918, and also the catastrophic floods of 1899 and 1922.

General Excess of Local Rainfall.—Long-continued excess of rainfall is also a very important factor. In fact, a severe flood cannot last for any length of time in North Bengal, without a considerable excess of the general rainfall A general excess, however, would not necessarily cause a flood; its effect would vary from area to area.

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(1) I had also hoped to be able to discuss evaporation in relation to the actual variations of humidity and temperature in North Bengal during flood periods. I regret, however, that the time at my disposal has not allowed me to do so.

(2) This is also true for other countries. Compare: "Excessive rainfall may result either from short heavy downpours, or from lighter but longer continued rainfall. In general, rains of the former type do the most damage, although disastrous floods occasionally result from rainfall of the latter type."—R. Ward, "Some Characteristics of the Rainfall of U. S. A." (*M. W. Rs. U. S., 1919, Sept., 631*).

In the hilly districts, in the submontane area, and in the comparatively raised country in the northwest, *i.e.*, in areas (A), (C-1) and (C-2), its chief effect is a general loosening of soil, by which conditions are made favourable for mischief being done by sudden and torrential downpours. Owing to the good drainage, a considerable excess of general rain can ordinarily flow away from these areas, and in the absence of cyclonic falls, does not give rise to serious flooding. On the other hand, in the north-eastern plain (area B-1), where drainage is unsatisfactory, heavy general rainfall is not only an essential ingredient for the occurrence of a severe flood, but is actually, by itself, sufficient to cause a slight or moderate one.

Along the riparian tracts of the Brahmaputra (area B-2) and of the Ganges (area B-3), its effect depends entirely on the level of the rivers. With a high river level, even a slight or moderate excess would be sufficient to produce floods, while with a low level of the river, a considerable excess would flow away without doing any damage. In the central area drainage appears to have deteriorated in recent years, and at the present time, any considerable excess of local rainfall is likely to give rise to floods.

(2) Water coming from adjoining areas.—The general slope of the country is towards the south and the south-east; we need therefore consider only the water coming from the north and the north-west.

The following table shows the average excess in inches, as well as percentages of the normal precipitation, for each area separately, for a number of important floods :—

Table 18—Percentage Excess Rainfall in each area.

Actual excess in inches within brackets.

Year.	1885.	1892.	1902.	1906.	1910.	1915.	1918.	1922.
Number of days.	61	7	30	24	23	8	9	7
Area affected ..	B-3, C-1	A-2, A-3, B-1, B-2, C-1, C-2.	A-3, B-1, C-2.	A-1, A-2, A-3, B-1, B-2.	B-1, B-2.	B-3, B-1, B-2.	B-2, C-1, C-2, C-3.	C-1, C-3.
Excess in area A-1 ..	−7 (−3·5″)	+61 (+3·7″)	+73 (+18·9″)	+118 (+24·5″)	+65 (+13·0″)	+138 (+9·5″)	+29 (+2·3″)	−38 (−2·4″)
Excess in area A-2 ..	−36 (−21·5″)	+398 (+27·0″)	+61 (+17·9″)	+206 (+48·5″)	+164 (+36·9″)	+131 (+10·2″)	−18 (−1·6″)	−37 (−2·5″)
Excess in area A-3 ..	−1 (−0·4″)	+478 (+21·9″)	+99 (+19·7″)	+202 (+32·4″)	+162 (+24·8″)	+181 (+8·9″)	+200 (+9·2″)	+128 (+5·9″)
Excess in area B-1 ..	−20 (−10·6″)	+398 (+19·1″)	+68 (+14·2″)	+118 (+19·6″)	+116 (+18·4″)	+144 (+7·9″)	+95 (+5·9″)	+212 (+10·2″)
Excess in area B-2 ..	−6 (−1·4″)	+85 (+2·3″)	+38 (+4·5″)	+116 (+11·0″)	+104 (+9·4″)	+155 (+4·8″)	+343 (+12·0″)	+630 (+17·0″)
Excess in area B-3 ..	+62 (+12·7″)	+135 (+3·1″)	+24 (+2·4″)	+53 (+4·3″)	+54 (+4·2″)	+7 (+0·2″)	+326 (+7·5″)	+535 (+12·3″)
Excess in area C-1 ..	+10 (+2·8″)	+275 (+8·8″)	+28 (+3·9″)	+50 (+5·4″)	+50 (+7·8″)	+103 (+3·7″)	+475 (+19·5″)	+675 (+21·6″)
Excess in area C-2 ..	−17 (−5·4″)	+368 (+13·6″)	+61 (+9·5″)	+69 (+8·6″)	+69 (+9·5″)	+93 (+3·9″)	+370 (+17·4″)	+572 (+21·2″)
Excess in area C-3 ..	+4 (+1·9″)	+89 (+2·4″)	+27 (+3·1″)	+60 (+5·6″)	+60 (+8·3″)	+58 (+1·8″)	+515 (+18·0″)	+930 (+25·1″)

In the hilly portions, *i.e.*, in area (A-1), this factor does not come into play, but in the submontane country, areas (A-2) and (A-3), a certain amount of damage may be directly caused by the onrush of water from the hills. In 1892 and 1906, when floods occurred in area (A-2) and (A-3), heavy rain had also fallen in area (A-1), while in 1902 a flood occurred in area (A-3), which was probably aggravated by heavy falls in the north.

In the north-eastern plain (area B-1) water from the north or heavy precipitation in area (A-3) usually acts indirectly by raising the level of the Tista and other drainage channels, and cannot do any direct mischief, particularly when the rivers are fully functioning. The Tista acts as an effective barrier, and prevents rainfall on one side of it from affecting the area on the other side directly.

Heavy precipitation in the north or in area (A-3), however, usually renders conditions favourable for the occurrence of a flood in (B-1), as in 1892, 1901, 1906, 1910 and 1915; while excessive rainfall in (B-1) or in the country drained by the Tista usually swells the Brahmaputra, and thus leads to sympathetic floods in the spill area of the Brahmaputra, especially in certain portions of Bogra and Pabna (1892, 1902, 1906, 1910 and 1915).

The spill area of the Ganges, owing to the peculiar position of the country, is little affected by excessive precipitation in the north while water coming from the Ganges does not appear to have any appreciable effect on the central areas (C-1), (C-2) and (C-3). Within the central area itself, water moves towards the south-east (as in 1918 and 1922), and the area of deepest flooding lies some distance to the south-east of the area of heaviest precipitation.

A glance at Table 18 shows that, almost without exception, the rainfall had been heaviest in the area in which the flood actually occurred, so that the water coming from adjoining areas could not be said to be a factor of great importance.

We conclude therefore that heavy rainfall in adjoining areas (or even in very distant areas, *e.g.*, the upper reaches of the Ganges or of the Brahmaputra) can become only indirectly effective by swelling the rivers and thus hampering or even preventing the water to flow away from the flooded area; but, except to some extent in the submontane country, can do very little direct mischief.

(B)—Outflow of Water.

(1) Interception loss.—The amount of water which spreads over leaf and tree surfaces in thin layers or collects in drops and blotches (here referred to as the " interception storage ") depends on the position and the physical characteristics (including surface tension) of the leaf or other surfaces concerned and also on the wind velocity and the intensity of rainfall.

Leaves of different plants vary greatly in their behaviour as regards interception storage. For many trees in the U.S.A., the loss has been estimated to vary from 0·02 inch to 0·07 inch per shower[3] and to approach these values for well-developed crops. It may reach or even exceed 0·10 inch per shower for large trees[4].

An increase in the wind velocity reduces the interception storage by one-third to one-half of the amounts occurring when this air is still[5], but increases the loss by evaporation, to which the interception storage is constantly exposed.

The amount of interception loss varies from shower to shower. The percentage loss is greatest (nearly 100 per cent.) for showers which do not exceed the interception storage capacity, but decreases rapidly as the rainfall increases. The amount of rain which reaches the ground has been estimated[6] to be below 10 per cent. for showers of less than 5 mm. (0·02 in.), below 22 per cent. for rainfalls from 5 mm. (0·02) to 9·9 mm. (0·04 in.), and to rise to 50 per cent. for showers in excess of 10 mm. (0·04 in.).

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(3) R. E. Horton in an article on " Rainfall Interception " (*M. W. R., U.S., 1919, Sept.*, 603—623) gives a comprehensive analysis of the available American and European data. He also gives a list of previous papers on this subject and refers to Raphael Zon's "Forests and Water in the Light of Scientific Investigation " (Final Report, National Waterways Commission, Washington, 1912) as giving a very full bibliography (pp. 274—302) of forest meteorology.

(4) J. F. Voorhees, " A Preliminary Study of Effective Rainfall," *M. W. R., U. S., 1925, Feb.*, 63-65.

(5) R. E. Horton, *M. W. R., U. S., 1919, Sept.*, 619.

(6) H. E. Hamberg, " De l'influence des forets sur le climat de la Suede," Stockholm, 1885 (quoted in " *Stream-flow Experiment*," p. 32).

The interception storage is believed to reach a constant average rate of about 25 per cent. in heavy rain[7].

(2) Surface evaporation.—This is an important factor, and has been experimentally studied to some extent, but definite figures for North Bengal are not available.

The controlling factors naturally are temperature, relative humidity and wind-velocity. It is stated that, all other factors being similar, for each Fahrenheit degree of temperature, within the natural range of large bodies of water, there occurs a change in the rate of evaporation averaging 6 per cent[8].

It has also been found that the evaporation depends on the product of the wind-velocity and the vapour-pressure deficit, which is defined as the difference between the maximum vapour-pressure at the actual air temperature and the vapour-pressure at the observed temperature[9]. The effect of barometric pressure is probably negligible[10].

Certain measurements are available about evaporation from large bodies of water such as lake-surfaces[11], or freely exposed water-surfaces in pans[12].

In Bengal rivers the evaporation has been estimated at 0·4 in. per day over open-river surfaces[13]. For our present purpose, a knowledge of evaporation from moist soils[14] and from capillary films surrounding vegetation and grains of soil is more important. Unfortunately precise measurements on these points are lacking.

(3) Sub-surface evaporation and transpiration.—The Rothamsted figures (given below in a footnote) indicates that loss by evaporation from under ground soil (20 inches or more below the surface) is very small and is practically negligible. Certain experiments at the University of Tennessee Experiment Station, U.S.A., also shows that "a negligible amount of water excapes from the watershed underground."[15]

In the United States, loss by transpiration has been estimated to vary from 4 in. to 6 in. (coniferous trees) to 10 in. (grasses and agricultural crops) for the whole season, and for a forest, range from a minimum of 0·002 in. to 0·021 in. per day to a maximum of 0·10 in. per day[16]. A plant may transpire more water than a water-body of equal surface evaporates. Experimental observations have shown that Prairie grass transpire about 60 inches for a six-month growing season. Cereal crops transpire at about the same rate, while alfa-alfa lost somewhat more water.[17]

For Colorado the total loss by evaporation and transpiration was found to amount to from 70 to 90 per cent. of the total precipitation[18].

From the observations at the Agricultural Experimental Station at Rothamsted, it would appear that, in England, in normal years (average of 50 years), about 50 per cent. of the rainfall evaporates, while in an exceptional

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(7) Horton (loc. cit.), *M. W. R., U. S., 1919, Sept., 603.*

(8) R. B. Sleight., "Evaporation from the surface of water and river-bed materials." U. S. Department of Agriculture—Journal of Agricultural Research, X. 5. 209—262 (quoted in *M. W. R., U. S., 1924, Feb., 99*).

(9) *E. S. Johnston, M. W. R., U. S., 1924, Feb., 100.*

(10) *M. W. R., U. S., 1924, Feb., 100.* The same paper gives experimental results with water taken from the Owens Lake, California, which showed the effect of varying specific gravity upon evaporation. Evaporation decreased as the sp. gr. of the brine increased, and for sp. gr. of 1·275 was about 27 per cent. less than distilled water. It is believed that the same result may be applied to other bodies of mineralised water. Surface crustation affects evaporation very considerably.

(11) In the Owens Lake, California, (size about 58,000 acres), the depth of evaporation was measured to be about 67 inches annually—(*M. W. R., U. S., 1924, Feb., 100*).

Average annual evaporation from a pan floating in Gatun Lake (Panama Canal Zone) is 62 inches. The greatest daily evaporation loss was 0·4" in March 1918—(H. G. Cornthwaite, "Evaporation in the Canal Zone"—*M. W. R., U. S., 1919, Jan., 29*).

In the Swiss Alps, evaporation near the lake-surfaces was found to vary from 0·2 mm. (0·01 in.) per day to 7·7 mm. (0·303 in.) per day depending on meteorological conditions. The mean evaporation for the period July 25—October 23, 1921, was 2·2 mm. (0·10 in. nearly) per day, or 35·6 in. annually, at a mean temperature of 12·3°C and with a mean wind-velocity of 2·8 metres per second—(J. Maurer and O. Lutschg, *Meteorologische Zeitschrift, 1924, March, 111—114*).

(12) Evaporation from a tank 4 feet by 4 feet capacity 250 gallons, set up at Stoner Hill, Petersfield (England), was found to lose 15·97 in. with an annual precipitation of 50·33 in. During the summer months June, July and August, evaporation was 8·26 in. out of a rainfall of 12·98 in.—(*Q. Jour. Met. Soc., 1925, April, 82*).

(13) Evaporation from a channel, 100 miles in length, with an average width of 400 feet would amount to 80 cubic feet a second—(*Reaks, 51*).

(14) Evaporation from "timber fringe" and "grassy marsh" in the Panama Canal Zone has been found to be about 75 per cent. of the evaporation from open lake—(*M. W. R., U. S., 1919, Jan., 30*).

(15) J. F. Voorhees (loc. cit) *M. W. R., U. S., 1925, February, 64*).

(16) "*Streamflow Experiment,*"

(17) F. E. Clements, "Grassland as a Source of Rainfall," *M. W. R., U. S., 1924, Nov., 541.*

(18) "*Streamflow Experiment,*" loc. cit., p. 29.

year (*e.g.*, 1921) as much as 63 to 65 per cent. may be lost through precipitation[19].

(4) Underground storage.—A considerable portion of the monsoon rainfall in North Bengal is used up to replenish what is generally known as the "underground waters," from which is derived the perennial supply of springs and streams. This is a relatively abundant supply, and is also drawn upon for loss by transpiration.

The total amount of under ground storage in any specified area may be approximately determined by measuring the decreases in discharge through streams during a given period when the flow is not influenced by rainfall[20].

Many of the rivers in North Bengal become very shallow during the hot weather and some dry up altogether. In normal years the underground storage is, however, replenished during the first half of the monsoon (roughly in June and July), and it is only the rainfall in the latter half (August and September) which is usually effective in causing floods.

An approximate estimate of the total loss of evaporation and transpiration may now be attempted. From the American data, it would appear that the interception loss is not likely to exceed 0·10 inch per day on an average. Loss by surface evaporation in North Bengal is likely to be greater than Europe, and a loss of 0·4 inch per day from open water surfaces is probably not an overestimate. Towards the middle of the rainy season, when the whole country becomes more or less waterlogged, condition becomes not dissimilar to the "grassy marshes" of the Panama zone, and the evaporation from such marshy grounds may be estimated at from 50 to 75 per cent. of the evaporation from open-water surfaces, *i.e.*, from 0·2 inch to 0·3 inch per day. Loss by transpiration is not likely to exceed 0·10 inch per day. The total maximum loss may, therefore, be taken as 0·4 to 0·5 inch per day.

The average daily rainfall (for the whole of North Bengal) is 0·54 inch. On the Rothamsted basis (50 per cent. footnote 19), the total loss by evaporation and transpiration would amount to 0·27 inch per day. The English climate, however, is much colder, and 0·27 inch per day is probably too low an estimate for North Bengal. The summer figures for England (Petersfield, footnote 12, p. 36) would give 64 per cent, or about 0·35 inch per day. The Colorado figures (70 to 90 per cent., footnote 18, p. 36) would give 0·38 inch to 0·49 inch per day, which agrees fairly well with our own estimate of 0·4 inch to 0·5 inch per day.

On the whole a total loss of 0·3 to 0·5 inch per day appears to be a reasonable estimate for North Bengal.

(5) Surface and sub-surface drainage.—Under ordinary conditions the remaining portion of the rainfall flows away as the run-off through streams. With a saturated soil, precipitations so small as 0·01 inch may produce a measurable response in stream-flow[21].

During and for a short while after rainfall, innumerable rivulets of surface water form everywhere in a watershed, and all flow towards some portion of the nearest stream. In heavy rain much water may actually reach the rivers by surface flow. If the drainage channels are functioning properly, surface flow, however, is not sustained for a long time, and is eliminated within a few days after the cessation of rainfall. But if the rivers themselves are full, the surface water would naturally be held up, and would thus give rise to floods of some kind or other.

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(19) "Rainfall and Percolation in Rothamsted, 1921"—*Quat. Jour. Met. Soc., 1922, Jan., 48.* The following figures are given for percolation at Rothamsted :—

Period	Annual rainfall.	Percolation through soil.		
		20".	40".	60".
	Inch.			
80 years' average	28·692	14,834	15,482	14,659
1921	16·093	5,766	5,984	5,479

(20) For example, if five days' discharge of 100,000 cubic feet reduces the rate of flow by 5 per cent., we may assume that the total residual water is 100 by 10,000 cubic feet.

(21) "*Stream-flow Experiments, 1922,*" p. 23.

The underground storage also moves to lower levels in accordance with hydraulic laws, " the velocity varying in direct proportion to the first power of the slope of the underground water table " . When the river level is lower than and intersects the underground storage, the sub-soil water seeps through the banks and bed and augments the stream-flow[23].

The run-off in streams and rivers naturally increases with the precipitation. In European countries, a linear relation has been found to exist between rainfall and precipitation[24]. In America, the run-off from a stream has been found to conform fairly well to a formula of the type $Q=(c-d)\ e$, where Q is the magnitude of flow, and " ce " a limit which this magnitude approaches. It has been found that " c " has a direct relation with the annual precipitations, while " e " has a direct relation to precipitation and slope, and an inverse relation to storage[25].

The flood-flow of a stream depends upon the size and shape of the watershed and its geographic position with respect to the prevailing direction of rainstorms. In North Bengal, the drainage is from north to south, that is, in a direction opposite to that in which the cyclonic storms from the Bay advance, the country is thus favourably situated with respect to the occurrence of floods, since a portion of the flood-water has an opportunity of running off before the flow from the head waters can reach the lower part of the stream.

The influence of forest-cover is to make the run-off slower on the whole, and damages caused by floods have been acknowledged in certain cases to be due to forest denudation[26]. Movement of ground water is also believed to be retarded in timber-soil[27], and clearing of timber in certain places most strikingly increased the stream-flow of rivers[28].

In the submontane area of North Bengal, the country has been extensively cleared in recent years for cultivation. This may have had some effect on the run-off of the Tista and the other mountain streams. The districts lying further south have been under cultivation for a long time, and no important change due to forest denudation can possibly have taken place there in recent times.

(6) Drainage Channels.—A high level of the Tista and other hill-stream acts as a favourable condition for the occurrence of floods in the submontane country (areas A-2 and A-3), and in the north-eastern plain (area B-1); it sometimes also becomes directly operative by actual overflow. A high level of local streams is an important factor in other areas as well, but usually acts indirectly by hampering drainage rather than by a direct overflow.

The level of the Brahmaputra is a factor of outstanding importance in area (B-1—the north-eastern plain), where the severity or duration of floods would be appreciably increased by a high level of the river, and where, provided the river level was low, floods would not occur even for a considerable excess of local rainfall.

It is naturally a dominating factor also in area (B-2—the spill area of the Brahmaputra), where a high level of the river may easily lead to local floods, if the rainfall is slightly or moderately above normal, or in isolated instances, even when the rainfall is not in excess. A high level of Brahmaputra would also hamper the quick draining away of water from the eastern portions of districts Bogra and Pabna, and once a flood had occurred, would prolong its duration in the east of the central area (C-3). It has, however, practically no influence in bringing about a flood in the central area, or in areas other than those mentioned above.

The level of the Ganges is the dominating factor in area (B-3). A high level of the river would cause floods in this area with a slight or moderate excess of local rainfall, or as in 1870,

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([23]) *Reaks, 51.*

([24]) The percolation supply is highest after the cessation of the rains, and becomes practically *nil* towards the end of the dry season, *i.e.*, in May or early June. The percolation supply in Nadia rivers has been estimated to average between four and six hundred cusecs during the dry season—(*Reaks, 51*).

([25]) Karl Fischer : " Precipitation and Run-off in the drainage basin of the Oder." Yearbook of Hydrology of North Germany, Special Communication, Vol. 3, No. 2 (abstract in *M. W. R., U. S., 1919, Oct., 743*).

([26]) S. L. Moyer : " An Approach to Run-off Expetancy," *M. W. R., U. S., 1924, Nov., 536.*

([27]) M. Hill : " Relation between Forests and Atmospheric and Soil Moisture in India " (Government of India), Calcutta, 1916.

([28]) J. T. Bode : " Influence of Forest Areas, etc.," *M. W. R., U. S., 1920, Nov., 637.*

([29]) " Increasing Run-off from Avoca Basin." Proc. Roy. Soc. Victoria XXXV (abstracted in *M. W. R., U. S., 1925, June, 263*).

Engler Arnold's " Experiments showing the Effect of Forests on the Height of Streams," Zurich, 1919, gives a comprehensive account of this subject.

even when local rainfall was below normal. On the other hand so long as the level of the Ganges remained low, *i.e.*, the drainage of the country remained unimpaired, floods would not occur, even with a considerable excess of local rainfall.

A high level of the Ganges may also become a source of complication in the central area by sending in a considerable volume of water in the Chalan Bil.

On the whole, the level of the Ganges does not appear to have exerted much direct influence on the occurrence of floods in the central or other areas of North Bengal, with the exception of area (B-3).

(7) Obstruction to Drainage.—We have seen that, with the exception of area (A), drainage is generally poor throughout North Bengal, and in many places is hardly sufficient to cope with the normal precipitation. The extreme flatness of the country also makes the drainage peculiarly susceptible to even very slight changes of level[29].

