Table 210.—Correlation between Level of the Mahanadi at Naraj and Rainfall.

Factors.	n	Correlation coefficient.
N (Height at Naraj) and R (Rainfall)	271	$+0{\cdot}4547 \pm {\cdot}033$
N (Height at Naraj) and G (Gauge)	266	$+0{\cdot}7712 \pm {\cdot}016$
R (Rainfall) and G (Gauge)	268	$+0{\cdot}0412 \pm {\cdot}040$

Working out the partial coefficients, we find the following regression equation in two variates :—

$$N = 1{\cdot}54\,(R) + 0{\cdot}67\,(G) + 23{\cdot}81$$

where N gives the predicted height at Naraj in feet.

The value of the multiple correlation is 0·88 which is quite high. This will enable individual forecasts being made within 1·2 feet on an average for floods above 83 feet at Naraj.

CHAPTER 29.—CORRELATION BETWEEN RIVER LEVELS AT DIFFERENT PLACES.

Sambalpur and Naraj.

I shall now consider the correlations between the river level at Sambalpur and Naraj. I have been able to collect daily readings at Sambalpur for the months of July, August and September for the periods 1883-86 (4 years), 1907-16 (10 years) and 1920-29 (10 years) or altogether 24 years. The datum for 1883—86 and 1907—16 was quite different from that used for the period 1920—29. Until very recently I was unable to obtain particulars of the former datum ; apparently no information was available in the Irrigation Department of either Orissa or the Central Provinces. Very fortunately I have been able to recover the datum while searching old records. I find that in letter no. 5016, dated Calcutta, 28th September 1894, addressed by W. Connan, Superintending Engineer, Orissa Circle to the Chief Engineer, Bengal, it is definitely stated that the Sambalpur gauge " zero " was 403·04 ft. above mean sea level. This information enables us to pool together the different periods. But as I was not aware of this fact until recently, I was obliged to calculate the correlations independently for the two periods*.

In order to find out whether the value of the correlation changed with the advance of the monsoon, I decided to work with the following periods :—July 1st—10th, 11th—20th, 21st—31st ; August 1st—10th, 11th—20th, 21st—31st ; September 1st—10th, 11th—20th, 21st—30th.

The coefficients of correlations for the river level at Sambalpur and Naraj on the same day are given in Table 211.

Table 211.—Sambalpur and Naraj Gauges : Coefficients of correlation for readings on the same day.

Period.		1883—86, 1907—16.				1920—29.				Whole period.				
		n.	r.	n—3.	z.	n.	r.	n—3.	z.	n.	n'.	r.	n'—3.	z.
July	1—10 ..	98	·683	95	·825	85	·770	82	1·013	183	180	·7257	177	·9104
	11—20 ..	97	·753	94	·974	96	·769	93	1·013	193	190	·7622	187	·9934
	21—31 ..	120	·793	117	1·072	105	·814	102	1·228	225	222	·8184	219	1·1447
		315				286								
August	1—10 ..	125	·793	122	1·072	99	·723	96	·904	224	221	·7642	218	·9980
	11—20 ..	123	·708	120	·875	94	·678	91	·817	217	214	·6950	211	·8500
	21—31 ..	130	·637	127	·746	110	·837	107	1·203	240	237	·7453	234	·9550
		378				303								
September	1—10 ..	139	·676	136	·813	109	·760	106	·859	248	245	·6869	242	·8334
	11—20 ..	132	·750	129	·984	108	·720	105	·900	240	237	·7416	234	·9463
	21—30 ..	107	·406	104	·497	89	·910	86	1·522	196	192	·7466	189	·9580
		378				305								
July	1—31 ..	n' (309)	·7613	306	·9051	(280)	·8105	277	1·1022	601	586	·7755	583	1·0264
August	1—31 ..	(372)	·7174	369	·8926	(297)	·7589	294	·9859	691	668	·7360	663	·9340
September	1—30 ..	(372)	·6160	369	·7904	(299)	·7907	296	1·0642	683	668	·7264	665	·9122
		1071				894								
July 1—September 30 ..		(1047)	·7100	1044	·8777	(870)	·7854	867	1·0503	1965	1914	·7449	1911	·9543

*Mr. Shaw in his note dated the 28th June 1938, corroborated again in his note of 20th December 1938, says that in 1917 the zero of the gauge was found from current G. T. S. levelling to be 449·26 instead of 403·04 and was altered accordingly.

We find that the correlation between the levels of the Mahanadi at Sambalpur and Naraj (the average of 3 daily readings taken at 6', 12 and 18 hours local time) on the same day has a fairly high value, individual coefficients for different periods being usually of the order of 0·6, 0·7 or even 0·8.

The correlation during the more recent period 1920—1929 is apparently closer than the correlation for the older period, but much reliance cannot be placed on this result.

In order to combine the values of the correlations I have used R. A. Fisher's z-transformations (*Statistical Methods*, 3rd edition, 1930, p. 164) given by

$$z=\tfrac{1}{2}\{\log_e(1+r)-\log_e(1-r)\}.$$

This value of "r" will be the correlation between the variates after elimination of the seasonal trend. In combining z it is necessary to multiply by n'=(n—3), and this is why this quantity has been exhibited in the tables. It will be noticed that on the whole the correlation is greatest in July.