There is some evidence to show that the drainage of the central area has deteriorated considerably during recent years. The chief natural factor at work has been the gradual raising of the ground level in the *bil* area (by the deposit of silt), and the consequent decay of the river channels.

The railway embankments[30], particularly those running from west to east, have also helped in this process by offering a certain amount of obstruction to the natural drainage of the area. They have also occasionally acted as barriers for holding up the flood water (1892, 1922) and have thus helped in either giving rise to floods or in prolonging their duration.

Other embankments or high roads or even minor artificial obstruction may also have contributed towards the continued deterioration of the drainage. It is, however, not possible to make an estimate about the exact nature or extent of their influence without local surveys.

([29]) "In a flat country, such as the plains of Bengal, it may be expected that a water-channel will be affected by comparatively insignificant events, which may nevertheless, be sufficient to give rise to changes of its course."—H. H. Hayden (Director, Geological Survey of India) and E. H. Pascoe (Superintendent, Geological Survey of India) "Note on the Geological Aspect of the changes that have taken place in the Rivers of Bengal," p. 20, Appendix I, *Hooghly River, Vol. I, 1919.*

([30]) Dates of opening of traffic of the important railway lines are given below :—

(1) Atrai to Parbatipur (metre)—28th August 1877.
(2) Sara to Atrai (metre)—19th January 1878.
(3) Jalpaiguri to Siliguri (metre)—10th June 1878 (converted to broad-gauge between 1914 and 1924).
(4) Parbatipur to Chirirbunder (metre)—18th July 1883.
(5) Chirirbunder to Jingapur (metre)—16th May 1884.
(6) Jingapur to Raiganj (metre)—15th February 1888.
(7) Raiganj to Katihar (metre)—1st July 1889.
(8) Santahar to Bogra (metre)—1st April 1889.
(9) Ishurdi to Bhangoora (broad)—1st July 1915.
(10) Bhangoora to Serajgunj (broad)—25th July 1916.

SECTION V.—SEASON AND FREQUENCY OF FLOODS; FLOOD PREVENTION AND FLOOD WARNINGS.

Season of Floods.

We have seen that more than three-fourths of the rainfall in North Bengal is concentrated in the four months June, July, August and September. We have also seen that there is comparatively little rainfall before June. So that in June, the soil, as well as the rivers, tanks and *bils* are usually dry, and conditions are definitely unfavourable for the occurrence of floods. It is therefore not surprising to find (Table 19) that almost all the floods in North Bengal occur during the three months July, August and September, and frequently towards the middle or end of the rainy season[1].

Table 19.—Classified list for North Bengal.

Month.	Catastrophic. (a)	Severe. (b)	Moderate. (c)	Slight. (d)	Total.
July	..	1	2	2	5
August ..	..	3	3	7	13
September ..	2	4	4	2	12
October ..	..	1	..	..	1
Total ..	2	9	9	11	31

We may now consider the frequency and season of occurence of floods for each area separately.

Table 20—Classified list for Area (A).

Month.	Catastrophic. (a)	Severe. (b)	Moderate. (c)	Slight. (d)	Total.
July	..	1	..	..	1
August ..	..	1	1	..	2
September ..	1	2	2	..	5
Total ..	1	4	3	..	8

In the hilly districts and in the sub-montane country drainage is good and floods are caused almost invariably by heavy local rainfall. Excessive precipitation in the hills occasionally give rise to floods in the Tista and other hill streams, and sometimes cause local floods by an overflow from the rivers. As will be seen from the above table, floods are usually of considerable intensity, and occur more frequently towards the end of the rainy season, when the ground has become thoroughly sodden with water. Owing to the slope of the country they are however quickly drained away.

Table 21—Classified list for Area (B-1).

Month.	Catastrophic. (a)	Severe. (b)	Moderate. (c)	Slight. (d)	Total.
July	..	1	1	..	2
August ..	..	1	1	2	4
September ..	..	1	..	..	1
Total ..	..	3	2	2	7

In the north-eastern plain, drainage is not satisfactoy and the intensity and duration of floods is determined to a great extent by the level of the Brahmaputra, and also partly by the level of the Tista and other hill streams. Floods generally occur in the middle of the rainy season, and are usually of considerable intensity.

Table 22—Classified list for Area (B-2).

Month.	Catastrophic. (a)	Severe. (b)	Moderate. (c)	Slight. (d)	Total.
July	..	..	1	2	3
August ..	..	..	2	2	4
September ..	..	..	1	2	3
Total ..	..	..	4	6	10

The country adjoining the right (west) bank of the Brahmaputra is extremely flat and lowlying, and during the rainy season, the level of the river actually rises higher than the surrounding country, and fails to function as a drainage channel. The drainage converges towards the eastern fringe of the marshy depression in Pabna, from where the water ultimately finds its way out through the Hurasagar into the Brahmaputra. The whole situation is dominated by the level of the Brahmaputra; heavy rainfall in area (B-1) also acts as a predisposing factor, by raising the

(1) The total number of floods in Table 19 is 31, against a total of 25 in column (3), Table 26, because sometimes a flood has extended over more than one month, and has therefore been entered more than once in Table 19.

level of that river. Floods occur quite frequently, and often continue for a long time, but are not usually serious in character.

Table 23—Classified list for Area (B-3).

Month.	Catastrophic. (a)	Severe. (b)	Moderate. (c)	Slight. (d)	Total.
July	..	..	..	1	1
August ..	..	1	3	5	9
September ..	..	2	3	4	9
Total ..	..	3	6	10	19

The riparian tract on the left (north) bank of the Ganges is also extremely flat and lowlying. During the rainy season, the level of the Ganges often rises higher than the level of the surrounding country, and sends in a considerable volume of silt-laden water into the *bil* area; floods caused by an actual overflow of the river are therefore not rare.

As will be seen from the above table, floods occur very frequently, particularly towards the end of the rainy season, but are usually of slight or moderate intensity.

Table 24—Classified list for Areas (C-1) and (C-2).

Month.	Catastrophic. (a)	Severe. (b)	Moderate. (c)	Slight. (d)	Total.
July	..	1	..	..	1
August ..	..	1	..	1	2
September ..	..	..	..	1	1
Total ..	..	2	..	2	4

The north-western country (areas C-1 and C-2) is situated at slightly higher level, and is well drained by a network of fairly active rivers. Floods, which are of rare occurrence, have been caused invariably by very heavy local precipitation, and have been sometimes aggravated or prolonged by serious holding up of the flood water by railway embankments.

Table 25—Classified list for Area (C-3).

Month.	Catastrophic. (a)	Severe. (b)	Moderate. (c)	Slight. (d)	Total.
July	..	..	..	..	..
August ..	..	1	..	1	2
September ..	1	..	..	2	3
Total ..	1	1	..	3	5

The drainage of the central area (which may be likened to a very flat and shallow basin with a hollow depression in one corner) converges towards the Chalan *bil* and the adjoining swampy land. The Atrai, the Jumna, the Nagar and several other small streams flow into this area, and drainage takes place slowly through the water-logged and marshy depressions; the water ultimately finding its way out into the Brahmaputra. The level of the *bil* area is being continually raised by deposit of silt, and consequently the river channels are steadily deteriorating.

Local precipitation is the most important direct cause of floods in this area; while obstructions to drainage, natural or artificial, constitute the most important indirect cause. Water coming from the north is not a factor of great importance, while a high level of the Ganges or of the Brahmaputra also do not appear to exercise much direct influence. The latter factors can aggravate and prolong the duration of floods to some extent, but cannot by themselves cause a flood in the central area.

Floods have been of comparatively rare occurrence in the past, but now that the drainage is steadily getting worse, are likely to occur in future with greater frequency.

Flood Frequency.

The following table gives the number of years in which floods had occurred in North Bengal during the period 1870—1924, *i.e.*, in 55 years. Sometimes more than one flood occurred in the same year; in column (2) such cases have been entered only once, under the most severe category; while in column (3) such years have been entered more than once under each appropriate category.

Table 26—Frequency of Floods.

1	2	3
Nature of flood.	Number of years of flood.	Number of flood.
(a) Catastrophic	2	2
(b) Severe	6	6
(c) Moderate	6	7
(d) Slight	5	10
Total ..	19	25

It would appear therefore that floods of some kind or other are likely to occur in North Bengal a little more frequently than once in every three years, or almost practically in every alternate year; moderate or severe floods about once in four years, and severe floods about once in seven years.

Catastrophic floods are also recorded to have occurred in 1787, when the course of the Tista was diverted eastwards[2], and in 1820, when the channel of the Karatoya was profoundly modified[3]. Catastrophic floods thus appear to have a frequency of two or three per century or about once in 35 years.

Severe floods are recorded to have occurred in 1838 in Rajshahi and other parts of the country[4], in 1864 in Rajshahi and Bogra, and in 1865 in Rajshahi.

Frequency of floods in other countries.

In the U.S.A., in the extreme upper Ohio river, a flood stage may be expected about once in each year, over the middle and lower reaches about once in one-and-a-half year, in larger tributaries once in two years, in Mississippi and Missouri rivers once in two-and-a-half years; in the lower Mississippi river and in the Arkansas river once in one and one-third years, and in Red river once in four years. For severe floods the frequencies are: upper Ohio 1 in $2\frac{1}{2}$, or 1 in 2 years; larger tributaries 1 in 3, lower Mississippi 1 in 5, Arkansas 1 in $5\frac{3}{4}$, and Red river 1 in 38[5].

Defining floods greater than the average by a specified amount as "great floods", A. J. Henry[6] states that the records of both American and European rivers show an average of 7 to 10 such great floods per century. The Danube has had 15 great floods in 178 years; the Seine at Paris, 22 in 271 years (1649—1919); the Necker in Germany, 8 in 73 years (1824—1919); the Main at Frankport, 8 in 89 years (1831—1919); and the Rhine at Coblenz, 11 great floods in 100 years (1819—1919).

Assuming that our category of "severe floods" corresponds to Henry's category of "great floods", it would appear that such floods are a little more frequent in North Bengal (about 14 per century) than in U.S.A., or Europe (7 to 10 per century). It is however difficult to decide whether the two categories really correspond or not.

Probability of occurrence of floods.

The sequence of flood years in North Bengal do not show any indication of the existence of a cyclic period in which great floods are repeated[7], nor does the interval in years between great floods bear any relation to the intensity of successive floods.

In fact the occurrence of great floods is conditioned by the synchronisation of a large number of factors. R. E. Horton[8] has explained that "the combination of causes which can produce an absolute maximum flood is very much more limited than the number of combinations which can produce an ordinary flood; in fact, it seems to me that the occurrence of increasing magnitudes of such events is essentially of the nature of phenomenon of exhaustion. The larger the magnitude of the event, the greater the difficulty of its occurrence."

Although the normal curve is not at all adequate for measuring the probability of very high excesses of rainfall, still it will serve to give some idea about the increasing difficulty of occurrence of floods of increasing magnitudes. I give below the departures of rainfall (expressed in terms of the S. D.) for the different areas, for the more severe floods in North Bengal.

Table 27—Rainfall Departure (in terms of S. D.) for each area.

Year.	1892.	1902.	1906.	1918.	1922.
Number of days ..	7	30	24	9	7
Area affected ..	A-2, A-3, B-1, C-1, C-2.	A-3.	A-2, A-3, B-1.	B-2, B-3, C-1, C-2, C-3.	C-1, C-2.
A-1	1·15	1·87	2·27	0·30	− 0·49
A-2	4·47	1·24	4·14	0·25	− 0·67
A-3	5·72	2·17	4·03	2·66	+ 1·60
B-1	4·24	1·50	2·37	1·98	+ 2·26
B-2	0·92	0·84	2·36	4·55	+ 6·41
B-3	1·75	0·69	1·00	4·36	+ 6·18
C-1	3·98	0·82	0·99	6·31	+ 8·69
C-2	3·85	1·03	1·38	4·93	+ 6·89
C-3	1·04	0·58	1·19	6·85	+11·74

(1) Described in section III, p. 30.

(2) *See* section III, p. 30.

(3) Mr. Simson is quoted in *Dist. Gaz. of Rajshahi (1916)*, p. 93, to have remarked in his "Sport in Eastern Bengal," that "the destruction was terrible, and none of the houses he knew remained standing."

(4) "*The Spring Floods of 1922*," p. 3.

(5) "The Distribution of Maximum Floods," *M. W. R., U. S., 1919, Dec., 863—865.*

(6) This is also true for other countries. "There is no evidence of a regular sequence of occurrence of floods for the reason that there is likewise no evidence of regular seasonal sequence of heavy precipitation." "*Spring Floods of 1922*," p. 4.

(8) *M. W. R., U. S., 1919, Dec., 866.*

If we arrange the flood years in accordance with the magnitude of rainfall departures (expressed in terms of the S. D.), we get the following order :—

1922 (+11·74 in C-3), 1918 (+6·85 in C-3).

1892 (+5·72 in A-3), 1906 (+4·14 in A-2).

1902 (+2·17 in A-3).

It will be noticed that the order of intensities of the floods is also the same as that given above. The excess departure is thus a convenient measure of the severity of the rainfall, and hence also of the intensity of the flood.

Now the probability of occurrence of any given departure increases very rapidly with the magnitude of the departure[9].

Hence it is clear that the probability of occurrence of great floods diminishes very very rapidly with the magnitude of the floods.

Prevention of floods.

It will be going out of my province to discuss the question of prevention of floods. I merely wish to note a few points in this connection.

Preventive measures may be considered under four heads :—

(1) Erection of retarding basins,

(2) Erection of embankments,

(3) Improvement of surface drainage, and

(4) Educating the inhabitants to take precautionary measures, and the issue of flood warnings.

(1) Erection of retarding basins.—The proposal is to construct flood absorption reservoirs and retardation basins, " by means of which part of the flood of any particular basin or basins can be held back whilst the discharge from some other catchment is allowed to pass off, and so reduce the volume of water coming upon the low areas at one time "[10]. This method has proved successful in certain parts of the United States and other countries.

Conditions in North Bengal do not however appear to be at all suitable for this method. We have seen that in North Bengal floods occur just where the heaviest rains fall, and that water coming from adjoining areas is usually not a factor of great importance. The natural lie of the country is also such that the chief purpose of retarding basins is automatically achieved. The rainstorms usually advance from south to north, while normal drainage is from north to south. So that a portion of the flood water in the south can easily get away before the heavier precipitations in the north can come down. We have also seen that the actual site of the heaviest rainfall fluctuates very irregularly from season to season. Taking all these into consideration we must conclude that the erection of retarding basins would not serve any useful purpose in North Bengal.

(2) Embankments.—In the riparian tracts some protection might be given by the erection of embankments, but this remedy is not available for a large area in the central districts. The inevitable result of the erection of river embankments will however be the raising of the river beds, which in its turn will lead to a progressively rapid deterioration of the other river channels in North Bengal, and will also make it increasingly difficult for the water in the central area to get away at all. Embankments, at best will therefore prove only temporary expedients, and are likely to make the situation far worse in the long run[11]. They will also be quite ineffective over a large part of the country.

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(9) We have already seen that a normal distribution is quite inadequate for the present data; we may however use it as a very rough (and wholly inaccurate) approximation for purposes of comparison. The probabilities of departures of 6·85 (in 1918) and 11·74 (in 1922) (after making an allowance for the disparity in the number of days) are vanishingly small and are once in $2·9 \times 10^{11}$ and $2·9 \times 10^{31}$ years, respectively. It is however important to observe that the probability of occurrence of the 1922 flood is enormously less than the probability of the 1918 flood.

(10) According to one competent authority, the estimated cost will not be less than three crores of rupees. I need not discuss here the financial aspects of the question.

(11) Captain F. C. Hirst has discussed the evil effects of embankments in detail in his paper on " the Kosi River " (*J. A. S. B., IV, 1908, 463—487*). He is of opinion that " the embankment is to blame for increases in floods in most circumstances " (p. 466).

This question has also been discussed by Mr. W. S. Inglis in his paper " The River of Bengal " (*J. A. S. B., V, 1919, 393—405*). He gives it as his opinion that " marginal flood banks, designed with discretion and with a proper understanding of the factors of the case, are of service. It is, however, fully recognised that they are a lesser evil than uncontrolled floods, than that they are in themselves a positive good " (p. 395).

Also see the " *Report on Nadia Rivers* " (1916) and " *Hooghly River* " (1919), published by the Government of Bengal.

(3) Improvement of surface drainage.—The fundamental problem is to get rid of the water in the central area quickly, and any improvement in the surface drainage is therefore likely to prove beneficial by preventing undue accumulation of water in the central area. Attempts should be made to remove (and prevent), as far as practicable, artificial obstructions to drainage, such as railway and road embankments, and to ensure the provision of a sufficient number of culverts and openings for the passage of flood water. Improvement of existing channel and systematic river-training are also likely to prove useful.

(4) Precautionary measures and flood warnings.—It must not however be forgotten that the basic difficulty of the situation lies in the comparatively low level of the central area, which cannot be remedied by any artificial means. Floods of more or less severe intensity are sure to occur until the level of the country is sufficiently raised, and a stable hydrological régime is established.

It would be necessary therefore to advise and educate the inhabitants to adapt their life to the changing conditions; to build their houses, as far as possible, on high grounds; to make provisions in their houses for raised platforms where human beings may take shelter during high floods; and also to construct raised mounds in the villages, where grain and valuable properties may be removed in times of danger. This plan has met with considerable success in America, and also in certain other countries, and there is no reason why it should not succeed in North Bengal also.

Flood warnings.—Much could also be done by the issue of timely warnings for mitigating the evils caused by floods.

The Indian Meteorological Department issues warnings of storms and heavy rainfall to 74 police-stations and 31 district and subdivisional officers in North Bengal. These warnings are based on the daily weather chart, and have reference to rainfall only, and not to floods.

Lieut.-Colonel D. C. Bates, Meteorologist, in his report on "Flood-Warnings in New Zealand" (1919) has noted "the prediction of floods may be attempted on (*a*) the weather chart, (*b*) the records of rainfall in the river basins, and (*c*) the actual rise of streams in their upper reaches. Owing to the known uncertainty, especially in respect of locality, in forecasting heavy rain", the first mentioned method is only applicable in a general manner, the second source of information is undoubtedly capable of development by provision of more observing stations[12] and improving means of communication of records[13], but the actual rising of the river affords the most certain and striking means of forecast, not only for the time but for the height of an inundation [14].

Conditions in India are in many ways similar to those in the United States of America, and it may not be out of place here to give a brief description of the organisation of flood warnings in the latter country.

For purposes of administrative control, river and flood service is organised under the River and Flood Division of the Weather Bureau. For forecasting, the division is divided into 68 district centres, to each of which is assigned one or more rivers. While special attention is directed toward the issue of flood warnings, a daily forecast of the rise and fall is made for those streams on which navigation is carried on. The total number of stations making daily readings of gauge heights for at least a portion of the year is 542 (in 1922). The number making occasional readings is 75. Most of the gauge-reading stations are also rainfall stations. The rainfall measurements of all classes of stations, of which there are about 4,000 in the United States, are available for Hydrological Studies[15]. During the last 30 years, at least, the issue of flood warnings in the United States of America appear to have been almost uniformly successful. In the beginning the authorities were charged with unduly alarming the people of the threatened

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(12) This is not an immediate necessity in North Bengal, as about 68 rainfall stations are already in existence there. A few more stations in certain districts would however prove useful.

(13) There is greater need for this. Only 9 out of the 68 observing stations send rainfall report by telegram on the day of occurrence to the Meteorological Office.

(14) Quoted in *Symon's Meteorological Magazine, 1919, Oct., p. 101.*

(15) The above figures are taken from "Daily River Stages," Vol. XIX (1921), published by the United States Department of Agriculture.

districts. The verification of the forecasts has however brought about a wholesome change of attitude, and forecasts are now readily accepted and acted upon without question[18]. Organisation of flood warnings on the lines of the United States Weather Bureau is feasible, and is likely to prove quite useful in North Bengal.

River gauges are at present maintained at Gauhati on the Brahmaputra, and at Mirzapore, Benares, Buxar, Dinapore, Monghyr, Rajmahal, Rampur Boalia and Goalundo on the Ganges. There are no gauges on any of the other rivers in North Bengal. In case the issue of flood warnings is seriously taken up, it would be absolutely necessary to start and maintain a large number of gauges in all the important rivers of North Bengal, and also to arrange daily telegraphic communication of gauge readings as well as of rainfall information to a central office. A few more rainfall stations would also prove useful. Arrangements will also have to be made for the analysis of the gauge readings and rainfall data for purposes of flood forecasts.

The want of reliable flood records is a great handicap. Considering its importance, it would be desirable to make arrangements for the systematic compilation of a flood register in future. The date of occurrence and subsidence, the period and character of rainfall, the area affected, and the nature and extent of damages are some of the points on which information should be gathered from all over the country, and the available information compared and analysed for record in a consolidated register. This would take time, and would involve a certain amount of recurring expenditure, but would probably be worth a good deal more than what it would cost.

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(18) *New York Herald, April 29, 1922*, noted that "the work of forecasting the water stage at various points between Cairo and New Orleans is helpful, as it gives timely warnings when the peak may be expected. The degree of accuracy attained by the Bureau is remarkable. For example, between 42·5 and 43 feet was forecast for Memphis by the end of March. On March 31st and April 1st the stage was 42·6".

The amount of property saved in the United States of America through the issue of flood warnings is often considerable. During the Spring Floods of 1922, the value of the property saved has been estimated at 8,000,000 dollars (against an actual loss of 7,000,000 dollars). The estimates were based on information obtained from reliable sources, and may be taken as approximately correct. None of the estimates was made by any Weather Bureau officials. ("*Spring Floods of 1922*," pp. 28-29).

Part II

Description of Floods

1870.

(Map Nos. 4/1870/1 & 5/1870/2.)

Several floods occurred in July and August at many places in North Bengal.

The Amrita Bazar Patrika (translation).—

July 21.—Floods are doing much harm in many places. Pabna has been flooded and *aus* and *aman* crops have been destroyed.

August 17.—This year north and south Bengal have been flooded severely.

August 18.—One correspondent writes from Pabna that crops have suffered severely from floods. Rice is selling at a high price.

Bengal Administration Report, 1870 (page 47)—

In the months of July and August the rainfall was exceptionally high, especially in the northern and eastern districts of Bengal; and this led to inundations over a large extent of country in those directions.

Patna Division.—In the Patna division, the districts which suffered most were those of Chumparun and Tirhoot. Of the former, a great portion was inundated by the overflow of the Nurainee, or big Gunduck; and there was much destruction of crops, especially indigo. The latter district suffered from the overflow of the small Gunduck and the Bhagiruttee rivers; the crops suffered, and the roads were unusually cut up. A spill from the Soane also inundated a portion of Shahabad, *viz.*, all the country between the river and Arrah. The damage caused was nowhere so severe as to cause any serious distress. In the Bhaugulpore division the crops suffered some injury in the districts of Bhaugulpore and Monghyr from the overflow of the Ganges.

Bhaugulpore Division.—The district of Purneah suffered more severely from the flooding of the Punar river, which was at first supposed to have been aggravated by a bund erected on the river Behra for the preservation of the station of Purneah. It was found on inquiry, however, that the bund had in reality been the saving of the district on the left bank of the river. Much damage was done to the crops, but not to such an extent as to cause distress.

Rajshahi Division.—In the Rajshahi division, the inundation of the Pudma caused great damage to crops in the Moorshedabad district, especially in the country, round Bhugwangolah, where some distress was felt. Relief however, when necessary, was promptly administered with the assistance of the neighbouring zemindars. The damage done in the Pubna district, in the direction of Comercolly and Serajgunge, was also great; the rivers, great and small, the Ganges, Brahmaputra, Ishamuttee and others, having risen considerably above their ordinary high level. But there were no fears of distress.

Presidency Division.—In the Presidency division, portions of the Kooshtea subdivision, in Nuddea were inundated; and the overflow of the Jellinghee also inundated certain portions of the subdivision of Meherpore. In Jessore too there was inundation in the subdivision of Jenidah, Magoorah and Nurrail, caused by the flooding of the Modhumatee and the Nobogunga, which are connected with the Pudma and the Gorai. But no distress was caused anywhere by these floods.

Dacca Division.—The districts of the Dacca division which suffered most from inundation were Dacca, Backergunge, Faridpur, Mymensingh, Cachar and Tipperah. There was considerable damage done to crops, but not such as to give rise to any distress.

Burdwan Division.—In the Burdwan division the country lying between Panchkoorah and Midnapore was inundated by the overflow of the Cossye, but there was no serious damage except to the sugarcane crop in pergunnah Bogree.

Rainfall Analysis.

In July very heavy rain fell at Buxa, the actual amounts being on the 1st, 17·00 inches; 2nd, 9·90 inches; 7th, 15·80 inches; 8th, 9·40 inches; 9th, 18·50 inches; 10th, 10·50 inches; 11th, 12·00 inches; 13th, 13·00 inches; 14th, 5·00 inches; 24th, 6·50 inches; the total for the whole month being 138·00 inches or an excess of over 216 per cent. The rainfall in Upper Assam was also in large excess. The level of the Brahmaputra must therefore have been exceptionally high. The rainfall at Darjeeling was not excessive, was in fact below normal, the only heavy fall being 3·58 inches on the 21st. At Jalpaiguri the excess was 36 per cent., the heavy falls being on the 1st, 3·75 inches; 2nd, 5·25 inches; 6th, 8·17 inches; 11th, 3·59 inches; 13th, 5·36 inches. At Rungpore the excess was 119 per cent., and the heavy falls were on the 1st, 4·00 inches; 2nd, 4·24 inches; 7th, 3·75 inches; 13th, 3·00 inches; 14th, 8·50 inches. Dinajpore had an excess of 31 per cent. with one heavy fall of 3·85 inches on the 7th. The rainfall was in slight excess at Malda 19 per cent. and at Pabna 8 per cent., but was actually in defect at Boalia by 10 per cent., Natore 6 per cent. and Sirajganj 35 per cent.

It is clear therefore that the July floods in Rajshahi and Pabna were mainly due to the overflow of the river Ganges and partly to the high level of the river Brahmaputra. It is also clear that the large excess at Jalpaiguri, Dinajpur and Rungpur (*i.e.*, north of the present Kaunia-Parbatipore-Kurigram line, which had not been constructed at that time) flowed away to the south without producing any local floods.

In August rainfall was in defect practically throughout the area to the north of Malda and Bogra. The excess in the south was also only moderate, the actual figures being Malda 5 per cent., Bogra 36 per cent., Sirajganj 41 per cent., Nator 5 per cent., Pabna 21 per cent. and Boalia 33 per cent. There were no falls of over 3 inches at these stations. Flow of water from the north was therefore not a complicating source. The August floods in Rajshahi and Pabna also were therefore due to the high level of the Ganges. A study of the present flood indicates that the normal drainage in Rajshahi and Pabna is only just sufficient to cope with the normal rainfall. Either a moderate excess of rainfall or an abnormal rise of the Ganges is sufficient to cause local floods, while both together is likely to lead to severe inundations.

1871.

(Map No. 6 1871/1.)

Extensive and severe floods occurred in Malda and Rajshahi during August, September and October.

The Bengal Administration Report, 1871—

The waters were out on this occasion from the end of August to the second week of October, and the whole of the country was flooded. It is believed that these were the highest floods on record in the Rajshahi district; but the damage done to the crops was comparatively small. The cattle suffered much from the loss of fodder, and the people were greatly inconvenienced by being driven to seek shelter on high places. When the water subsided Cholera broke out in epidemic form. The *boro aman* rice crop, however, grew on in most places uninjured, and managed to keep its head above the waters, even when they rose quickly; and eventually a very fair rice harvest was reaped.

The Hindu Patriot—week ending September 11—

By the overflow of the great river Pudma, the lower part of the district of Rajshahi, that is, by far the greater part of it is generally inundated at this time of the year, that is, in autumn. But the inundation of the pre at year has been most disastrous. The oldest man living does not remember to have seen such a deluge, several of the fairest villages have been swept over by the flood, looking like one vast sheet of water studded here and there with huts and trees. It is needless to say here that the growing crops will be destroyed.

The Bengal Administration Report says—

On only two occasions are floods known to have occurred on such a serious scale as to affect materially the general harvest of the district. The first took place in 1838, and the second in 1865; the latter was mainly caused by excessive rainfall within the district. Again in 1871, heavy rainfall caused extensive inundations in Rajshahi as in other districts that are washed by the Ganges.

Rainfall Analysis.

In the first half of August rainfall was actually below normal throughout North Bengal and there were no falls of over 3 inches. In the second half many heavy falls occurred and rainfall was in excess over the greater part of the area. The following stations had a fairly large excess: Darjeeling 52 per cent., Jalpaiguri 56 per cent., Buxa 14 per cent., Rungpur 87 per cent., Dinajpur 67 per cent., Bogra 90 per cent., Boalia 60 per cent. The excess at Nator 12 per cent., Sirajganj 11 per cent. and Pabna 7 per cent. was small, while Malda was actually 33 per cent. in defect. Heavy falls were 3·36 inches at Buxa on the 20th, 5·65 inches at Jalpaiguri, 3·00 inches at Buxa and 3·30 inches at Rungpur on the 22nd and 3·42 inches and 3·40 inches on the 25th and 27th at Buxa. Rainfall for the whole month of August was however deficient at most places. Pabna, Dinajpur and Rangpur showed a very small excess and Boalia a moderate excess of 40 per cent.

In the first week of September considerably greater rainfall than the average occurred in the east, the excess varying from about 50 per cent. to 150 per cent. Heavy falls were on the 2nd, 3·04 inches at Gaibandha; on the 3rd, 6·00 inches at Natore, 5·40 inches at Buxa, 3·70 inches at Rungpur; on the 4th, 5·46 inches at Darjeeling and on the 5th 4·01 inches at Pabna.

From the 12th to the 16th rainfall was in large excess throughout the south-eastern portion of North Bengal, actual percentage departure being Malda 136, Boalia 101, Pabna 298, Sirajganj 103, Bogra 207, Gaibandha 206, Dinajpur 153 and Rungpur 63. Heavy falls were 4·37 inches at Darjeeling on the 13th, 5·03 inches at Gaibandha on the 14th, 3·20 inches at Bogra on the 15th and 3·40 inches at Dinajpur on the 16th. Rainfall was however again below normal in the north.

From the 23rd to 30th, rainfall was in slight or moderate excess over the central part of the area but was in defect at Buxa (—10) and along the Ganges at Boalia (—42) and at Pabna (—26). Boalia had 3·20 inches on the 22nd, Jalpaiguri 3·00 inches and Darjeeling 3·58 inches on the 23rd and Buxa 4·00 inches on the 24th.

The month of September as a whole showed moderate excess varying generally from 20 to 90 per cent. in the south-east. Rainfall at Jalpaiguri was in defect by 46 per cent. and at Buxa by 19 per cent.

We thus see that the local rainfall although above normal was never exceptionally heavy. We must look elsewhere for the cause of the flood.

The Hindu Patriot—week ending October 9—

Inundation at Rajshahi.—The north part of this district and the country in the same line eastward, from their geographical position receive the flood direct from the north while the southern part which is watered by the mighty Padma is inundated by water apparently coming from the south. Sometime even

if we do not have plenty of rain in the north, the southern parts may still be overflooded by the Pudma..... This year the rain is excessive and this district has been attacked by the flood from both these sides (north and south) simultaneously and so the whole country is under water..... In some places towards the east and the south of the town the embankment has given way and in other places it has been overflowing and the calamity in the district is quite unprecedented. The loss of life occasioned by the falling of houses and specially by that of the mud-walled ones is small but the injury to cattle is beyond description.

The Administration Report says—

Rajshahi is subject to floods caused by the annual rising of the Ganges, and often aggravated by excessive rainfall. In moderation, these annual inundations instead of being a source of mischief are of the greatest possible benefit by fertilising the soil.

The Malda District Gazetteer gives a more detailed description :—

These floods result not from local rainfall, but from an abnormal rise in the rivers, of which the most important is the Ganges. Most of the rivers, and streams which flow through Malda take their rise in the northern mountains, and are therefore peculiarly liable to sudden freshets caused by the melting of snow and excessive rainfall in the hills. The crops damaged are the *bhadoi* and *aghani*, particularly in the *diara* and the lower portions of Tulshihata and Kharla thanas. Much damage is also done to the mulberry, as a flood renders the leaf useless for feeding the silk-worm. As a rule floods are not accompanied by direct loss of human life or cattle. The main loss to property, other than standing crops, is, that in the *diara* tracts the floods cause changes in the main stream of the river, with the result that areas of cultivated and homestead lands are cut away by the river, and the inhabitants of whole villages are reduced in a night to the position of landless labourers. On the other hand, of course, new *chars* form, and the layer of silt which a high Ganges flood deposits everywhere ensures as a rule good crops for several succeeding years.

In August the main source of danger was the rising of the Ganges. *The Amrita Bazar Patrika* has the following (*week ending August 26*) (translation) :—

A correspondent from Rajshahi writes that they fear that they may be washed away by the Padma (*i.e.*, the Ganges) at any moment. A "bund" protects the town, but the water has risen so high that nobody knows how long it will survive. Now and then rumours spread that it has already given way and the people of the town begun to run away in all directions in order to save their lives.

Evidently the exceptionally high level of the Ganges was the chief contributary cause. The widespread and long continued excess of rainfall aggravated the situation. If rainfall had been normal, the Ganges in spite of its high level might have succeeded in carrying away all the water. If the river level had been normal, the excess water might have drained off through the normal channels. But the two together produced an exceptionally severe flood.

It should be noted that the actual excess of rainfall was never very high, but with the rising of the Ganges a great deal of it accumulated and caused the flood.

In the first week of September rainfall at Boalia was in defect. It is significant that the following appeared in the *Englishman* on the 7th :—

The latest accounts from the flooded districts of Bengal show that the floods are everywhere *abating*. The people seem to have got over the floods pretty well and they are apparently accustomed to be inundated more or less every year. There has been some harm done to the roads in Rajshahi.

With the increase of rainfall later on the floods also increased in intensity. This shows that the drainage was almost balancing the normal rainfall. Even a slight easing off of rainfall led to a partial subsidence of the floods while a slight strengthening caused an increase.

It seems clear therefore that when the Ganges level is above normal severe floods in Malda and Rajshahi are likely to occur through even a moderate excess of local rainfall.

It must also be noted that the rainfall at Darjeeling, Buxa and Jalpaiguri, *i.e.*, in the north was generally below normal. Thus water coming from the north was not an important factor.

1874.

(Map No. 7/1874/1.)

Moderate floods occurred in Rajshahi and Pabna. The *Amrita Bazar Patrika* wrote (translation):—

Week ending September 10: In the north-western part of the country the Ganges flooded the fields into a vast sheet of water. Water is steadily rising. The Padma swelled so much that Goalundo is nearly under water and many parts of Pabna have been washed away, and crops have been destroyed..... Gradually the water will spread all over Bengal and if the water of the Ganges increase at this rate then within a month a great flood will occur in Bengal.

Week ending September 14: At Pabna the water rose abnormally and destroyed all crops.

During the period 29th August to 8th September rainfall was above normal at several places: the excess percentage being Natore 179, Pabna 41, Bogra 16 and Jalpaiguri 17. Elsewhere it was normal or in defect. Heavy falls were, on the 3rd Natore 3·14 inches, Jalpaiguri, 4·98 inches; on the 4th and 5th Natore 3·45 inches and 3·39 inches; on the 7th Jalpaiguri 3·32 inches.

From the 9th to the 15th September there were heavy falls throughout North Bengal. Chief amounts were on the 10th, Dinajpur 3·26 inches, Chanchal 5·84 inches, Cooch Bihar 3·60 inches; on the 11th Jalpaiguri 5·24 inches, Gaibandha 3·00 inches, Cooch Bihar 3·40 inches; on the 12th, Jalpaiguri 6·60 inches, Cooch Bihar 3·78 inches; on the 13th Gaibandha 3·00 inches; on the 15th, 4·58 inches. The excess was from 100 to 200 per cent. at most places and over 200 per cent. at Jalpaiguri and Buxa.

The levels of both the Ganges and the Brahmaputra were abnormally high. The gauge readings (for which records are available from 1874) at Buxar, Dinapore (87 miles from Buxar), Monghyr (197 miles), Sahebgunge (291 miles), Rampur Boalia (381 miles), Goalundo (501 miles) on the Ganges and Gauhati on the Brahmaputra amply show this.

The minimum readings over low water before the flood were 22′8″ at Buxar and 22′3¼″ at Dinapore on the 16th, 23′0″ at Monghyr on the 18th, 26′3″ at Sahebgunge on the 19th, 23′11″ at Rampore Boalia and 18′10″ at Goalundo on the 20th; after the heavy falls of rain in the last week of August the gauge readings rose to 30′9″ at Buxar on the 29th, 27′9½″ at Dinapore on the 30th, 26′9″ at Monghyr on the 1st September, 30′7″ at Sahebgunge on the 2nd, 26′3″ at Rampore Boalia on the 5th and 20′1″ at Goalundo on the 16th. A considerable volume of water, was also coming down the Brahmaputra. At Gauhati the gauge reading rose from 22′0″ on the 17th August to 27′7½″ on the 7th September. This also explains the persistent character of the high level at Goalundo where the gauge reading practically never fell below 19′7″ throughout the month of September.

The excess rainfall was confined, it will be noted, to the extreme south-east and the extreme north and was never very large. The flood in Pabna must therefore have been mainly due to the high level of the Ganges aggravated, no doubt, by the high level in the Brahmaputra coupled with the local excess in rainfall. The Ganges evidently failed to carry away even the slight or moderate excess of rainfall and consequently caused the flood by backing up the rain water.

It is interesting to note in this connection that several heavy falls occurred between the 25th and the 30th September.

On the 25th, Boalia had 3·35 inches, Malda 3·14 inches; on the 26th Buxa 4·42 inches, Darjeeling 3·47 inches, Gaibandha 3·00 inches, Rungpur 4·13 inches, Bogra 3·30 inches, Malda 6·14 inches, Chanchal 5·64 inches, Cooch Bihar 5·74 inches; on the 28th Jalpaiguri 6·57 inches, Darjeeling 4·84 inches. The excess percentage was Darjeeling 868, Chanchal 565, Malda 486, Jalpaiguri 357, Nator 268 and over 100 per cent nearly everywhere else. But apparently all this water flowed away without causing serious floods.

The gradient of the rainfall excess was from north-west to south-east and thus followed the gradient of the ground level. This probably allowed the water to spread and flow away through the normal channels without accumulation. The railway lines were not in existence at that time and apparently there was no obstruction to a smooth even flow of the water from north-west to south-east.

1875.

The Amrita Bazar Patrika records a slight flood in Pabna towards the end of August :—

August 26 (translation): Floods are being reported from many districts..... Crops have suffered in Pabna.

Rainfall was in slight or moderate excess in the south during the whole of August, actual figures being Chanchal 92 per cent., Malda 45 per cent., Boalia 17 per cent., Nator 13 per cent., Sirajganj 33 per cent. and Pabna 58 per cent. In the north rainfall was in defect.

Towards the end of August heavy falls occurred in the south-east corner. Chief amounts were on the 24th, Cooch Bihar 4·20 inches, Rungpur 4·92 inches, Bogra 3·79 inches, Pabna 4·80 inches, Sirajganj 3·50 inches; on the 25th Buxa 3·30 inches; on the 27th Pabna 3·13 inches. The excess was 136 per cent. at Sirajganj and 369 per cent. at Pabna.

The gauge readings show that the level of the Ganges was steadily rising throughout the month of August. It became 31′8″ at Buxa, 26′10″ at Dinapore, 26′3″ at Monghyr, 28′9″ at Sahebgunge on the 11th, 25′3″ at Rampore Boalia on the 12th, attained a height of 21′4″ at Goalundo on the 10th and was actually washed away on the 20th. At Gauhati the reading was highest, 27′6″ above low water on the 8th and the 9th. At Goalundo the gauge reading remained above 20′ almost throughout the month.

There can be very little doubt that the present flood was again a river flood aggravated by heavy local rainfalls and was chiefly due to the failure of the Ganges to drain away the flood water.

1879.

In August a flood of slight or moderate intensity occurred in Rajshahi.

The Amrita Bazar Patrika writes (*week ending August 28*) :—

Doleful accounts of the approach of a great inundation are reaching us from several parts of the country. A Rajshahi correspondent says, "Water (in the Ganges) is increasing alarmingly this year. A little above one foot of water more and the whole town will be washed away. The damage caused by the unusual flood can better be imagined than described. We have a dreary prospect before us indeed."

Rainfall Analysis.

Rainfall in the north from 16th to 20th August was very large, more than 100 per cent. in excess at most places and more than 200 per cent. over a large area. The excess was at Meckhleganj 201, Mathabhanga 221, Dinhatta 315, Kurigram 260 north of the Teesta and Jalpaiguri 155, Nilphamari 322, Rangpur 253, Dinajpur 182, Gaibandha 188, Panchbibi 194, Churamon 175, Chanchal 224, Mahadevpur 156 and Sherpur 159 to its south. Heavy falls were on the 16th, Panchbibi 3·73 inches; on the 17th, Churamon 3·50 inches, Dinajpur 3·06 inches; on the 18th, Rangpur 3·13 inches, Chanchal 5·32 inches, Dinhatta 4·15 inches, Mathabhanga 3·65 inches; on the 19th, Buxa 4·36 inches, Nilphamari 5·52 inches, Dinhatta 4·55 inches, Meckhleganj 3·00 inches, Mathabhanga 3·04 inches; on the 20th Kurigram 3·28 inches, Nilphamari 3·11 inches, Cooch Bihar 3·38 inches, Meckhleganj 6·86 inches, Mathabhanga 4·12 inches; on the 21st Jalpaiguri, 5·12 inches, Kurigram 3·38 inches, Dinhatta 3·75 inches.

As a consequence the level of the Brahmaputra remained exceptionally high throughout August and September. The gauge reading remained at 30·40 feet over zero for three successive days, 21st to 23rd August and practically never fell below 25 feet.

In spite of the heavy rain in the north no flood appears to have occurred in the land lying to the south of the Teesta. The Teesta and its tributaries were evidently functioning well and succeeded in carrying off a large volume of water from the north. The central area also was free from floods showing that the flow of water from north to south over the Nagar and the Karatoya basins was even and smooth.

There is no evidence of any accumulation of water anywhere.

The new line from Sara to Parbatipur had been just constructed but the West-East lines had not yet come into existence. The waterways on the Sara-Parbatipur line had also been much more extensive at that time. It seems probable therefore that before the construction of the West-East lines the natural drainage of the tract between the Teesta and the Ganges had been sufficient to cope with even a large excess of rainfall in the north.

As will be gathered from the above analysis the flood in Rajshahi was almost entirely due to the high level in the river Ganges. Exceptionally heavy rain fell in July and August at Moradabad, Bareilly, Shahjahanpur, Naini Tal, Almora, Gorakhpur, Muttra, Etah, Farukhabad, Partabgarh, Chakrata, Mussoorie, Dehra Dun, Jalaun and Lalitpur, the excess in many cases being considerably over 100 per cent. (*Report on the Meteorology of India for 1879, pages 140, 144*). In August there was an excess at most stations in Bihar, and especially at Purneah; where, on three days, heavy falls were registered, *viz* : 5·83 inches on the 6th, 5·22 inches on the 18th and 4·79 inches on the 20th. Towards the end of the third week other stations also received heavy falls.

The level of the Ganges rose very considerably in the last week of August and the gauge reading became 31 feet at Mayapore and 28·50 at Benares on the 11th, 23·75 feet at Buxar on the 12th, 29·55 feet at Dinapur on the 13th, 21·62 feet at Monghyr on the 14th, 23·66 feet at Sahebgunge on the 16th, 21·66 feet at Rampore Boalia and 20 feet at Goalundo on the 17th. At Rampore Boalia and at Goalundo the level continued to rise steadily and remained over 23 feet and 20 feet respectively for a long time.

During the period 16th to 22nd August rainfall along the Ganges basin in Rajshahi was only in slight excess, actual percentages being Malda 12, Rampore Boalia 13, Natore 20 and Pabna 24. There were no exceptionally heavy falls.

The flood in Rajshahi was thus a typical river flood primarily caused by the heavy rainfall in U. P. and Bihar and the consequent rise of the Ganges level.

1885.

(Map Nos. 8/1885/1 & 9/1885/2.)

Extensive and very severe floods occurred in North Bengal in September.

The Amrita Bazar Patrika wrote on the 17th September :—

It appears that in many parts of Bengal the people have eaten up their last grain. What they had has been washed away by the great inundation which has flooded almost all the districts of the Province. Hundreds of villages have been totally destroyed, and men, women and cattle swept away by the torrent. Thousands of people in those places have been rendered homeless and are likely to die of starvation, if no material help is sent to them at once..... Rajshahi which is one of our best rice-producing divisions is already a vast sheet of water in many places.

The Malda District Gazetteer has the following :—

The towns of English Bazar and Nawabganj are protected by embankments. In 1885 owing to floods in the Ganges relief measures were necessary in parts of Kalichak, Sibganj and Nawabganj from September to November; 42,491 persons were relieved gratuitously at a cost of Rs. 11,579 and 6,954 persons were provided with work.

Rainfall Analysis.

In August rainfall in North Bengal was below normal over the greater part of the area. It was in slight or moderate excess in the south-west corner, *i.e.*, along the Ganges basin. The actual percentage figures are Chanchal 27, Gajol 40, Malda 56, Sibganj 75, Boalia 2, Manda 34, Nator 45 and Pabna 24.

There were however exceptionally heavy falls throughout August along the upper reaches of the Ganges. The percentage excess at certain stations are given below: Dehra Dun 142, Roorkee 124, Muzaffarnagar 125, Meerut 79, Bulandshahr 83, Aligarh 95, Moradabad 53, Bareilly 84, Budaun 138, Shahjahanpur 131, Muttra 82, Agra 86, Mainpuri 167, Furrukabad 241, Etwah 116, Etah 56, Cawnpore 50, Fatehpur 73, Banda 57, Haminpur 58, Lalitpur 81, Srinagar 48, Pithoragarh 132, Pilibhit 108, Rudarpur 53, Unao 63, Nawabganj 50, Sitapur 84, Kheri 94, Rai-Bareilly 76, Gaya 56, Buxar 90, Jamooee 76, Bhagalpur 85. In fact August was a very wet month in the greater part of North-Western India and Bihar, owing to a series of cyclonic depressions which traversed Northern India, or were formed in the Upper Provinces. Unusually heavy falls were recorded at Dehra Dun on the 2nd (10¾ inches), and also at Lalitpur (6½ inches), and Pilibhit on the 6th (7 inches); at Dehra Dun on the 8th and 9th (18½ inches); at Rudarpur on the 8th (7 inches) and at Bareilly (6½ inches): besides numerous instances of falls between 3 inches and 5 inches in 24 hours.

The level of the Ganges rose exceptionally high. The gauge-reading rose to 40·92 feet at Mirzapore and 38·07 feet on the 9th August, 32·70 feet at Dinapore on the 10th, 25·17 feet at Rampore Boalia and 20·33 feet at Goalundo on the 18th. At Rampore Bolia the level continued to rise until it attained a value of 27·08 feet on the 9th September after which it gradually subsided. The level of the Brahmaputra however appears to have been not far from normal, the Gauhati gauge fluctuated between 19·5′ and 24′ during the month of September, and was not abnormally high.

In September rainfall was above normal almost throughout North Bengal except in the extreme north-east. Heavy falls were on the 1st, Buxa 3·64 inches, Meckhleganj 6·58 inches; on the 2nd, Dinajpur 5·57 inches, Dinhatta 4·62 inches, Cooch Bihar 4·45 inches, Mathabhanga 3·94 inches; on the 3rd, Pabna 4·92 inches; on the 4th, Darjeeling 4·88 inches, Nilphamari 3·87 inches, Panchbibi 6·21 inches, Meckhleganj 3·25 inches; on the 5th Maldah 3·15 inches, Gajol 3·75 inches; on the 6th Sibganj 4·02 inches; on the 7th Nator 3·00 inches and Pabna 3·95 inches. After a short break again on the 12th, Rangpur 3·10 inches, Mathabhanga 3·21 inches; on the 13th, Jalpaiguri 5·68 inches and Kalimpong 3·00 inches; on the 15th Jalpaiguri 3·55 inches; on the 16th, Buxa 4·44 inches; on the 19th, Naogaon 7·75 inches. After another break on the 23rd, Gajol had 3·39 inches; numerous and very heavy falls occurred on the 24th, Churamon 3·84 inches, Raiganj 4·78 inches, Dinajpur 4·90 inches, Jalpaiguri 7·08 inches, Siliguri 6·43 inches, Darjeeling 9·66 inches, Kalimpong 6·96 inches, Nilphamari 3·24 inches, Gajol 4·01 inches, Cooch Bihar 7·15 inches, Mathabhanga 4·25 inches and Meckhleganj 9·45 inches. The excess was from 50 to over 100 per cent. above normal in the central and the south-eastern districts.

With the single exception of Meckhleganj rainfall was normal or in defect to the north of the Teesta. It was only in slight excess at Siliguri, Jalpaiguri,

Nilphamari, Rangpur and Gaibandha. Water from the north could not thus have been a contributary source. We see, therefore, that heavy local falls *in the flooded area* itself together with a very high level of the Ganges were mainly responsible for the present flood.

It is significant that on the 24th September, *The Amrita Bazar Patrika* noted :—

> Floods have now reached their culminating point. The water is subsiding in many places and it is hoped that within a fortnight it will retire wholly..... Rajshahi, Maldah and Dinajpur have..... seriously suffered by the floods.

This report must of course have been written before the 24th, the day on which very heavy falls occurred. Obviously it refers to a partial subsidence of the floods following the break in rainfall from the 17th to the 22nd. It brings out clearly the critical balancing between rainfall and river drainage in the flooded area.

The peculiar southerly dip of the rainfall line near Dinajpur showing comparatively heavy local rainfall in that region, and the consequent occurrence of a flood should also be carefully noted.

It should also be noted that in September a considerable excess of rainfall in the central area flowed away without causing a flood, probably owing to the good drainage offered by the Brahmaputra. The Sara-Sirajganj (1913-15), and the Santahar-Bogra (1893-96) lines were not then in existence.

1886.

(Map No. 10/1886/1.)

The Amrita Bazar Patrika—week ending 23rd September :—

Heavy rains and floods have all but destroyed both the *aus* and *aman* crops in large tracts in Berhampore, Nuddia, Bogra, Purnea and Maldah..... Houses of several lakhs of people have been washed away. These almost entirely belong to the agricultural classes.

The Bengal Administration Report :—

The flood in the Ganges at Rampur Bauleah was abnormally high during the year 1886, causing a breach near Kalitola, and necessitating the construction of a retired line of embankment at Nawabgange. The floods in the Jessore district were less severe than usual, but damage was nevertheless done to the Calcutta and Jessore road. The river Goomte, in the Tipperah district, overflowed its embankments and inundated the whole country, causing damage to the Chittagong Trunk Road near the Meghna. In the Dacca and Faridpur districts there were also high floods which submerged most of the villages in those parts and did much damage to the district roads and bridges.

The diversion road from Mattigurrah to Kurseong at the 5th mile was washed away by the heavy rain which fell during October; the unusually heavy rains of June, July, August and September caused serious landslips on the Hill Cart Road, Peshoke and Teesta Valley Roads, and damage was also done to the suspension-bridge over the Riang Jhora on the latter. A heavy slip also occurred on the Hill Cart Road at Tindariah, which blocked the main drain of that place and caused other mischief.

Rainfall Analysis.

Rainfall was very heavy on certain days in September. On the 7th, Raiganj had 5·41 inches, Buxa 3·36 inches; on the 8th, Nator 5·10 inches, Raiganj 6·48 inches, Gaibandha 3·35 inches, Kurigaon 3·15 inches, Ulipore 4·57 inches, Bogra 3·52 inches, Pabna 4·05 inches and Sirajganj 3·37 inches; on the 9th Darjeeling 4·16 inches, Gaibandha 3·85 inches, Rangpore 3·30 inches, Kurigaon 4·12 inches, Chanchal 4·02 inches, Dinhatta 3·54 inches, on the 10th, Dinajpur 4·53 inches, Balurghat 4·74 inches and Darjeeling 3·95 inches. The excess was over 200 per cent. at most places in the south, while rainfall was actually in defect at most places to the north of the Teesta.

Heavy falls again occurred towards the end of September. On the 23rd, Mahadevpur had 5·40 inches, Alipur Duars 4·48 inches, Gajol 4·23 inches, Cooch Bihar 3·82 inches, Meckhleganj 3·47 inches and Mathabhanga 3·97 inches; on the 24th, Naogaon 3·10 inches, Churamon 3·95 inches, Balurghat 6·25 inches. Darjeeling 3·16 inches and Panchbibi 3·37 inches; on the 25th Rangpur 3·87 inches, Nowkhilla 3·42 inches and Dinhatta 5·58 inches. The Teesta must have risen very high.

Ganges level above Rampore Boalia rose very high towards the end of August and the beginning of September, but fell rapidly towards the end of September. At Rampore Boalia and Goalundo it remained high, practically above 23′ and 20′ respectively almost throughout the month. The level of the Brahmaputra also was exceptionally high and the gauge reading at Gauhati registered above 25′ practically throughout August and September.

Heavy rainfall in the central area is likely to cause extensive floods in Maldah if the Ganges level is high, and in Bogra if the Brahmaputra level is high and in Pabna if either of the two river levels is high.

1890.

The Pabna District Gazetteer :—

There were heavy floods in the Sadar Subdivision in 1890. In the town of Pabna the southern portion of the Civil and Criminal Courts was flooded by the Ichamati, which had joined forces with the Padma, and many metalled and unmetalled roads were submerged and seriously damaged. Almost the whole of the town was more or less under water for nearly a month. After this an embankment with sluice gates was constructed along the right bank of the Ichamati to protect the town from further inundations.

Rainfall Analysis.

In July, rainfall at Pabna itself was below normal although heavy rain fell at Rampur Boalia and Sibganj higher up on the Ganges. Rainfall was also above normal to the north of Pabna but only to a slight extent. In August rainfall was below normal throughout the southern districts. From the 20th to the 31st August rainfall was above normal at many places but there was nothing very exceptional in the rainfall which can explain the Pabna flood.

Heavy rain, however, had fallen along the Ganges basin throughout July. A series of 5 depressions traversed Northern India during this month. They "either originated in the North-Western Provinces or drifted to that area and broke in excess over nearly the whole Provinces. The rainfall was, especially heavy in Kumaon and Rohilkand". Naini Tal had an excess of 34·90 inches (131 per cent.), Ranikhet 11·52 inches (85 per cent.), Rudarpur 24·31 inches (147 per cent.), Pilibhit 12·96 inches (74 per cent.), Bulandshahr 11·69 inches (137 per cent.), Gorakhpur 13·29 inches (98 per cent.), Sitapur 10·06 inches (86 per cent.), Saharanpur 12·25 inches (95 per cent.), Mussoorie 11·13 inches (35 per cent.), Dehra Dun 13·29 inches (51 per cent.). "The average rainfall of the whole Province during the month was 17·67 inches, which was 5·45 inches, or 45 per cent. in excess of the mean normal rainfall."

Bihar and Chota Nagpur received almost daily rain from the 6th to the end of the month. The rainfall was exceptionally large in Bihar, heavy downpours of 3 or 4 inches in 24 hours being of frequent occurrence. The total rainfall of the month was hence more or less largely above the normal, the excess ranging from 1·01 inches at Barh to 15·33 inches at Arrah. The centres of heaviest rainfall were Arrah 28·44 inches (116 per cent. in excess), Motihari 24·30 inches (106 per cent), Muzaffarpur 23·02 inches (102 per cent.), Bihar received an average excess of 7·73 inches or 65 per cent. above its normal amount.—(*Annual Report on the Meteorology of India, 1890, page 225*).

In August rainfall was below normal in North-Western Provinces, but was in moderate excess in Bihar, heaviest rainfall occurring in the districts of Gaya 20·95 inches (91 per cent. in excess), Patna 17·38 inches (68 per cent.) and Buxar 16·59 inches (60 per cent.).

The level of the Ganges must have risen abnormally high which probably led to an overflow of the Ichamati. At Rampur Boalia the gauge registered 25·08 feet on the 5th August and remained above that figure, throughout the month attaining an almost record value of 26·21′ on the 26th. At Goalundo also the gauge reading was above 21 feet throughout the month, the highest value being 22·33′ on three successive days 7th to 9th August. The gauge reading at Gauhati reached 27·20′ on the 5th and became still higher towards the end of the month. The slight or moderate excess in the central and southern districts aggravated the situation to some extent. It is significant however that "the rainfall of the month (July) in Assam was in slight defect in the western districts of the Brahmaputra valley". Rainfall in the northern districts (south of Teesta) was also in defect. Water from the north could not therefore have been a complicating source. We conclude that the Pabna flood was a local one and was mainly a river, or more particularly, a Ganges flood.

Floods also occurred in the Dooars and Darjeeling Districts. *The Englishman* says :—

August 1: Floods in Dooars—Dooars July 28.—..... Since the 1st of June there have been 50 rainy days, 12 under 1 inch, 12 over 1 and under 2, 8 over 2 and under 3, 8 over 3 and under 4, 5 over 4 and under 5, 3 over 5 and under 6, 1 over 6 and under 7 and 1 over 7 leaving 7 days without rain and we have had over 3 inches to-day. Roads of

course do not exist now..... Rivers are almost impassable, even the smallest ones that are generally fordable at all times. The Teesta at one time was so high that the ferry-man refused to cross people. In fact we have had a cold wet time of it.....

In portions of the Duars and Cooch-Bihar rainfall was from 30 per cent. to 50 per cent. above normal in July, and from 80 per cent. to 100 per cent. above normal in August.

August 11: Floods in the Darjeeling District—..... This will be opening the line for traffic between Gyabaree and Siliguri. The Goomte section has been almost abandoned as little or nothing can be done in the present unsettled state of the Puglajhorah. The whole of the road between the 23rd and 24th miles show signs of disappearing and in some places the rails and sleepers are left high and dry. It is estimated that 5,00,000 cubic yards of the road have been washed away at the 23rd mile and 3,00,000 cubic yards at the 27th mile. Both of these places are the crossings of the Puglajhorah, and it is said that it will be a matter of many months' work to restore the road to its original state.....

1892.

(Map Nos. 11/1892/1 & 12/1892/2.)

Extensive and severe floods occurred over a very large area in North Bengal in July.

The Englishman—

July 12.—Owing to a rise in the river Dharla the railway between Kurigram and Dharla has been breached in two or three places and arrangements have had to be made for the Assam Mail Steamer to connect with the Eastern Bengal State Railway at Kurigram instead of at Dharla. On the Magalghat branch traffic has been interrupted by the sinking of a bridge but arrangements have been made to tranship passengers and mails.

The Behar section of the Eastern Bengal State Railway between Parbatipur and Raiganj has suffered somewhat severely during the last two days from floods due to heavy rainfall in the districts north of the line. On Saturday afternoon the river of the flood water to the north of the line was rising rapidly and in one place between Dinajpur and Chirirbander the water was 3 inches above rail level. The first breach in the line occurred on Saturday night at a bridge to the east of and near Dinajpur, one pier and one abutment of which was washed away, together with a portion of the bank besides the abutment. On Sunday morning two more bridges failed between Dinajpur and Chirirbander and one between Dinajpur and Birol. A fifth bridge failed on Monday morning between Chirirbander and Parbatipur. Traffic has been temporarily suspended between Parbatipur and Raiganj.

July 15.—Reports from the Western Duars state that a very wet season has now culminated in a fall of 50 inches of rain between the 29th of June and 12th of July. The rivers are in high flood and bridges have been carried away and roads breached all over the district. At one place about a score of tea laden carts were caught in a river bed by the descending flood and swept away, 12 of the carmen being drowned. The low lying tea gardens and rice fields are in a more or less swampy condition. The ryots of the Jalpaiguri district have had trying times of late. Last year the crops failed for want of moisture, and now they are being ruined by the excess. At the moment the most serious feature is the cutting off of supplies for the inland bazar which feeds a population of tea garden coolies estimated at 1,000,000 souls. Last week rice was selling at the Dam Dim Bazar at the famine rate of from 5 to 6 seers per rupee. It is to be hoped that the weather may soon moderate and the re-opening of communications be rendered possible.

July 19.—The floods in North Bengal..... By means of a ballast engine I proceeded to the scene of the disaster and found that 34 miles of permanent way had been inundated and where the water had subsided 14 breaches were experienced between Chirirbander and Birol. At the 84 miles of the Behar Section I noticed a 80-feet breach with the west abutment scoured out and the girders on that side sunk about 9 inches. At 114 miles in the breach there was nearly the same condition. There were 14 breaches and the telegraphic wires and posts were lying all over the banks at an angle of 45 degrees ..... Through traffic has been entirely stopped since the 11th instant. The inhabitants have been washed away and a large number of cattle drowned. The people had to take refuge on the turnpike road. The country from Jatrapur to Raiganj has been washed out and the people are homeless. The line is also flooded from the 70th mile to Birol for a distance of 62 miles... ..... Between Barsoe and Kissengunge there are 19 breaches and a number of telegraphic posts are down. The greatest damage is between Barsoe and Sadani, a distance of seven miles, and between the thirteenth and sixteenth miles at Dilkula on the Barsoe and Kissengunge extension. The floods are at present subsided but there are anticipations of a re-occurrence early next month. The crops have not suffered.

Two ballast trains are blocked at Chirirbander and a passenger train at Raiganj.

July 20: The Floods in North Bengal—Breaks in the Parbatipur and Kurigram Section.—It appears that the mischief began on the line on the 7th instant when the heavy rains which had previously fallen flooded the Teesta, Mahanadi, Dharla and Atrai besides which other streamlets rising in the same part of the hills added to the catastrophe. On the 7th instant the Atrai washed out the 20 ft. of the bank besides the abutment of a bridge about 6 miles from Siliguri but by Saturday this breach had been repaired. On the 18th instant the floods had reached the line between Parbatipur and Dinajpur, washed away 4 culverts and breached the line in 4 different places that is between Parbatipur and Dinajpur. A deep hole was scoured below the bridge at the 8th mile at Parbatipur but it is hoped that the bridge will be saved by filling up the hole with boulders and stones from the hills around Sahibganj..... Between Kurigram and Dhurla two serious breaches, one of 120 feet and one of 150 feet, have occurred.

July 21: The Floods in Bengal.—In the Kurigram and Dhurla section the Teesta shows unmistakable signs of another considerable rise though the water is not at present as high as it has been but gives every promise of beating the record should it continue as at present. The present record is within 6 inches of the Kaunia Bank and this is considered phenomenal even by the oldest of inhabitants.

The Hindu Patriot—

July 28.—In the Rangpur district the flood seems to have been unprecedented for those parts. The river Dharla rose in high flood on the evening of the 9th with the result that the greater portion of the town of Kurigram, the kutchery compound, the jail and the subdivisional officer's residence were standing about 2 feet in water. Inside the jail there is stated to have been 3½ feet of water. Several breaches occurred on the line and many of the bridges below Kurigram were rendered unsafe. The

people were in great distress and in some cases relief had to be sent to them in the shape of boats to help them to get off in safety from the submerged tracts.

The Statesman—

July 14.—A correspondent writes to us under yesterday's date: Letters received yesterday and to-day from Dinajpur would send a thrill through the heart of everyone. You have been recently informed by the Manager, Eastern Bengal State Railway, that the train service between Raiganj and Parbatipur (in the district of Dinajpur) has been temporarily suspended owing to heavy floods in that district. But you do not know what amount of damage the recent flood has done to the residents of the town of Dinajpur. The whole old town was under water for 24 hours. Water began to rise on the evening of Saturday last at the tremendous rate of 1½ feet per hour. By midnight the town was submerged. The next morning it looked like one vast sheet of water, the top of houses and trees only relieving the monotony. The quarter of the town known as Kalitola, Marwari-bazar and Balubari suffered most from the overflow. The town of Dinajpur is composed mainly of mud-built, *kutcha* houses. Most of these houses gave way and many people have been rendered homeless. Some have taken shelter under the roofs of kindly neighbours and some in the spacious building of the town police-station. Except two infants and some cows no loss of life is reported. The loss of money is estimated at a lakh of rupees. Fortunately the water began to subside at 7 P.M., on Sunday. It is certain that such a flood is unprecedented in the history of that town. In 1841 the town was once flooded but the water began to subside after an hour and a half. The cause of the recent flood is that the Teesta has flooded its banks. The Atrai is a branch of this river and the Purnabhawa is a branch of the Atrai. Purnabhawa flows down the town of Dinajpur and the Atrai some 5 miles to the east of it. Mails from and to Dinajpur are now carried in boats and by runners. It is rumoured that through railway connection cannot be restored under a month.

July 19.—The report that 5 bridges on the Eastern Bengal State Railway had been washed away turns out to have been exaggerated. Beyond Parbatipur 34 miles of permanent way have been inundated and where the water has subsided 14 breaches are to be observed between Chirirbander and Berole. At the 8¼ miles of the Behar section a 80-feet bridge has had its west abutment scoured out and the girders on that side have been sunk about 9". At 11¼ miles another bridge is in nearly the same condition. Through traffic has been entirely stopped since the 11th instant, the inhabitants have been washed out and a large number of cattle drowned. The people had to take refuge on the turnpike road. The country from Jatrapur to Raiganj has been washed out and the people are homeless. The line is also flooded from the 7th mile to Berole for a distance of 62 miles. At present the rivers have fallen and a vista of mud meets the eye showing very clearly how high the waters must have risen. The Teesta has receded about 9 inches since the 12th instant, but another rise is expected very shortly. Between Barsoe and Kissengunge there are 19 breaches and a number of telegraph posts are down. The greatest damage is between Barsoe and Sadani, a distance of 7 miles, and between the 13th and 16th miles at Dalkala on the Barsoe and Kissengunge extension. The floods are at present subsiding but there are anticipations of a recurrence early next month. The crops have not suffered. Two ballast trains are blocked at Chirirbander and a passenger train at Raiganj.

The Hindu Patriot—

July 28.—In Dinajpur the first intimation of a flood was the overflowing of a small stream Gogra, on the afternoon of the 9th instant. The greater part of the town became submerged and matters gradually got worse as night advanced. The people seem to have been in a great state of panic and tried to cut the main road across but this was put a stop to by the Collector. At 2 A.M., the District Engineer found that the cause of mischief was the overflowing of the Atrai river. The water had risen to within a few feet of the bund but as the water of the Punarvaba was two feet lower, the Collector ordered the bund to be cut in order to direct the waters of the Atrai into a different channel. This is stated to have practically saved the town for the consequence would have been terrible if the flood had once topped the bund. The railway on either sides of Dinajpur was breached and a good deal of destruction to property is reported not so much among the poorer as the middle classes.

The District Gazetteer, Dinajpur—

Floods.—As to floods—though small local ones, caused by the rivers overflowing their banks, are of almost annual occurrence and do more or less damage to crops in particular localities—the only really serious one of which any account has been preserved was that of the 9th July 1892. This appears to have been an inundation from the Atrai which by way of the Gabura and Ghagra streams swept down on the town of Dinajpur from the north-east and washed large numbers of the inhabitants of the northern and eastern quarters out of their houses. At one time it seemed likely that the whole of the central portion of the town might be destroyed, but the timely cutting of the Darjeeling road let the water off and relieved the pressure. A dangerous feature of this flood was that it made its first appearance in the evening, and darkness which ensued added greatly to its terrors. By the exertions of the local officials the people of the quarters most affected were got out of their houses without loss of life and collected in places of safety. Money was distributed to them for their maintenance and to assist them in the rebuilding of their houses. It would seem that the Punarbhaba also was in flood in this occasion, though not to the same extent as the Atrai, as we learn that the water level in the former was two feet lower than the level of the flood from the north-east. Any way, the railway line was breached on both sides of the town. On the east the mails had to be transported for some distance by boat while on the west they were carried over the breach, which was apparently of small extent compared with the other, by means of an elephant borrowed

from the Maharaja. An enquiry into the cause of this disastrous flood led to the conclusion that the railway line, which bisects the district from east to west, was in large measure responsible for the damage done, by holding up the flood water coming from the north. To obviate this, the water-way was greatly increased with, it would seem, satisfactory results, as no flood worthy of the name has occurred since.

The Administration Report (page 426)—

Mishaps on account of floods appear to have been confined to the Darjeeling district during the rainy season of 1892. On the Tista Valley Road traffic was stopped for 22 days, owing to the scouring away of the timber bridge over the Galijhora. A temporary structure of 80 feet span was, however, constructed during that interval to replace the bridge thus destroyed; heavy slips also occurred in several of the miles. On the road from the Tista bridge to Rishi the heavy rains of the 12th July 1892 caused serious damage, a 60-feet timber bridge and three of 30-feet being carried away and traffic interrupted for some time. The damage from floods on the road from Rikisum junction to Jungirguard was slight, but on that from Darjeeling to Tista *viâ* the Runjeet there were heavy slips and the road sunk badly in the 14th mile. The approach road to the Runjeet bridge was cut away entirely, but has been renewed. Serious slips occurred on the road from Jore Bungalow to Tista *viâ* Peshoke, and cart traffic was stopped for a while.

Considerable damage was done to the Terai roads by the extraordinary heavy rainfall between the 2nd and 7th July 1892; one span of the Champta bridge on the road from Mattigurah to the Hill Cart Road was destroyed by floods, the wingwalls of bridge No. 15 on the road from Mattigurah to Kurseong were scoured away, while the road from Mattigurah to Naxalbari suffered most severely, several sections of the bank being breached, but the damage to culverts and bridges was slight. A 20-feet masonry culvert on the Ganges and Darjeeling road was badly damaged. Compared with previous years, however, the Darjeeling Hill Cart Road suffered very slightly. A small settlement occurred at the Lower Paglajhora, and the railway line was blocked for a short time on the 24th May, owing to the wall of bridge No. 61 having yielded: the bridge at Rungtong also gave way on the 20th June and on the 17th July a heavy rock came down at the 41st mile, causing a temporary block on the line. Some slips took place on the Lebong road in the first section, one occurred at the back of the Convent, which blocked the road and caused some damage, but the slips were cleared and a revetment wall was subsequently built: in the second section a slip occurred at "Bachelor's Cot", belonging to the Kuch Bihar Raj estate, and necessitated the building of a revetment wall to avert any possible danger to the house; a portion of the Birch Hill Park Road also slipped down. Along the third section several slips occurred, which required the hillside to be cut back in order to obtain the full width of road again: the damage done represents a total value of about Rs 8,000.

The following extract is taken from the weekly reports of the Tagore Estate in Rajshahi.

5th to 28th July: Rain fell practically every day and the flood water rose steadily.

Rainfall Analysis.

Exceptionally heavy rain fell throughout North Bengal during the first week of July. Chief amounts were Churamon 7·63 inches, Raiganj 7·64 inches, Balurghat 4·80 inches, Siliguri 3·73 inches, Kurigaon 4·54 inches, Nilphamari 3·45 inches, Panchbibi 5·05 inches, Chanchal 3·80 inches, Gazol 4·33 inches on the 1st; Kurigaon 5·63 inches, Ulipur 4·87 inches on the 2nd; Jalpaiguri 3·75 inches, Alipore Duars 3·20 inches, and Mathabhanga 6·32 inches on the 3rd; Alipore Duars 3·52 inches, Falakata 4·15 inches, Nagarkata 3·93 inches, Buxa 11·27 inches, Kurseong 5·50 inches and Nowkhila 3·15 inches on the 4th; Raiganj 3·12 inches, Falakata 3·35 inches, Buxa 7·19 inches, Nilphamari 8·48 inches, Meckleganj 4·79 inches and Mathabhanga 6·87 inches on the 5th; Churaman 6·44 inches, Raiganj 3·73 inches, Dinajpore 3·10 inches, Jalpaiguri 5·22 inches, Alipore Duars 8·17 inches, Falakata 3·18 inches, Buxa 7·24 inches, Rangpur 3·22 inches, Nilphamari 5·25 inches, Chanchal 3·63 inches, Dinhatta 4·16 inches, Cooch Behar 4·87 inches and Mathabhanga 5·40 inches on the 6th; Balurghat 3·45 inches, Jalpaiguri 7·28 inches, Alipore Duars 8·72 inches, Falakata 7·25 inches, Nagrakata 10·73 inches, Buxa 12·15 inches, Siliguri 10·73 inches, Nilphamari 5·80 inches, Dinhatta 3·52 inches, Cooch Behar 8·83 inches, Meckliganj 4·87 inches and Mathabhanga 4·25 inches on the 7th.

The actual excess during these days was more than 200 per cent. over a large area (*Map No. 12/1892/2*).

The most important fact which emerges from a study of this flood is that, in Dinajpur and Rangpur it was much aggravated by the holding up of the flood water by the Raiganj-Parbatipur-Kurigram line. Water from the hill swelled the rivers and serious overflows occurred from the Mahananda above Kissenganj, from the Atrai below Siliguri and near Dinajpur and Chirirbander and from the Dharla below Magalghat and near Kurigram.

Excess rainfall diminished towards the south *i.e.*, along the natural drainage of the country. It appears probable

that if the flood water could spread freely towards the south the severity of the flood would have been considerably less.

It will be noticed that rainfall from 1st to 8th July to the south of the railway line was also in large excess. The percentage excess was Churamon 269, Chanchal 227, Gajol 124, Balurghat 119, Ulipur 163, Nowkhila 109, Malda 66, Panchbibi 52, Gaibandha 23, Sherpur 53, Nator 40, Sirajganj 18 and Pabna 65. The water here apparently flowed away without causing any floods. This was due to the level of the Ganges remaining more or less normal as will be seen from the analysis of the gauge-readings given below.

The gauge reading at Rampur Boalia did not exceed 5·08′ in June. Up to the middle of July gauge-readings at Mirzapore, Benares, Buxar were low and did not exceed 6 or 7 feet, Sahebgunge and Rampur Boalia showed a steady increase from the 10th July but the gauge readings did not reach 20 feet before the last week of July. This rise must of course have been due to the flowing away of the excess rainfall. The Goalundo gauge-reading was however high throughout the month, rising steadily from 16·17 feet on the 1st July to 20·08 feet on the 31st. The comparatively high level at Goalundo was due to the great volume of water coming from the Brahmaputra. The gauge at Gauhati registered over 22 feet throughout the month, the maximum 26·50 feet occurring on the 13th.

Rainfall in the Brahmaputra valley (+0·54/15·64 = +3 per cent.), in North Bihar (+2·07/12·18 = +16 per cent.), North-Western Provinces, East (+2·38/11·84 = +20 per cent.), North-Western Provinces, Central (+0·44/11·52 = +4 per cent:), North-Western Provinces, West (+0·25/9·92 = +3 per cent.), North-Western Provinces Sub-Montane (−2·11/14·63 = −15 per cent.), South Oudh (+1·43/10·75 = +13 per cent.) and North Oudh (+0·82/11·69 = +7 per cent.) was generally only in slight excess. Both the Brahmaputra and the Ganges could thus carry away the greater part of the flood water. This explains the comparatively rapid draining away of the water in the tract below the railway line.

It is also significant that water from above Gajol, Balurghat and Panchbibi did not produce a flood in the southern districts.

We again see that both to the north of the railway line as well as to its south the main problem is one of allowing the water to drain away quickly to the south and to the east. To the north of the railway line water was held up by the railway line and caused a severe flood; to the south water could flow away owing to the normal condition of the Ganges and did not do any harm.

A flood also occurred in Serajganj towards the end of July. *The Statesman* reported on the 21st July (Serajganj)—

> There has been a very high flood this year and only a foot and a half lower than the highest known flood of 1890. There was a very good harvest both in *dhan* and jute but the fields are under water and cultivators are in great distress. . . .

The Serajgunge flood, as will be easily gathered from the analysis of rainfall and gauge-readings given above, occurred just after the level in the Brahmaputra became highest and was clearly due to an overflow of that river.

1898.

Moderate floods occurred in September in several parts of North Bengal in the Dooars area. The following extract is taken from *The Amrita Bazar Patrika of September 25:—*

Darjeeling.—Many brick-built houses which were in a somewhat damaged condition after the earthquake of 1897 have collapsed in consequence of the rainfall. Many parts of the interior are fearfully overflooded. Numberless people in the deora tracts of the district are living on *machans* erected in their houses where flood waters have entered. Unless these waters recede at an early date the prospect of *Kalai* crop is almost nil. The *Bhadoi* and winter paddies have at places been damaged by inundation. The outturn of winter paddy is still expected to be a favourable one.

The Bengal Administration Report also notes:—

The rainfall in the Darjeeling district was some 8 inches in excess of normal, and much damage occurred on the hill roads in consequence, traffic on the Tista Valley road being interrupted for seven days.

Rainfall Analysis.

Rainfall was generally heavy throughout September. From the 1st to 11th September, rainfall in the districts of Jalpaiguri, Rangpur and Cooch Behar, was over 100 per cent. in excess. From the 12th to 22nd comparatively heavier falls occurred in the south, the excess being greater than 200 per cent. over a considerable area. Taking the whole period 1st to 22nd into consideration, there was an excess of more than 100 per cent. over the greater part of North Bengal, the excess at Darjeeling being about 200 per cent. The average excess for North Bengal for the whole month of September was 57 per cent. Exceptionally heavy falls were on the 16th September, Mathabhanga 13·10 inches, Falakata 10·65 inches and Siliguri 8·15 inches.

Apart from the moderate local floods in the Dooars noticed above apparently no floods of importance occurred in other parts of North Bengal, in spite of the large excess of rainfall. There were exceptionally heavy falls in both North Bihar (average excess 164 per cent.) and South Behar (average excess 112 per cent.) and also in the eastern submontane portion of the North-Western Provinces (old style, now the United Provinces). Rainfall in the rest of the Gangetic valley was generally in defect. This probably kept the river level below Malda and Rajshahi normal or lower than usual and did not interfere with the draining capacity of the Ganges. The rainfall in the Brahmaputra valley was in slight defect, so that the level of the Brahmaputra was also probably normal or lower than usual.

We see that in spite of heavy rainfall serious floods did not occur in North Bengal owing to the quick draining away of the water rendered possible by a low level in both the Ganges and the Brahmaputra.

1899.

(Map Nos. 12/1/1899/1 & 12/2/1899/2.)

Very severe and destructive landslips occurred in the Darjeeling district in September; but no flood of importance appears to have occurred in the plains.

In September, rainfall in Assam hills and the Brahmaputra valley was only 11 per cent. above normal. The level of the Brahmaputra was thus probably more or less normal. The rainfall in the submontane districts of North-Western Provinces and in the Punjab was, however, in very large defect; the variation being from 70 per cent. to 100 per cent. below normal. Rainfall in North Bihar was about 16 per cent. above normal but taking into account the heavy defect in North-Western Provinces and the Punjab it seems fairly certain that the draining power of the Ganges was not seriously impaired. If anything, the river level was probably lower than the average.

In the first week of September North Bengal received daily moderate rain but there were no particularly heavy falls. From the 13th to the 18th heavy general rainfall (connected with a cyclonic storm which travelled north-westwards through the Central Provinces and North-Western Provinces as far as Cawnpore and recurved to the east) occurred in Bihar and North Bengal. Chief amounts were on the 13th, Falakata 7·05 inches, Alipore Duars 5·22 inches; on the 14th, in Bihar—Kissenganj 11·64 inches, Farvesganj 3·30 inches, and in North Bengal—Thakurgaon 4;25 inches; on the 15th in Bihar, Gopalganj 5·31 inches, Rosera 5·26 inches, Amnaur 5·15 inches, Motihari 4·48 inches, and in North Bengal Deviganj 5·78 inches, Fulbari 4·50 inches, Baghdogra 4·20 inches; on the 16th Sunderganj 8·06 inches, Ramganj 6·17 inches, Dinajpur 4·75 inches, Ulipore 4·38 inches, Rangpur 4·31 inches; on the 17th Churamon 9·93 inches, Dinajpore 7·85 inches, Baghdogra 7·65 inches, Chanchal 7·52 inches, Dinhata 6·44 inches, Gazol 3·56 inches and on the 18th Cooch Behar 5·15 inches.

The percentage departure for this period was greater than 100 per cent. over a very large tract in the north and was greater than 50 per cent. over the whole of the central area. Rainfall however was normal or in defect in the south along the Ganges.

On the 24th and 25th exceptionally heavy rains occurred which were entirely controlled by a cyclonic storm which crossed the coast near Saugor Island and passed northwards to the Sikkim Himalayas. There were numerous falls exceeding 6 inches on 24th September in Santal Parganas and the Bhagalpur district in Bihar. Chief amounts being in the Santal Parganas Mohagama 15·61 inches, Barkope 12·35 inches, Goodda 10·12 inches, Bhagya 8·50 inches, Barharwa 8·40 inches, Pakaur 7·75 inches and in Bhagalpore Banka 11·81 inches, Bansil 9·07 inches and Bhagalpore 7·53 inches. In North Bengal on the 24th Sibganj had 7·30 inches, Darjeeling 5·30 inches, Kalimpong 4·80 inches, Kurseong 4·67 inches, Pedong 4·42 inches and Mongpoo 3·25 inches. On the 25th Darjeeling had 19·40 inches, Kurseong 15·18 inches, Mongpoo 12·96 inches, Kalimpong 9·16 inches, Siliguri 3·98 inches, and in Bihar Farvesganj 10·60 inches, Ararea 8·00 inches, Supaul 7·98 inches and Chaupreon 7·51 inches. The rainfall in the Himalayas began on the 23rd and continued during the 24th and early morning of the 25th on which date the storm however disappeared. The rainfall abruptly ceased and fine weather prevailed throughout the province.

Disastrous landslips occurred at many places "causing considerable loss of life and doing unprecedented damage to roads, bridges and buildings, both within the town itself and in the neighbourhood and the Darjeeling district, while some lesser injury resulted to the roads in the Jalpaiguri district and in Monghyr. Communication with Sikkim was practically cut off by the damage to, and destruction of, important bridges. The cost of the necessary repairs and protective works due to the fury of the cyclone has been estimated at a total of sixteen to eighteen lakhs of rupees".—(*B. A. Report*, page 208).

The District Gazetteer of Darjeeling (p. 105) notes:—

Up to the 24th the monsoon rainfall had been some 17 inches in excess of the average and although there had been a partial cessation during the previous week, there was no break in the rains sufficient to permit of any appreciable drying of the soil before the unprecedented fall of the 24th and 25th.

The heaviest excess amounting to from 800 per cent. to 1,500 per cent. above normal occurred in the neighbourhood of Darjeeling. The excess was more than 300 per cent. in the area to the north of the Kaunia-Kurigram line and more than 100 per cent. over a large tract in the west, but was more or less normal over the whole of the south-eastern area.

We have already seen that the level of the Brahmaputra was about normal and that of the Ganges probably considerably lower than the average. The great volume of water falling down in the Darjeeling district, although causing unprecedented local damage, evidently found its way out through the Tista and the Brahmaputra without giving rise to floods in the plains. The heavy precipitation in North Bihar was also drained away fairly quickly by the Ganges. We thus see that provided there is no impedence in the river drainage even unprecedented falls in the Bengal hills will not necessarily cause floods in the plains.

The departure percentage for the month as a whole shows the same thing. Inspite of the considerable excess of rainfall over the greater portion of the northern district there was no flood in the low-lying lands to the south. Presumably the excess water was all drained off through the ordinary river channels. There is no evidence of an onrush of water from the north flooding the low-lying southern districts.

1902.

(Map Nos. 12/3/1902/1 & 12/4/1902/2.)

AUGUST.—In the middle of August a slight flood was reported in Cooch Behar. *The Amrita Bazar Patrika* wrote on—

August 18.—The Cooch Behar Narrow Gauge State Railway is reported to have been badly damaged by floods and rendered not very safe for traffic but all the necessary steps and precautions are being taken to restore the line for safe working.

A slight flood was also reportd from Rangpur. (*The Amrita Bazar Patrika*, August 21.)

Rainfall Analysis.

Chief falls were on the 8th August Buxa 7·97 inches, Mathabhanga 4·05 inches; on the 9th Kalchini 5·56 inches; on the 10th Buxa 9·09 inches, Mekliganj 5·50 inches, Kalchini 5·47 inches, Alipore Duars 5·39 inches, Govindaganj 5·05 inches, Kurigaon 4·93 inches and Ulipur 4·48 inches; on the 11th Kurseong 13·25 inches, Fulbari 9·57 inches, Mongpoo 9·06 inches, Siliguri 9·00 inches, Alipore Duars 8·65 inches, Darjeeling 7·91 inches, Mathabhanga 7·42 inches, Cooch Behar 6·92 inches, Bogra 5·14 inches, Jalpaiguri 5·00 inches, Meckliganj 4·86 inches, Nagrakata 4·48 inches and Dinhata 4·48 inches; on the 12th Ulipur 5·30 inches, Mongpoo 4·90 inches; on the 14th Buxa 4·20 inches; on the 15th Dinhata 5·09 inches, Cooch Behar 4·75 inches and on the 17th Buxa 9·24 inches Meckliganj 7·50 inches, Falakata 7·05 inches and Fulbari 4·43 inches. The rainfall from the 8th to the 19th August was over 100 per cent. in excess in a large tract to the north of the Tista and also on a small strip on the right bank extending down to Rangpur. Rainfall in the Brahmaputra districts of Assam was about 22 per cent. in excess and in the Assam hills about 11 per cent. above normal. The level of the Brahmaputra was thus probably slightly or moderately higher than usual. The heaviest falls in the Darjeeling hills and in the Jalpaiguri and Cooch Behar districts poured in an exceptionally large volume of water into the Tista which probably overflowed and caused the floods on its either banks.

It should be noted that rainfall in the central area was also exceptionally heavy. The excess departures were: Balurghat 268, Panchbibi 103, Naogaon 116, Bogra 191 and Nowkhilla 158.

Exceptionally heavy falls were on the 10th Bogra 7·30 inches, Nowkhilla 3·50 inches; on the 11th Manda 5·11 inches, Bogra 5·14 inches, Nowkhilla 4·10 inches, Balurghat 3·17 inches, and on the 12th Balurghat 4·52 inches and Nowkhilla 3·42 inches.

No flood either in the central or in the south-eastern districts is however reported. The comparatively smaller rainfall in the south and a low level of the Ganges was probably sufficient to allow all the water to escape without doing any damage. We again notice that exceptionally heavy falls in the north do not appear to constitute a source of danger to the south.

SEPTEMBER.—More severe floods were reported in the Jalpaiguri district in the month of September.

The District Gazetteer (*Jalpaiguri*) gives a very full account :—

The river began to rise rapidly at about 3-30 P.M., on September 27th and continued to rise steadily till 5-30 P.M. on the 28th when it reached a height of eighteen inches above the highest flood level of the preceding ten years; during these fourteen hours its rise was six feet. It remained at its maximum height for about half an hour and then began to fall as rapidly as it had risen; by 6-30 P.M. on the 28th it had fallen to the height of an ordinary flood.

* * * * * *

On the west of the Tista the river began to overtop its banks at Rangdhamali about 9 miles above Jalpaiguri and spread over the country as far as the river Karla; in this area the rise was gradual as the water had plenty of room to spread. Below Jalpaiguri the Eastern Bengal State Railway runs for a considerable distance parallel to the Tista and at not a great distance from it. The Railway embankment, which has in this section few bridges and culverts, checked the free spread of the flood water, which made a wide breach in it and flowed away with considerable violence over the rice-fields until it reached the Ghoramara river. Between this breach and the Mandalghat railway station there were several other breaches, and a bridge was washed away.

On the east bank the condition of the country is somewhat similar; the river flooded the country below Gazalduba, but the water encountered no check until as far south as the Domohani station on the Bengal-Duars Railway. From this point the railway embankment runs at a distance of not more than half a mile from the river, and the water, making

a large breach 200 feet wide south of Domohani station rushed down an old *khal* in the direction of Mainaguri. The flood water cut the railway again near the Bhotepati station and rejoined the Tista. The country between the railway line and the river was flooded for several miles south of Jalpaiguri.

Damage done by the floods.—Loss of life was not heavy and was confined to places where the rise of the water was rapid. Three herdsmen, who were grazing buffaloes on a large *chur*, were not able to reach the high bank in time and were drowned; at Barnes Ghat three women and two children, members of a sweeper family living in a hut on the extreme edge of the river, were swept away and drowned. The total number of lives lost was only ten. Comparatively little damage was done to the crops; the winter rice benefitted by the silt deposited by the flood; the standing jute was unharmed, but much of the jute which was being steeped was washed away and lost. The loss of cattle was serious, but it is difficult to form an accurate estimate of it; 200 dead cattle and 10 buffaloes were counted along the banks of the river and the Deputy Commissioner put the total loss at 350 head of cattle and 20 buffaloes. The villages on both sides of the river were full of stray cattle which had been carried down by the floods and it took a long time before they were all claimed and restored to their owners. There was a large herd of nearly 500 buffaloes on the Nathua Khal when it was submerged in the flood and no less than 79 of them were rescued at the Mandalghat village 15 miles down stream; nearly all the buffaloes got ashore at one village or another.

The damage done to the railways has been already mentioned. The big breach on the Eastern Bengal State Railway took over ten days to repair and 3rd class passengers were sent round by Lalmanir Hat and the Bengal-Duars Railway. A bridge was carried away on the Jalpaiguri road and another on the Jalpaiguri-Alipur Road, but otherwise the roads received comparatively little damage.

Rainfall Analysis.

In the Brahmaputra division of Assam rainfall was nearly 50 per cent. above the average while the rainfall in the Assam hills was more or less normal. Rainfall in all the districts of North Bengal was considerably above normal, the excess being 138 per cent. in the Darjeeling district, 91 per cent. in the Jalpaiguri district and 82 per cent. in the Cooch Behar district. Moderate or heavy rain continued almost throughout the month. In the last week of September chief falls were on the 20th Siliguri 5·90 inches, Alipore Duars 5·40 inches; on the 21st Thakurgaon 7·64 inches, Siliguri 6·92 inches, Cooch Behar 5·85 inches; on the 26th Kalchini 5·74 inches, Darjeeling 4·96 inches and on the 27th Mongpoo 14·87 inches, Darjeeling 12·20 inches, Kalimpong 11·68 inches, Kurseong 11·45 inches, Pedong 7·97 inches, Cooch Behar 7·77 inches, Nagrakata 7·12 inches, Mecklignanj 6·90 inches, Fulbari 6·60 inches, Atwari 6·42 inches, Jalpaiguri 6·27 inches, Buxa 5·88 inches, Kurigaon 5·40 inches, Siliguri 5·56 inches, Mathabhanga 5·35 inches, Dinhata 5·03 inches and numerous other falls of 4 and 3 inches.

The District Gazetteer clearly points out :—

> The flood in 1902 was confined to the basin of the Tista river and was caused by general and extremely heavy rain in the Darjeeling hills on the 27th September. Darjeeling itself reported a rainfall of 12 inches for the 24 hours and the downpour was even heavier in other places in the hills. The rainfall at Jalpaiguri during the month of August was above the average and in September more than twice the normal amount of rain fell; the Tista was in consequence very full when a further volume of water was poured into it.

It is important to observe that rainfall was in considerable excess at several places in the central area: Rangpur 107 per cent., Dinajpur 75 per cent. and Panchbibi 118 per cent. Rainfall in the United Provinces and in North Bihar was also in moderate excess, so that the level of the Ganges was probably higher than usual. This, of course, meant diminished drainage from the southern districts. On the 26th, 27th and 28th rainfall was fairly heavy in Bogra, Pabna, Rajshahi and Malda. Yet no flood of importance appears to have occurred in this area. The departure percentages for the month of September as a whole explains the general situation. An excess of over 50 per cent. occurred throughout the northern districts. The heaviest excess of 100 per cent. or over being confined to the Jalpaiguri and Darjeeling districts and certain other isolated areas. The excess in the southern area was generally slight (except at Sirajganj and Rampur Boalia). We see again that the large volume of excess water in the north caused floods in Jalpaiguri but was able to drain away through the Brahmaputra and the Ganges without causing any floods in the south.

1906.

The Englishman (August 17) notes:—

In Patna, Sonthal Parganas and Malda crops suffered slightly from floods.

For the period 1st to 11th August rainfall was from 20 to 90 per cent. in excess in the Malda district. The rainfall, however, was not excessive anywhere and the flood could not have arisen merely from rainfall alone.

The rainfall throughout Bihar and the United Provinces of Agra and Oudh and also in South and South-East Punjab was above normal. *The Monthly Weather Review* for August 1904, p. 277, notes :—

A very heavy fall of rain was received in parts of North Bihar on the 10th and 11th and this heavy rain resulted in a flood on the Ganges, the water breaching the bund and flowing over the surrounding country near Monghyr on the 17th. The flood was not as serious as at first believed and the loss of life was small. The depth of flood water was about 5 feet. The Ganges gauge at Monghyr shows that the river rose to 25 feet above zero on the 14th, attained its maximum height, 27 feet 3 inches, at noon on the 19th and on the 25th still read 25 feet 9 inches. The river had thus on the 25th been for 12 days above 25 feet. The highest recorded reading on the gauge was 28 feet above zero at 6 P.M. on the 8th September 1901, but during the 1901 flood, the water was over 25 feet for 6 days only.

The present flood is thus evidently due to the exceptionally high level of the Ganges. Even a slight excess of local rainfall may thus be sufficient to cause a flood if the river drainage is seriously impeded.

1906.

(Map Nos. 13/1906/1, 14/1906/2, 15/1906/3 and 16/1906/4.)

Severe and extensive floods occurred in the districts of Cooch Behar, Jalpaiguri, Rajshahi, Pabna and Malda in August and September.

The Statesman of 7th August published the following news from their special correspondent, dated August 4 and 5:—

Floods in Siliguri (August 4).—The heavy rain of the past few days have caused numerous breaches in the Darjeeling line. Passengers by both up and down mail trains to-day had to tranship and walk between Tindharia and Rungtong, because the line is breached in about 6 places on the north bank of the railway. A serious breach has also occurred below Huldibari. About 3 miles of line have been washed away and a breach has given way. Passengers for Calcutta are advised not to proceed.

(August 5).—The breach in the north bank of the line below Huldibari turns out to be more serious than at first reported..... The railway authorities wire that transhipment of passengers is impossible.

The Statesman, August 8, 1906:—

Heavy floods are reported on the bank of the Dooars Railway on the 3rd and 4th. Traffic is stopped north of the Latiguri Neora bridge. The original line is damaged and the line is breached by floods on the Daina and Khanavarty rivers and also between the Khanavarty river and the Binnaguri station.

Cooch Behar Railway partly damaged.—Intimation has been received by wire that the Cooch Behar State Railway has been badly breached in several places, owing to the overflow of the Dharla river. It is impossible to gauge the full extent of the damage or to say what further may occur or how long it will be before the line can be put in order.

The Hindu Patriot of August 7 had the following:—

Darjeeling Floods.—Following the wire received on Saturday that the Teesta river had breached the main line (Darjeeling route) over a length of 5 miles south of Jalpaiguri and that transhipment was reported as impracticable and that through booking had stopped last night, a further wire was received from Gitaldaha (the junction of the Cooch Behar 2 feet 6 inches line with the Assam line) to say that some 10 miles of line south of Cooch Behar was submerged and many bridges lost. On the main line to Dhubri, Gitaldaha was flooded and two or three bridges near Pateswari were severely damaged. All the above damage was due to excessive floods in the Dharla river. All rivers on the Gauhati extension are in excessive floods.

The Bengalee of August 12 reported:—

Cooch Behar in flood.—The flood has destroyed the standing crops to a considerable extent. The Cooch Behar State Railway line has been breached in several places and the traffic has been completely disorganised. The telegraph line had also been interrupted but has since been restored. We have not got the Calcutta Mail for the last three days. It is feared the railway line cannot be set right before the Puja..... There has already been some rise in the prices of necessaries of life. Unless prompt measures are taken and facilities offered by the State for the importation of rice there will be considerable suffering among the poor.

The District Gazetteer for Jalpaiguri says:—

Floods in 1906.—In 1902 the floods were confined to the basin of the Tista river, but in 1906 they were general over the whole district. Heavy and continuous rain fell in July during which month 40·65 inches were registered at Jalpaiguri and the fall was even more heavy in the part of the district near the hills. In previous years floods were caused by sudden downpour of rain lasting a comparatively short time; the feature of 1906 was the long succession of rainy and sunless days. On the night of August 3rd and morning of August 4th all the rivers and streams in the district rose simultaneously and the damage done to railways and roads was enormous. Owing to the interruption of communications it was some time before the full extent of the mischief could be ascertained.

Jalpaiguri town.—At Jalpaiguri nearly 24 inches of rain fell between 8 A.M. on July 28th and 8 A.M. on August 4th. The river Tista which had been rising steadily began to rise very fast on the night of August 3rd and by 6 o'clock next morning much of the town was flooded. The water rushed through the compound of the Deputy Commissioner's bungalow, and across the road into the compound of the Circuit House where it was over two feet deep; the cutcheries were surrounded with water and at one time it looked as though some of the temporary buildings would fall; steps were taken to remove the records, but the river fell as fast as it had risen and it was not necessary to do this. West of the Karla river the place was flooded right up to the Club, and the houses were standing in water; the Superintendent of Police spent the morning in a boat rescuing the women and children in the police lines and taking them to his own house for safety. In the Bazar considerable damage was done on both sides of the Karla river, which was fed by a *Khal* running into it from the Tista, and several houses fell.

Damage done by the flood.—There was no loss of life and the number of cattle drowned was remarkably small considering how widespread the floods were. Some damage was done to the *aus* rice crop the continuous rain delayed the harvest, and in a few instances close to rivers, crops were destroyed by the rush of water. The principal damage was, however, to communications; every railway and every road of importance in the district were breached and traffic stopped. The rain continued for over a fortnight after the big flood, and seriously interrupted the work of restoring communications. During the first 20 days of August not

one day passed without rain, the amount registered at Jalpaiguri in this period being 48·96 inches, and at Alipur Duars 50·28 inches.

Railways—The Eastern Bengal State Railway.—There was a bad breach near Mandalghat on the Eastern Bengal State Railway and part of a masonry bridge was carried away. No train got through on August 4th and no mails were delivered, as it was impossible to get them over the breach where the rush of water was so great that an elephant could not cross it. The Engineers set to work promptly and by August 8th trains were running through on a diversion.

The Cooch Behar State Railway.—On the Cooch Behar State Railway there was a succession of breaches between Gitaldaha Junction and the river Torsa, including two large gaps where bridges had been washed away. A mile from Alipur Duars a culvert was washed out and a hole 20 feet deep scoured by the water; it took more than six train loads of boulders to fill up this hole. It is a remarkable fact that the bridges, consisting of wooden piles and iron girders on the road running parallel to the railway, stood the flood, while the corresponding masonry structures on the railway were washed out, though the road bore the first rush of the water. The line was opened for all classes of traffic on August 19th with one transhipment at the largest breach, where a bridge was washed away.

The Bengal-Duars Railway.—Some damage was done to the Bengal-Duars Railway north of Domohani station, but the section of the line from Lalmanir Hat to Mal Junction, including the small but important branch to Ramshai Hat, was soon in working order. At Mal the line divides, one branch going west to Bagrakot, and the other east to Madari Hat; these branches run parallel and close to the hills and across the water line of the country; they bore the full brunt of the floods and were literally smashed to pieces. West of Mal several bridges were washed away including the one over the Kumlai river and a series of breaches were made in the embankments, the widest of which was near the Chel river. The eastern branch suffered most severely; there was a large breach in the embankment between Mal and Chalsa stations, but the worst damage was done between Chalsa and Nagrakata. North of the railway line the Jaldhaka river divides into two streams, one of which is called the Hathinalla; these are spanned by two large bridges, each about 500 feet long, between which there is a high embankment, which was protected by a rocky islet covered with trees. The flood cut away the island and about 1,100 feet of the embankment; the Hathinalla bridge stood but not a yard of embankment remained attached to it, and in the gap a swift stream flowed over a stony bed. All the protective works were swept away and not a vestige of them was to be seen after the floods had subsided. Farther east the Diana river cut away 900 feet of embankment, and there were numerous smaller breaches including one rather large one near Madari Hat. It was not until November that this section of the line was open to traffic again.

Telegraph Lines.—The telegraph lines from Jalpaiguri to Alipur Duars, Ramshai Hat and Mal were uninterrupted, but all the lines to other parts of the Duars were broken down.

The Bengalee reported on August 17:—

Pabna.—The flood has risen very high and there is a danger of a failure of the autumn crops. This means famine for one year more. Rice is selling at Rs. 4-8 per maund (*kanchi*). To-day a large number of beggars were waiting upon the District Magistrate while he was in Court..... There are evidences of the distress being felt in the town also. The other day a respectable looking young girl came begging to a local zamindar and she was so weak that she could hardly speak. It is time for the authorities to intervene.

September 2: Distress in the Pabna District.—The present situation of the villages Dhobakhola, Nagarbari, Pukurpar and all the surrounding parts in the district of Pabna is unspeakably miserable. The houses of one and all are as it were floating on water due to the heavy flood on the main branch of the Brahmaputra. Throughout the villages there can be found not even an inch of ground above water. Animals and insects are dying in numbers for want of food and protection. Snakes have made their way into the recesses of human habitation and cases of snake bite are not unfrequent. The heavy flood has destroyed jute and *aus* crops as well as the houses of many a poor man. The other day the godown of the R. S. N. Co.'s Nagarbari Ghat station was on the way of being carried away by the force of the river current and would have actually had that fate had it not been protected with due care and dexterity by the Station Master and the Company's Inspector who was here on that day for inspection. Further, the distress is all the more aggravated by the uncommon rise in the price of the rice. Even coarse rice is selling here at Rs. 8 per maund. Most of the people are living on scanty meals. The prices of other necessary articles are also exceedingly high. Fruits and vegetables are rare—they are all destroyed by the flood. The farmers are no longer able to save their cattle for want of fodder—the poor beasts are tied to their posts in water as high as their breast.

The District Gazetteer has the following:—

Pabna: Floods of 1906.—In August 1906 there were serious floods which affected nearly the whole of the district, many villages being submerged and roads being breached. In the Sadar subdivision 1/3 to 1/2 of the *aus* crop had been harvested, but the rest of the crop was almost wholly destroyed; in the Sirajganj subdivision 2/3rds of this crop had been reaped before the floods, but the greater part of the rice still on the ground was destroyed or seriously damaged.

The Bengalee, September 11, published the following:—

Distress in Rajshahi.—An Appeal.—A severe distress owing to scarcity of food grains is reported from all parts of Rajshahi. The unusual flood caused serious damage to the *aus* crop and added considerably to the difficulty of the situation. The

Rajshahi Famine Relief Committee have started relief operations on a moderate scale helping able-bodied men and women with relief works and men of limited resources with cheap rice sold to them at a rate considerably below the market price and with gratuitous distribution of food to those who by long starvation have become unfit for work. A woman suffering from chronic starvation died last night inspite of all efforts of the Committee to save her life. Her two infant daughters suffering from chronic starvation are merely skeletons. Funds are urgently wanted to continue the relief operations without which death from starvation is apprehended to be inevitable. Kind hearted ladies and gentlemen are earnestly requested to come to the help of suffering humanity.

September 15: Distress in Malda.—So long our poor district did not feel the necessity to give publicity to her distress as she did not feel the pinch so keenly before the advent of the flood. Rice and all the vegetables and other eatables have been selling at famine price for these two months and a half and the state of things has at last assumed a fearful aspect. Only one parallel to the present scarcity is remembered by the oldest men living and that was the famine that devastated the whole province in the year 1876. It will be no exaggeration to say that the present famine is almost unprecedented in the annals of the district of Malda..... We looked forward with hope to the *aus* crop which has also been washed away by the persistent and high flood of the last few days.

The District Gazetteer for Malda has the following :—

During the floods of 1906 the price of rice rose to 6 seers per rupee, and it was found necessary to advance a lakh of rupees under the Agriculturists' Loans Act. The price of rice was high on account of the unusual demand from East Bengal as the crops were in the *barind* portion of the district which is too high to be flooded.

It will be seen from the above reports that the floods were extremely severe in the districts of Cooch Behar and Jalpaiguri and severe in the district of Pabna while in Rajshahi and Malda the distress was mainly due to high prices of foodstuff arising indirectly through excessive rainfall.

Rainfall Analysis.

In July rainfall was above normal throughout the northern districts, the excess being from 50 per cent. to 100 per cent. in Cooch Behar and in portions of Jalpaiguri and Rangpur. The soil in the northern districts must therefore have been in a a sodden condition. Rainfall in the southern districts was slightly below normal. Rainfall in Assam Hills was 27 per cent. above normal and in the Brahmaputra valley nearly normal. Rainfall in North Bihar, United Provinces East and East Sub-montane and in both South and North Oudh was above normal.

Towards the end of July the level of the Ganges rose very high. The gauge reading at Mirzapore became 30 feet on the 29th, Benares 29·50 feet on the 31st, Dinapore 30 feet on the 28th, Monghyr 23·25 and Rampur Boalia 20·10 feet on the 31st. The gauge at Gauhati registered 29 feet on the 19th July and except for the first week remained over 24 feet throughout the month. The level of both the Ganges and the Brahmaputra were thus abnormally high.

The rainfall in August was above normal in the Brahmaputra valley by 24 per cent., North U. P. 14 per cent., was in moderate excess in the Assam Hills 41 per cent., Sub-montane U. P. 50 per cent., Sub-montane Punjab 39 per cent. and in large excess in East Bengal 57 per cent., North Bihar 78 per cent. and the Punjab Hills 94 per cent.

The gauge readings on the Ganges continued to be high throughout August. At Rampur Boalia it reached 26·30 feet on the 25th (against an absolute record of 27·25 feet) and remained over 23 feet over the greater part of the month. The condition of the Brahmaputra was still worse. The Gauhati gauge reading practically never fell below 27 feet and reached the record height of 32·25 feet on the 24th.

The level in both the Ganges and the Brahmaputra therefore remained exceptionally high throughout the flood period.

Heavy rainfall began in the northern districts from the 27th of July and continued almost unbroken for more than a fortnight. It was controlled by a depression which appeared off the coast near Chittagong on the 25th with a central depth of 0·25 inches, and the next day had deepened to nearly 0·33 inches, had crossed the coast of Bengal and caused heavy rainfall in that province". —(*Monthly Weather Review*, July 1906.)

Chief amounts were—

On the 27th July Darjeeling had 4·98 inches, Kalimpong 4·46 inches; 29th Dinhatta 4·15 inches; 30th Siliguri 3·85 inches, Darjeeling 4·18 inches, Kalimpong 3·28 inches and Mongpoo 3·06 inches; 31st Siliguri 4·13 inches, Jalpaiguri 4·65 inches, Alipur Duars 3·67 inches, Falakata 4·20 inches, Nagrakata 6·10 inches, Buxa 4·02 inches, Kalchini

7·59 inches and Kumargram 6·40 inches; 1st August Jalpaiguri 3·26 inches, Alipur Duars 4·88 inches, Buxa 4·21 inches, Kalchini 6·06 inches, Kumargram 3·46 inches and Cooch Behar 4·70 inches; 2nd Kalimpong 3·60 inches, Jalpaiguri 3·28 inches, Alipur Duars 3·35 inches, Falakata 3·30 inches, Nagrakata 7·13 inches, Buxa 5·35 inches, Kalchini 6·84 inches, Kumargram 4·72 inches, Cooch Behar 3·80 inches, Meckliganj 4·03 inches and Mathabhanga 3·30 inches; 3rd Siliguri 3·21 inches, Debiganj 3·06 inches, Nagrakata 11·54 inches, Buxa 5·22 inches, Kalchini 7·20 inches, Kumargram 4·15 inches, Cooch Behar 4·16 inches, Meckliganj 4·92 inches, Mathabhanga 3·02 inches and Kurigaon 3·09 inches; 4th Siliguri 11·30 inches, Kurseong 3·87 inches, Jalpaiguri 4·02 inches, Nagrakata 15·74 inches, Buxa 8·54 inches, Kalchini 6·85 inches, Kumargram 3·84 inches and Cooch Behar 3·72 inches; 5th Siliguri 4·53 inches, Alipur Duars 3·73 inches, Falakata 4·30 inches, Nagrakata 4·13 inches, Buxa 3·22 inches, Kalchini 3·30 inches and Cooch Behar 6·45 inches.

The gauge reading at Mirzapore rose to 30·00 feet on the 11th September, attained the maximum 43·25 feet on the 15th and remained high throughout the month. The gauge reading at Benares reached 41·17 feet on the 15th, at Buxar 30·00 feet and at Dinapore 33·00 feet on the 16th, at Monghyr 25·08 feet on the 17th and 18th, at Sahebganj 23·92 feet on the 19th, at Rampur Boalia 23·05 feet on the 21st and 22nd and at Goalundo 22·25 feet on the 22nd September 1906. The Gauhati reading diminished steadily but remained above 25 feet during the first half of the month.

The rainfall in the northern districts of Darjeeling, Jalpaiguri, Cooch Behar and Rangpur for the period from 27th July to 5th August is shown in the accompanying map (Map No 13/1906/1) as also the excess percentage (Map No. 14/1906/2). It will be noticed that the excess was considerably over 200 per cent. in the extreme north-west and over 100 per cent. through the north-east and the south-east portions of North Bengal. The rainfall was also in considerable excess throughout the remaining portion of North Bengal.

The severe flood in the northern districts in the first week of August was evidently caused by the heavy local rainfall. The flood area coincided roughly with the area of excessive rainfall but was situated a little towards the south-east. The flood in Cooch Behar and in portions of Jalpaiguri on the left bank of the Tista, however, began to subside fairly rapidly so that communications were restored within about a fortnight. But the flood on the right bank of the Tista continued for a much longer period partly owing to the continued heavy rain and also partly to the diminished draining off. It is again important to notice that the extremely severe flood in the districts of Darjeeling, Cooch Behar, Jalpaiguri and portions of Rangpur did not apparently cause any appreciable flooding in the districts lying immediately to the south.

The flood in Pabna was thus caused not by the water rushing down through the land area in the north but by the abnormal rise of the Brahmaputra (due to the great volume of water coming down from the Tista and also from the Assam Hills, the Brahmaputra valley and western districts of Eastern Bengal) aggravated by the local excess in rainfall. The situation was further complicated by the very high level of the Ganges itself. The severity of the flood in this district was greatest in the extreme south-east, near Nagarbari and the confluence of the Ganges and the Brahmaputra. It seems pretty clear from the accompanying map that water gradually accumulated in this portion of the district and the flood was mainly due to the serious holding up of the excess water by a high river level. It is also significant that the flood in Pabna although less severe than that in the northern districts apparently continued for a much longer time. This fact confirms the view that the flood was primarily due to obstructed drainage rather than to excessive rainfall.

We have already noticed that the distress in Rajshahi and in Malda occurred much later and was more or less due to the operation of economic factors. A considerable destruction of crops must have occurred throughout North Bengal and there was an abnormal rise in the price of food-stuff which gave rise to widespread famine conditions in Rajshahi and Malda.

The Malda District Gazetteer pointedly notes—

The price of rice was high on account of the unusual demand from East Bengal.

1910.

(Map Nos. 17/1910/1 & 18/1910/2.)

A moderate flood occurred in the first half of July in Cooch Behar.

The Amrita Bazar Patrika reported :—

July 13.—Owing to heavy floods the Bengal Duars Railway eastern extension has been breached at miles 106, 109 and 111. Transhipment is impossible until the flood subsides.

July 18.—Owing to heavy and incessant rains and tremendous rush of water from the hills greater portion of Cooch Behar and its neighbourhood is under water. The river Torsa and other rivers are over flooded inundating villages and the localities on both sides of the rivers. The cottages of the poor are also under strong currents. Many have left their home and hearth and taken shelter in places not overtaken by flood water. People are coming from here and there not knowing where to get shelter. Many live under the shade of trees without food or money. There is no doubt that the flood is mostly due to a rush from the hills. We are very glad to hear that the officers of the Cooch Behar State are taking prompt measures to remove the distress of the people.

July 22.—Owing to tremendous rush there have been several breaches on the railway line between Dinhatta and Dewanhatta railway stations and so the train services on this side of the railway have been totally stopped and the mails are being carried by trollies. The complete stoppage of passenger and goods traffic has entailed an innumerable loss to the company. The public too is not less inconvenienced. There is no knowing yet when the breaches will be righted.

In the same report it was however mentioned that the flood water was subsiding and the people were going back to their huts.

August 1.—The flood has nearly subsided... ..... The rain has now ceased and the sky is cloudless.

August 6 : Sirajganj.—Nearly all the roads and premises in the town are now under water.

August 9 : Sirajganj.—The flood is subsiding.

Rainfall Analysis.

Rainfall was in moderate excess nearly everywhere in North Bengal. The heavy falls were confined almost exclusively to the districts of Cooch Behar, Jalpaiguri and Rangpur in the north and to the extreme south-east corner of Pabna. In the districts of Jalpaiguri and Cooch Behar and in Siliguri heavy rain commenced from the 8th and continued almost uninterrupted till the end of the month. Chief amounts (from the 8th to the 31st July) were :—

On the 8th Nagrakata had 3·20 inches, Buxa 5·30 inches, Kalchini 4·52 inches, Meckliganj 3·25 inches and Mathabhanga 4·07 inches; on the 10th Cooch Behar 5·28 inches and Fulbari 3·90 inches; on the 11th Jalpaiguri 3·40 inches, Falakata 3·81 inches, Nagrakata 4·37 inches and Meckliganj 4·34 inches; on the 12th Buxa 5·40 inches and Kalchini 4·05 inches; on the 13th Buxa 11·20 inches, Kalchini 9·66 inches, Kumargram 3·78 inches and Cooch Behar 4·73 inches; on the 14th Nagrakata 8·42 inches, Buxa 4·30 inches and Kumargram 5·70 inches; on the 15th Alipur Duars 9·90 inches, Falakata 4·64 inches, Nagrakata 3·75 inches, Buxa 5·40 inches, Kalchini 4·70 inches, Kumargram 4·50 inches, Cooch Behar 9·33 inches, Meckliganj 3·19 inches, Mathabhanga 6·83 inches and Fulbari 8·00 inches; on the 16th Falakata 3·00 inches; on the 17th Kalchini 4·05 inches; on the 18th Alipur Duars 4·08 inches, Buxa 3·60 inches, Kalchini 3·00 inches, Kumargram 3·60 inches and Siliguri 7·45 inches; on the 19th Siliguri 7·17 inches; 21st Siliguri 3·54 inches; 23rd Debiganj 4·08 inches; 24th Nagrakata 4·59 inches, Buxa 3·20 inches, Kalchini 3·70 inches, Kumargram 6·50 inches and Meckliganj 4·59 inches; 25th Jalpaiguri 3·34 inches, Alipur Duars 5·08 inches, Falakata 3·45 inches, Nagrakata 5·46 inches, Kumargram 4·10 inches, Dinhata 4·52 inches, Cooch Behar 4·96 inches, Mathabhanga 4·92 inches, Fulbari 3·33 inches and Siliguri 3·29 inches; 26th Nagrakata 3·35 inches and Siliguri 6·55 inches; 27th Jalpaiguri 3·00 inches, Meckliganj 3·64 inches and Siliguri 7·12 inches; 28th Buxa 3·60 inches, Kumargram 3·80 inches, Dinhata 6·43 inches, Cooch Behar 5·24 inches, Mathabhanga 5·68 inches and Siliguri 4·75 inches; 29th Jalpaiguri 3·90 inches, Nagrakata 5·85 inches, Buxa 7·60 inches, Kalchini 4·35 inches, Cooch Behar 3·05 inches and Siliguri 4·25 inches; 31st Jalpaiguri 5·18 inches and Nagrakata 4·40 inches.

During the same period heavy rain also occurred throughout Assam and East Bengal, the excess being 32 per cent. for Assam and 37 per cent. for East Bengal as a whole. Rainfall in the Darjeeling district was very unevenly distributed. It was in very heavy excess in Siliguri but was not far from normal in the hills.

The level of the Ganges was moderate above Rampur Boalia and did not exceed 15 feet at Mirzapore, Benares and Buxar. At Rampur Boalia itself the gauge-reading rose steadily from about 11·0 feet on the 1st July to 19·70 feet on the 31st, showing the normal draining away of the excess rainfall.

The level of the Brahmaputra was on the other hand very high throughout the months of July and August. The lowest gauge-reading 24·50 (a very high figure by itself) occurred on the 12th July. The reading then steadily increased to 30·10 feet on the 31st July, 30·20 feet on the 1st August and remained above 28 feet till the 9th and did not fall below 26 feet during the whole of the month of August.

The floods in the Jalpaiguri and Cooch Behar districts were due to the excessive local rainfall and also perhaps due to a certain amount of water coming down from the hills. The flood however subsided rapidly owing to good drainage.

The flood in Sirajganj which occurred several days later was due partly to local rainfall and also undoubtedly partly to the abnormally high level of the Brahmaputra. The Sirajganj flood in this respect shows a close analogy to the general flood in the Pabna district in 1906. Heavy flooding of the Tista is apparently likely to be accompanied by a flood in the Pabna district, especially if helped by even a moderate excess of local rainfall.

1915.

(Map Nos. 19/1915/1 & 20/1915/2.)

Exceptionally heavy falls of rain on the left bank of the Tista caused considerable amount of damage to crops and communication in the Duars.

The Englishman reported :—

August 16.—The Manager, Bengal-Dooars Railway, Domohani, wires that owing to very heavy rain in the Dooars, where a fall of 20 inches in 14 hours was received at one tea garden, 700 feet of embankment at miles 10½ on the Bengal-Dooars Railway have been carried away by the Jaldacca river..... First and second class passengers and the mails and parcels are being crossed on elephants but the booking of goods, livestock and lower class passengers is stopped for the present.

Darjeeling : August 16.—The Mahanaudy, which of course is insignificant in size, is now a swollen river in deep flood which extends from bank to bank.

Heavy falls (due to a shallow depression in Bihar) occurred in the Jalpaiguri and Darjeeling districts for about a week from the 7th to the 15th August. Chief amounts were : - On the 7th Falakata had 3·85 inches, Buxa 3·52 inches, Kalimpong 6·02 inches; on the 8th Darjeeling 9·35 inches, Mongpoo 11·34 inches, Kurseong 8·51 inches, Pedong 5·09 inches; on the 9th Kalchini 3·08 inches, Kumargram 3·80 inches; on the 10th Kalimpong 3·35 inches; on the 11th Nagrakata 14·18 inches, Buxa 10·21 inches, Kalchini 3·84 inches, Kumargram 3·80 inches, Siliguri 5·52 inches, Pedong 3·80 inches; on the 13th Debiganj 4·90 inches; on the 14th Jalpaiguri 3·06 inches, Alipur Duars 6·88 inches, Kalchini 4·40 inches and Kumargram 7·52 inches.

The Jaldacca flood was clearly due to the excessive local rainfall. The heavy rainfall in the north however did not cause any floods in the central or the southern districts.

Floods also occurred in the Pabna district in the first week of September.

The Amrita Bazar Patrika reported :—

September 3.—The floods in the eastern parts of the Pabna district have done much harm. Many houses are under water and the cattle are dying for want of food. Scarcity is prevailing in almost all parts of the district.

September 6.—Owing to heavy floods the whole village of Sthal (Pabna) is under water. The Local Association, the Library—the only public library in the village—has been severely damaged. The floods are still increasing and it is feared that famine will soon follow.

September 8.—Information has reached here that there has been heavy flood in Mathura and Shahzadpur Thanas. Several houses in nearly all villages are under water. Bharuga and Shahzadpur High English Schools have been closed on account of the flood.

Rainfall was in slight excess in Assam and in considerable excess in Bihar (21 per cent.) and United Provinces East (43 per cent.).

The gauge-reading at Rampur Boalia rose from 18 feet on the 1st August to 22·50 feet on the 17th and 18th August, to 24·0 feet on the 8th and 9th September, and did not fall below 22 feet till the 14th of September. The gauge reading at Goalundo rose from 22·50 feet on the 1st August to 25·25 feet on the 28th, 29th and 30th August and did not fall below 25·0 feet before the 15th of September. Remembering that the highest gauge-reading recorded at Goalundo* was 25·75 (in 1906) the exceptionally high level of the river would be easily appreciated. The level of the Brahmaputra also was exceptionally high. The gauge-reading at Gauhati remained above 28 feet throughout the month of August and did not fall below that figure before the 26th of September. The highest reading, 31 feet, occurred on the 17th and 18th August.

There was also a slight or moderate excess of rainfall in the east during the first week of September which, coupled with a high river level, probably accounted for the floods in Pabna.

*The height of the Goalundo gauge was changed by 5·78 feet from 1st June 1903. To compare reduced levels 5·78 feet should be deducted from readings before 1st June 1903 or added to readings taken after that date.

1918.

(Map Nos. 21/1918/1 & 22/1918/2.)

A severe flood occurred in the end of August in Rajshahi and Bogra.

The Amrita Bazar Patrika (*August 29*) published the following :—

Naugaon, August 28.—There is an unprecedented flood in Naugaon. The old subdivision, the town and the moffusil are under water. The people have become homeless and are starving. The cattle are drifting away in indescribable distress. A Relief Committee has been formed. The local resources are inadequate. Outside help in men and money is urgently required. Water is still rising. Any help will be thankfully received by the Secretary, Relief Committee, Naugaon, District Rajshahi.

August 31—Flood in Bogra.—Our correspondent at Bogra wires as follows under date August 30:—Since my last wire authentic information have been received from centres in the affected area which is about 100 square miles with a population of 1,000. Houses being of mud collapsed in the first rushing of water and are going down daily. People are living on the high banks of tanks, house tops and on railway embankments exposed to wind and rain. Storage of foodstuff is ripe (*sic*) and in some places washed away and in other places 6 to 7 feet under water. Transplanted *Aman* is under 6 to 7 feet of water and there is no hope for it. About 2,000 families are affected. People are starving. Seven to eight hundred rupees is daily necessary to provide people with famine food. There is no hope of early subsidence of the flood. The standing water is strewn with dead cattle, dog and other domestic animals and their bodies are in a state of decomposition. Bamboo and plantain trees are not available for making rafts nor boats of any description. Money is insufficient. We are badly in need of men and money.

Flood at Bogra and Rajshahi.—Many village in the districts of Bogra and Rajshahi (specially the adjacent villages of the Santahar junction of the E. B. Ry.) have been visited by a terrible inundation which has rendered the people homeless. Inmates of many houses including women and children have taken shelter on elevated pieces of lands and on the railway line. Sufferings of the distressed know no bounds—some are starving and some are being ill-fed with unboiled rice which sells 5½ seers a rupee. We hope and trust men of sympathetic and generous heart will at once come to our help.

The Bengalee, September 1.—

Flood in Dinajpur.—On account of heavy rains since June last, considerably in excess of the average of the previous years, the pools, tanks, canals etc., were almost full to the brim and the continuous downpour from the 23rd to the 26th August resulted in a flood in the town such as has not been witnessed here within living memory. Numerous houses both *pucca* and *kutcha* have collapsed. Ramnagar, Belubari, Balmadanga, Ghasipara, and Paharpur have suffered considerably. Some of the important streets of the town were under water and strong currents of water flowed across them. The river Purnabhaba also rose in high flood and penetrated into the low-lying part of the town. Reports from the interior is very meagre but news of devastation is reaching the Sadar. The railway line between Dinajpur and Kachra has been breached at several places and two bridges have been washed away. Train service has been stopped between the stations named above. Trains from Parbatipur have to go back from Dinajpur.

September 6, 1918.—The area affected by flood in Bogra is about 100 sq. miles. Houses being of mud have collapsed. 2,000 families are distressed..... Flood is subsiding very slowly.

The flood is not limited to a certain place (in Rajshahi). It has spread over Dinajpur, Bogra and in some places of Rangpur.

The Amrita Bazar Patrika : —

September 7, 1918: (Editorial).—Heartrending details of distress occasioned by high flood continue to come from the districts of Rajshahi and Bogra. Naugaon, a subdivision in the Rajshahi district, has suffered most and thousands of people have been rendered homeless. We understand the old subdivision is under water and the condition is similar to what was considered in the area affected by the Damodar flood. Relief work has been started at Naugaon and the Relief Committee is doing its level best to render as much help as is possible with the resources at its disposal. We understand that a sum of Rs. 50,000 will be necessary for the relief of the people in the affected area in the subdivision of Naugaon. Of the 4,000 villages affected by the flood the Committee has been able to extend relief operations to 100 villages only.

September 9: Natore.—The whole of the Singra Thana is overflooded owing to the abnormal rainfall in the last week of August. The water has gone 4 feet above the highest flood level. In other words the people are homeless.

September 11: Naugaon.—Six deaths are reported. The water seems to be stagnant though the river on the east is one foot higher than that in the west but flow is retarded for want of openings in the railway, especially at Adamdighi.

The Amrita Bazar Patrika :—

September 3.—Bogra flood is increasing. The people are suffering more and more. Local resources are inadequate. To remedy this workers and money are urgently necessary. Loss of life is apprehended unless instant help is received.

The Bengalee :—

September 3 : Flood in North Bengal.—We understand that the flood in Bogra district and in Naugaon Subdivision and other parts of North Bengal is of a far more serious character than was at first apprehended.

September 4.—At Naugaon the Bazar is under water. The site between Naugaon and Balihar is overflooded. The whole area is

under water. In Balihar excepting the Bazar the whole village is under water..... The surrounding villages are more or less under the same condition. All communication has become impossible except by boats..... The whole Subdivision of Naugaon is under two feet of water..... The Committee estimates that a sum of Rs. 50,000 will be necessary for the relief.

Amrita Bazar Patrika :—

September 5: Bogra.—Unusual flood in the western part of the district has made 2,000 families homeless and about 1,000 people foodless..... Though there is small subsidence of flood in some places in the north part of the affected area the water is rising in the south to the consternation of the Committee and its workers in the affected areas. A barrier has been created by high embankments of the junction of the E. B. Ry. and B. S. B. railway which cut each other nearly at right angles at Santahar junction.

Tagore Estate Weekly Reports recorded (translated from Bengali) :—

Very heavy rain commenced from the 23rd August and continued incessantly till the 25th. All *kutcha* houses were destroyed in the surrounding villages and the people fled to houses built on high land and on the raised banks of the Sara-Santahar railway line.

Rainfall Analysis.

In July rainfall was in considerable excess in Assam (45 per cent. above normal). In August rainfall was again in excess in Assam and was also considerably above normal in Bihar.

Moderate or heavy rain began to fall from the 18th August practically all over North Bengal. On the 19th Sitabganj had 3·45 inches, Birganj 3·30 inches, Jalpaiguri 3·40 inches, Nowkhilla 3·40 inches; on the 21st Mahadevpur had 3·41 inches; on the 22nd Nawabganj had 3·19 inches, Tanore 4·25 inches, Bogra 3·51 inches, Malda 3·14 inches, Gazol 3·65 inches and on the 23rd Saidpur 4·82 inches. The greatest excess in the month, 200 per cent. above normal, occurred in the central area. The heaviest downpour was confined to the 3 days from the 24th to the 26th. Excepting for a few isolated heavy falls rainfall decreased very considerably from the 27th and was nothing unusual for the next 8 or 10 days.

The level of the Brahmaputra remained high throughout July and August. The gauge reading at Gauhati registered 29 feet on the 13th August and did not fall below 26 feet in August. The level of the Ganges on the other hand was comparatively low. The gauge-reading at Rampur Boalia fluctuated between (allowing for a change of the gauge-zero by 42·00 feet) 6·90 fe.. and 11·40 feet in the month of July and between 9·90 feet on the 1st August and 18·20 feet on the 30th August; it remained below 14 feet till the 25th of August. The gauge-reading at Goalundo was of course comparatively high due to the high level of the Brahmaputra but did not go beyond 24·00 feet (corrected 18·22 feet) before the 27th August.

A careful study of the flooded area shows that the flow of the excess rainfall was mainly from the north-north-west to the south-south-east. The outlet through the Ganges was not seriously impaired and the area on the left bank of the Ganges from Nawabganj to Goalundo was practically free from flooding. On the other hand the banks of the Brahmaputra from a little below Kurigaon to Goalundo were more or less submerged.

It will be noticed that the greatest damage was done in the near neighbourhood of the areas of exceptionally heavy falls and also in an area in Pabna near the Sara-Sirajganj line between Bhangura and Ullapara.

The flowing down of water from the north was a factor of importance only in the central area, that is in the neighbourhood of Adamdighi and in the south-western side near the Sara-Sirajganj line. Drainage of water from the north was not a factor of any importance in the Dinajpur area.

The direct cause of the flood was the heavy rainfall on the three days 24th, 25th and 26th of August. The heaviest excess amounting to from 8 to 10 times the normal fall occurred in the area covered by the rainfall stations Rangpur, Parbatipur, Saidpur, Dinajpur, Gangarampur, Gazol, Malda and Balurghat and also in the area covered by Naogaon, Tanore, Rampur Boalia and Natore. The heaviest excess amounting to from 5 to 8 times the normal fall occurred practically throughout the area covered by Sunderganj, Pirganj, Nawabganj, Parbatipur, Gomastapur, Gaibanda, Bogra, Sherpur and Sirajganj. A serious flood occurred almost immediately in the Raiganj, Dinajpur and Balurghat area but it is probable that the flood in this area subsided comparatively rapidly.

The flood in the neighbourhood of Naogaon also occurred almost immediately. This flood was due undoubtedly to the excessive local fall and also very likely to

a flowing down of water from the Gangarampur Balurghat area. The flood in Bogra appears to have occurred two or three days later indicating that it was to a considerable extent due to the flowing down of the water from the area lying to the north and to the north-west.

The flood in Bogra remained high for a fairly long time. On September 6 the *Amrita Bazar Patrika* reported: "Though there is small subsidence of flood in some places in the north part of the affected area the water is rising in the south." There cannot be any doubt that the Santahar-Bogra line was proving the chief obstacle against the quick flowing away of the flood water. In the Naogaon area also the flood water remained stagnant for a very long time. On September 11, the *Amrita Bazar Patrika* reported: "The water seems to be stagnant though the river on the east is one foot higher than that in the west but flow is retarded for want of openings in the railway especially at Adamdighi".

In the Malda district the flood water apparently drained off quickly into the Ganges.

It will be noted that the comparatively low level of the Ganges saved the low lands lying immediately to the north of the river in Rajshahi and Pabna from being inundated. On the other hand the high level of the Brahmaputra certainly aggravated the flood near Serajgunj and in the eastern parts of the Pabna district.

1919.

A flood of slight or moderate intensity occurred in the end of August and in the first week of September.

The Amrita Bazar Patrika reported on—

August 29: Pabna Notes.—The river Padma is approaching the town with a rapidity that has baffled all human skill to stop it.....

August 30.—The erosion of the river Padma which after consuming several villages near Pabna is now threatening the district town itself is indeed a matter of serious consideration.

The Statesman published the following on—

September 6: Pabna.—Portions of the compound of the District Magistrate's bungalow has been washed away by the river Padma flooding from the Dewangunge ferry ghat up to the District Magistrate's house. A narrow strip of land about 100 yards in breadth alone intervenes between river Ichamati and the Padma which if covered will bring the two rivers in contact.....

The Amrita Bazar Patrika had the following on—

September 8.—A portion of the compound of the District Magistrate's bungalow on the south-east corner has been washed away by the river Padma..... The Private Secretary to His Excellency the Governor of Bengal has sent the following letter to the Chairman of the Pabna Municipality: "I am desired to say that His Excellency in Council is giving the matter his careful consideration and the Hon'ble Mr. Cowley has recently visited Pabna to make enquiries regarding the position..... The representation has now been forwarded to the Secretary to the Government of Bengal, Irrigation Department."

The Administration Report for 1919 reported:—

In the Northern Circle the floods in the river Ganges were unusually high and remained above R. L. 60·00 at Rampur Boalia for two weeks. The Municipal ring Bund at Bosuri was overtopped and breached in several places: sluice No. 4 on the embankment No. 56 B was washed away on the 13th September 1919. The breaches have been filled up and the question of re-constructing the washed-out sluice is still under consideration.

The rainfall was above normal during the period 25th August to 6th September, but there was no exceptionally heavy falls and local rainfall could not possibly have been the chief factor.

Rainfall in August was above normal in the Punjab, United Provinces and in Bihar. A depression "appeared in the north of the Bay on the morning of the 23rd with centre nearly 200 miles east of Gopalpur. It increased slightly in intensity on the 25th, began to move on that day, crossed the Orissa coast on the 25th, and filled up on the west of the United Provinces on the 31st. The fifth formed in the north-west angle of the Bay on the 30th and lasted till the 2nd September, when it reached Bihar. These disturbances caused on many days widespread and heavy rain." (*Vide Monthly Weather Review* for 1919, page 95.)

The gauge readings at Mirzapore (highest reading 49·75 feet on the 12th August), Benares (43·50 feet on the 13th), Buxar (31·92 feet on the 13th), Dinapore (33·90 feet on the 15th), Monghyr (26·17 feet on the 17th and 18th) show that the level of the Ganges was abnormally high. The gauge reading at Goalundo was over 22 feet during the greater part of August and the first half of September.

The Pabna flood was thus probably due to an overflow from the Ganges.

1922.

(Map Nos. 23/1922/1, 24/1922/2, 25/1922/3, 26/1922/4, 27/1922/5 & 28/1922/6).

The floods were due to exceptionally heavy rainfall in North Bengal. A depression formed in the Bay of Bengal on the 21st September which passed due north and gave exceptional falls on the 23rd, 24th, 25th and 26th. The actual rainfall for the week ending 27th September is shown in Map No. 23/1922/1. The heaviest rainfall occurred in the Atrai and Purnabhava basins. The percentage departures are shown in a separate Map, No. 25/1922/3.

The actual rainfall for this week at some of the stations was of the same order as the normal rainfall for the three months July, August and September. Balurghat had 49·95″ against a tri-monthly normal of 35·11″; Gangarampur 37·03″ (tri-monthly normal 41·88″); Churamon 32·90″ (tri-monthly normal 38·48″); Gazol 31·64″ (tri-monthly normal 38·20″); Nithpur 27·05″ (tri-monthly normal 36·27″); Naogaon 31·42″ (tri-monthly normal 33·98″); Manda 34·35″ (tri-monthly normal 32·57″); Natore 27·75″ (tri-monthly normal 34·28″). It will be seen therefore that in the central rainfall areas almost as much rain fell in one week as during the course of three months in a normal year.

I have determined the approximate boundaries of the flood area from descriptions given in the daily newspapers as well as from an article in the *Modern Review*, November 1922, by Meghnad Saha, M.A., D.Sc., Professor of Physics, Allahabad University, Publicity Officer of the North Bengal Flood Committee. This article was compiled from all the information which reached him in the course of his duties as Publicity Officer. I also saw him personally and gathered such information as I could from him.

I take the following description from his article:—

> By the 24th instant all the rivers in the Dinajpur district began to swell and overflow their banks. The rain water accumulated in South Dinajpur, began to move southwards along the Atrai basins, along the Tangan and the Purnabhaba.
>
> The rain water descending from the Balurghat subdivision swept across the Balurghat Hilli District Board Road, and brushed against the railway line. Up Santahar, this volume of water bifurcated. The upper part broke through the upper section of the line, between Jamalgunge and Akkelpur at several places, on the night of the 25th September the Mail train starting from Darjeeling on the 25th instant for Calcutta reached Parbatipur the next morning, but could not proceed further, because the line some miles south of Parbatipur was reported to be under water and the news of the breach at Akkelpur became known to the railway officials. The passengers had to stay at Parbatipur for four days and were then sent to Calcutta by another long devious route. The breach was not repaired till the 28th September, and the first train along this track reached Calcutta on Monday, the 1st October. On moving further south, the flood water came at right angles against the Bogra-Santahar line and breached it at several places, east and west of Adamdighi. The flood-water spread as far as Kahaloo. Thence it made its way to the south through the Raktadaha bil, to the Chalan bil tract in Rajshahi and Pabna to be again held up by the Sara-Serajgunge line. In that line there was a breach between Bhangura and Goakhara, though not a very serious one.
>
> The western half of the flood water, from Dinajpur spread over the Atrai basin, comprising the whole of the Naogaon subdivision. But it could not breach the railway line which acted like a double dam across this volume of moving water. The only way of escape was through the channel of the Atrai and some other small rivers which under such exceptional circumstances could discharge only a small fraction of the water accumulated behind it.
>
> The flood water being held back effectively began to rise in level and extent further over the district. People looked with dismay on the boiling sheet of water beneath them which seemed likely to swallow everything lying above it. They soon saw their paddy fields, their homesteads, being submerged under water. They were driven to take shelter on high grounds, on trees, on boats, on hastily improvised rafts, on roofs of houses, which began to collapse under them and on railway embankments. The water-level continued to rise till it exceeded the average annual flood level by eight to nine feet. The difference of level on the west and on the east side of the railway line amounted to from four to five feet, a clear indication that the railway line was blocking the free passage of water.
>
> A worker of the Bengal Relief Committee who visited the area on the 2nd October, describes that the country looked like an open sea, dotted here and there with tops of trees and patches of high land, on which all classes of people were huddled together, waiting for the water to subside.
>
> Water began to subside from Friday, the 30th September but the process was very slow amounting to only three inches in 24 hours. After the 30th, there were occasional showers of rain, though not on a very large scale. In a fortnight (13th October), only three feet of

water had been drained off. As the *aman* crop had been lying under water for over a fortnight it became a total loss.

We have learnt from subsequent investigation that for 15 days there was little change in the flood-level. Even after that it went down very slowly. By this time the paddy fields which had been lying under 8 feet of water for more than a fortnight were lost beyond all hopes of recovery. The ganja crop in Naogaon shared a similar fate. In fact, nothing was recovered from the watery desert.

The flood passed over only Western Bogra but the destruction of houses and property in the wake of the flood was sudden, and quite as severe as in Rajshahi. Owing to the breach, however, east and west of Adamdighi, the flood water passed off rather quickly, and much of the *aman* crop is said to have survived the deluge.

In the Panchupore Singra area water began to rise from the 26th, on the 27th it was from 6 to 7 inches higher than the usual level and remained stationary for 7 days, subsidence began from the 4th October.

I also quote in full his remarks on the extent of damage done :—

It is best to quote from the official *communique* which is held to be an underestimate by all non-official visitors to the scene.

The principal areas affected are nearly 400 square miles in the district of Bogra, 1,200 square miles in the district of Rajshahi in varying degrees and a small area in Pabna. There has been a considerable loss of crop and destruction of houses. In the district of Rajshahi, it is estimated that the loss of the winter rice crop in the affected area is on the average 70 to 75 per cent. The loss of the ganja crop is estimated at 90 per cent. In Bogra, however, the loss of the winter rice crop is not estimated at more than 20 to 25 per cent. of the whole. The huts demolished or damaged in the area affected in the district of Rajshahi are estimated at 50 or 60 per cent. Many, however, with tin or thatched roofs can be repaired again. In Bogra, the loss of homesteads is not estimated at more than 5 per cent. or 10 per cent. in the worst cases. The loss of the cattle is also substantial.

As to the non-official estimates we quote the following from *The Statesman* of the 15th October :—

"The Governmental" estimate as to the loss of and damage to property is held to be, in almost every respect, a considerable underestimate. In the Bogra district the loss has been estimated by the Assistant Director of Public Health at over one crore of rupees. In the village of Talson alone, seven small huts out of fully 200 dwellings have been left standing.

After a visit to the Naogaon subdivision I am on good authority to say that the damage to property and destruction of cattle is much more serious than is indicated by official estimates. The Naogaon subdivision has a population of something over five lakhs and fully sixty thousand dwellings have been destroyed within its boundaries by the flood.

Practically all the ganja crop is hopelessly damaged, while only an infinitely small part of the growing rice crop will be available this season.

The area affected in Rajshahi is three times the area in Bogra, and the loss to houses, property and crop is admitted to be more severe. We can, therefore, put the loss at Rajshahi and Pabna combined at 5 crores of rupees. Altogether, the floods have caused a total loss of six crores of rupees.

Tagore Estate Weekly Reports (translated from the original Bengali) :—

Very heavy rain continued without interruption from the 23rd to 27th September and flood water rose very rapidly. On the 26th September the flood level rose by about 4 feet in one day and continued to rise steadily till the 30th September. Most of the houses are under water and the majority of the mud-built houses have collapsed. Many people have taken shelter on the banks of the railway line.

Rai Bahadur Rala Ram, C.I.E., I.S.O., late Chief Engineer, Eastern Bengal Railway, at the request of the Railway Board undertook an investigation and submitted a report on the 8th December 1922. I take the following extracts from his report :—

The rainfall at Dinajpur and in the neighbourhood of Balurghat flooded the Jumuna and Atrai rivers; and this coupled with the local fall at Naogaon and in the north-west corner of Bogra District, which is drained across the main line by the Tulsiganga (a tributary of the Jamuna river), caused an unprecedented flood in the low-lying country west of the main line, from a point about 15 miles north-west of Santahar to about 15 miles south of Santahar (about 2 miles beyond the Atrai crossing). Judged by the level of water on the floors of the quarters in the European Colony at Santahar, the flood of 1922 was about 2 feet 8 inches higher than that of August 1918.

The flood water from this area has eventually to drain into the Ganges at Goalundo, and the velocity with which the water can drain off the flooded area depends on the level of the water in that river. In the present year the level of the Ganges at Goalundo on 26th September 1922 was 27·2, whereas on the 25th August 1918, the date of the previous flood, the level stood at 23·1. In the present case, therefore, the rate of flow was much retarded and the rise of flood level at Santahar and its neighbourhood was proportionately higher.

Floods east of main line above Santahar.— The catchment area of the Tulsiganga, which is one of the tributaries of the Jamuna river, lies on the east of the main line. Judging from the rainfall at Balurghat on the opposite side of the main line, it would seem that the rainfall on a good deal of this catchment area must have exceeded 40 inches. The result was that the Tulsiganga came down in high flood, and its water being further augmented by a fairly large contribution from the west of the line, through a bridge over the Chota

Nadi or Kata Jamuna, flooded the tract of country lying to the east of the main line between miles 188½ and 180.

The only outlet for the combined flood of Tulsiganga and Chota Nadi was through Tulsiganga bridge, mile 182¾, and some minor openings, the direction of flow being from east to west. In the present case, however, as the country on the west side was heavily flooded, the velocity through the bridges was much diminished. The water not being able to get away fast enough to the west side, continued to pile up against the east side of the railway embankment which is not very high. It evidently passed over the rails, and about midnight of 25th September caused a breach to the north of Akkelpore station.

Beyond the Tulsiganga bridge the overflow continued to run southwards parallel to the main line. There was some cross flow, from east to west, through bridge openings and over the permanent way, but the bulk of the overflow found its way to the pocket formed between the main line and the Bogra branch.

Before concluding the subject of floods in this part of the country, it may be mentioned that, just south of Jamalganj station, the line crosses a depression about a mile in length with practically no outlet to the west. At this place the overflow from the Chota Nadi in the first instance went over the rails from east to west, and subsequently returned to the east side again (when the flood subsided), to be finally drained to the west through the breach at Akkelpore.

Floods on Santahar-Bogra Line.—The section next to be dealt with is that from Santahar to Bogra. This section has suffered most damage, extensive breaches having formed on both sides of Adamdighi station, while elsewhere right up to the Nagore bridge ballast was washed away down stream for considerable distances. Two small bridges were entirely wrecked, and minor damages were caused to some other bridges. Most of the damage on this section occurred early on the 26th September, the last train which passed over this section being 4 Down, which is due at Santahar at 5·0.

For the first 3½ miles where 200 feet of waterway exists, the flood level on this section seems to have just reached the top of formation. Beyond this point there was no opening for about 2¾ miles; and in this length the water went over the rails, the line from mile 177-10 to 178-12 being breached in many places. The longest breach was 500 feet and the aggregate about 2,000 feet. Again, from mile 181 to 185½ the flood was high enough to wash the ballast away from certain lengths. Talora station yard was also badly flooded.

The trouble in the present year has been due to the fact that in addition to the flooding due to the heavy local rainfall, the overflow from Tulsiganga on the north-west, and from Nagore on the north-east side, had to be passed, both these rivers being at least 2 feet higher than ever known before.

Floods on the Sara-Serajganj Railway.—From the report submitted by the Executive Engineer, Eastern Bengal Railway, Paksey District, I find that the flood started coming down against the Sara-Serajganj line on 25th September, and reached its maximum on 28th, or 2 days later than in the case of the main line near Santahar. The subsidence was very slow, and the current through the bridges is said to have attracted notice about the 30th September.

Rai Bahadur Rala Ram made special investigation about the level of the Ganges and notes:—

A glance at the river levels will show that the Ganges at Goalundo was on the rise from 23rd to 27th September, the total rise in this period being 1·30 feet. The river was then steady for 3 days, and between the end of September and 5th October there was a further rise of ·40. The fall commenced on the 6th when the river started going down at the rate of 6 inches per day. It is no wonder therefore that the floods remained on this and other areas till the middle of October.

He also mentions in this connection that the level of—

both the Ganges and the Brahmaputra were rising at the time and were 4 feet to 5 feet higher than the normal level at this time of the year. Excepting in the years 1920 and 1921 when the levels of the Ganges at Goalundo were between 27·0 and 28·0, the levels for the last week of September during the last 12 years have never been higher than 23·5, and in some years the levels have been as low as 17·5.

Lieut.-Col. C. R. Hearn, D.S.O., R.E., Chief Engineer, Eastern Bengal Railway, wrote a note on the Report of Rai Bahadur Rala Ram. The following extracts are taken from this note:—

It seems that the flood moved at about 10 miles per day down to the Atrai crossing of the main line and at about 6 miles per day from that crossing of the Bogra line to the Sara-Sirajganj line.

The high floods of 1922 were caused by a concatenation of three unfavourable circumstances—

(*a*) heavy rainfall east of the main line,

(*b*) heavy rainfall west of the main line,

(*c*) a relatively high level in the Ganges.

Had either (*a*) or (*b*) occurred singly the whole country would not have been flooded simultaneously or to the same extent. The bridges in the main line would have been able to discharge water continuously into areas not already full of water, although those bridges would have been stressed to a greater extent by a greater afflux.

Rainfall Analysis.

The following table gives a detailed analysis of the rainfall in each flood-area for each day of the week ending 27th September 1922. Under each day, the first row gives the actual rainfall in inches, the second row gives the excess rainfall divided by the standard deviation, and the third row the same excess divided by the daily normal rainfall. For certain stations for which individual S.D.'s were not available, I have used the average S.D. for the area under consideration :—

Day.	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3	Whole area.
September 1922.										
21st	0·30"	0·08"	1·30"	0·43"	Nil	0·27"	0·58"	1·12"	0·21"	0·42"
	−0·52	*−0·65*	+0·91	*−0·18*	..	*−0·04*	+0·39	+0·90	*−0·22*	+0·03
	−59	*−85*	+140	*−31*	..	*−7*	+66	+170	*−37*	+6
22nd	1·07"	1·13"	1·05"	0·89"	0·54"	0·85"	0·60"	0·47"	0·44"	0·91"
	+0·03	+0·75	+0·61	+0·23	+0·31	+1·24	+0·42	+0·07	+0·19	+0·78
	+4	+98	+94	+41	+59	+193	+72	+13	+31	+129
23rd	0·61"	0·35"	1·24"	1·60"	0·47"	1·21"	1·61"	0·35"	0·63"	1·02"
	−0·16	*−0·29*	*+0·84*	*+0·87*	+0·20	+2·04	+2·12	*−0·09*	+0·53	+0·96
	−19	*−39*	+130	+154	+38	+317	+360	*−16*	+88	+157
24th	0·48"	0·87"	2·45"	2·18"	2·73"	2·86"	5·77"	3·31"	4·63"	3·37"
	−0·31	+0·40	+2·30	+1·39	+3·76	+5·72	+9·16	+3·73	+7·74	+4·54
	−36	+53	+353	+246	+703	+886	+1550	+695	+1280	+748
25th	1·42"	0·91"	2·80"	3·19"	5·4"	3·41"	6·96"	5·47"	6·49"	4·51"
	+0·79	+0·42	+2·72	+2·30	+7·96	+6·94	+11·17	+6·51	+11·11	+6·27
	+91	+60	+418	+407	+1488	+1075	+1890	+1218	+1836	+1036
26th	0·32"	0·57"	1·48"	1·58"	10·25"	2·68"	4·32"	6·76"	8·98"	4·25"
	−0·50	Nil	+1·13	+0·85	+15·60	+5·32	+6·71	+8·17	+15·58	+5·87
	−57	0	+173	+151	+2915	+825	+1135	+1530	+2577	+971
27th	0·05"	0·31"	0·95"	1·54"	0·80"	2·23"	2·34"	5·19"	3·48"	2·08"
	−0·81	*−0·34*	*−0·49*	+0·81	+0·72	+4·32	+3·36	+6·01	+5·67	+2·57
	−93	*−45*	+76	+145	+135	+669	+569	+1126	+938	+424

It will be seen from the above table that rainfall was in slight or moderate excess in the first three days; the heaviest fall on the 21st occurring in (C-2), on the 22nd in (B-3), and on the 23rd in (C-1) and (B-3). Rainfall increased very considerably on the 24th, attained a maximum intensity on the 25th and 26th, and decreased considerably on the 27th. On the 24th heaviest falls occurred in (C-1) and (C-3), and on the 25th and 26th practically all over the central and southern districts.

It will be noticed in the map for 1922, that the flooded area is divided into two portions: one (with the darker shading) representing the area of deepest floods, and the other (with a lighter shading) representing the area of comparatively slighter floods. For purposes of comparison I have considered these two areas separately in the following table, which gives (for the whole week ending 27th September, 1922) in column (1) the weekly normal rainfall (in inches), column (2) the weekly mean standard deviation, column (3) the actual rainfall (in inches), column (4) the excess rainfall (in inches), column (5) the excess expressed as a percentage of the normal, and in

column (6) the same excess divided by the S.D. :—

	Normal rainfall (in inches).	Standard deviation (in inches).	Actual rainfall (in inches).	Excess rainfall (in inches).	Excess percentage.	Excess ÷ S.D.
Flooded Area—						
(1) Heavy	2·35"	2·05"	31·61"	29·26"	1247	14·26
(2) Slight	2·42"	2·16"	25·45"	23·03"	964	10·77
(3) Total	2·39"	2·11"	28·73"	26·34"	1104	12·49
A-1 ..	6·1"	4·98"	3·7"	− 2·4"	−37	− 0·49
A-2 ..	6·8"	4·14"	4·3"	− 2·5"	−37	− 0·61
A-3 ..	4·6"	3·70"	10·5"	+ 5·9"	+128	+ 1·60
B-1 ..	4·8"	4·31"	15·0"	+10·2"	+212	+ 2·36
B-2 ..	2·7"	2·02"	19·7"	+17·0"	+630	+ 8·41
B-3 ..	2·3"	1·99"	14·6"	+12·3"	+535	+ 6·18
C-1 ..	3·2"	2·37"	24·8"	+21·6"	+675	+ 8·69
C-2 ..	3·7"	3·08"	24·9"	+21·2"	+572	+ 6·89
C-3 ..	2·7"	2·14"	27·8"	+25·1"	+930	+11·74

It will be seen from the above table that the intensity of rainfall was greatest in the area of deepest flooding, and that the intensity over the whole of the flooded area was greater than that over any other area. It will also be seen that rainfall in the north, *i.e.*, in areas (A-1) (A-2), (A-3) and (B-1), was not far from normal, and water coming from that region could not have been a factor of any importance.

I have left out further consideration of the present flood, as a full discussion of this flood will be found in the main report of the Flood Committee as well as in other appendices attached thereto.

ABBREVIATIONS.

1. Hooghly River	"Report on the Hooghly River and its Head-Waters", Bengal Secretariat Book Depot, Calcutta, 1919.
2. J. A. S. B.	Journal of the Asiatic Society of Bengal, Calcutta.
3. Mem.	Memoirs of the Asiatic Society of Bengal, Vol. III, No. III. "Journals of Major James Rennell" edited by T. H. D. La-touche, Calcutta, 1910.
4. M. W. R., U. S. ..	Monthly Weather Review, U. S. Department of Agriculture, Washington.
5. M. W. R.	Monthly Weather Review, published by the Indian Meteorological Department.
6. Q. J. Met. Soc. ..	Quarterly Journal of the Royal Meteorological Society.
7. Reaks	"Report on the physical and hydraulic characteristics of the rivers of the delta", Hooghly River, Appendix II.
8. "Spring Floods of 1922" ..	"Report on the Spring floods of 1922, M. W. R., U. S., Supplement No. 22, Washington, 1923.
9. "Stream flow Experiments" ..	"Report on Stream-flow Experiments at Wagon Wheel Gap., Colorado", M. W. R. Supplement No. 17 (U. S. Department of Agriculture), Washington. 1922.

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(6) Rajshahi (1916), by L. S. S. O'Malley.
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