We next proceeded to find the correlation of the river level at Naraj on one day with the river level at Sambalpur on the previous day. The actual values are given in Table 212.

Correlations are again closer in the period 1920—1929. Also the highest correlation now occurs in the month of August (+0·8843), July (+0·8335) taking the last place. The greater correlation between the river levels at Sambalpur and Naraj in August probably represents the closer physical connection brought about by a higher average level of the river.

Comparing with corresponding value in Tables 211 we notice that in every case (with the single exception of the values for July 1—10 in the earlier period) the magnitude of the correlation increases for a lag of 1 day. The physical explanation is obvious. The water at Sambalpur begins to arrive at Naraj on the 2nd day, and thus raises the correlation for a lag of one day.

Table 212.—Sambalpur and Naraj Gauges : Correlations with one day's lag.

Period.		1883—86, 1907—16.				1920—29.				Whole period.				
		n.	r.	n—3.	z.	n.	r.	n—3.	z.	n.	n'.	r.	n—3.	z.
July	1—10 ..	98	·565	95	·632	85	·859	82	1·282	183	180	·7356	177	·9331
	11—20 ..	99	·831	96	1·184	96	·795	93	1·077	195	192	·8141	189	1·1313
	21—31 ..	100	·900	106	1·468	96	·906	93	1·495	205	202	·7948	199	1·0745
		306				277								
August	1—10 ..	120	·900	123	1·468	100	·902	97	1·971	226	223	·9348	220	1·6898
	11—20 ..	124	·831	121	1·184	94	·845	91	1·232	218	215	·8370	212	1·2046
	21—31 ..	139	·724	136	·907	108	·941	105	1·745	247	244	·8482	241	1·2412
		389				302								
September	1—10 ..	139	·855	136	1·190	109	·879	106	1·365	248	245	·8568	242	1·2717
	11—20 ..	132	·703	129	·870	107	·918	104	1·550	239	236	·8285	233	1·1762
	21—30 ..	98	·610	95	·699	88	·968	85	2·054	186	183	·8734	180	1·3389
		369				304								
July	1—31 ..	n' (300)	·8070	297	1·1088	(271)	·8605	268	1·2848	583	568	·8335	565	1·1923
August	1—31 ..	(383)	·8284	380	1·1768	(296)	·9310	293	1·6005	691	676	·8843	673	1·3874
September	1—30 ..	(363)	·7427	360	·9490	(293)	·9272	295	1·6308	673	659	·8162	655	1·2343
		1064				883								
July 1—September 30 ..		(1040)	·7563	1037	1·0783	(839)	·9124	856	1·5326	1947	1896	·8602	1893	1·2762

In view of the importance of the subject the correlations with a lag of two days were also calculated and are given in Table 213. For convenience of comparison the correlation for the same day and for 1 day and 2 days' lag have been all shown together in Table 214.

Table 213.—Sambalpur and Naraj gauges : Correlations with 2 days' lag.

Period.		1883—86, 1907—16.				1920—29.				Whole period.				
		n.	r.	n—3.	z.	n.	r.	n—3.	z.	n.	n'.	r.	n'—3.	z.
July	1—10 ..	100	·671	97	·704	84	·866	81	1·309	184	181	·7558	178	·9793
	11—20 ..	99	·929	96	1·646	97	·724	94	·907	196	193	·8595	190	1·2804
	21—31 ..	121	·862	118	1·290	103	·822	100	1·156	224	221	·8447	218	1·2285
		320				284								
August	1—10 ..	125	·862	122	1·290	100	·891	97	1·421	225	222	·8753	219	1·3480
	11—20 ..	125	·947	122	1·799	99	·862	96	1·257	224	221	·9167	218	1·5577
	21—31 ..	137	·709	134	·877	110	·796	107	1·086	247	244	·7518	241	·9698
		387				309								
September	1—10 ..	140	·906	137	1·500	109	·895	106	1·442	249	246	·9017	243	1·4747
	11—20 ..	132	·792	129	1·065	108	·907	105	1·500	240	237	·8535	234	1·2602
	21—30 ..	86	·618	83	·713	79	·954	76	1·867	165	162	·8548	159	1·2646
		358				296								
		n'												
July	1—31 ..	(314)	·8415	311	1·2171	(278)	·8092	275	1·1159	604	589	·8259	586	1·1679
August	1—31 ..	(381)	·8661	378	1·3079	(303)	·8493	300	1·2456	696	681	·8596	678	1·2818
September	1—30 ..	(352)	·8211	349	1·1535	(290)	·9198	287	1·5757	654	639	·8744	636	1·3441
		1065				889								
July 1—September 30 ..		(1041)	·8410	1038	1·2154	(865)	·8675	862	1·3141	1954	1903	·8557	1900	1·2678

Table 214.—Sambalpur and Naraj ; comparison of correlations with different lags.

Period.		1883—86. 1907—16.			1920—29.			Whole period.		
		Same day.	1 day lag.	2 days lag.	Same day.	1 day lag.	2 days lag.	Same day.	1 day lag.	2 days lag.
July	1—10	·683	·565	·671	·770	·859	·866	·7257	·7356	·7558
	11—20	·753	·831	·929	·769	·795	·724	·7622	·8141	·8595
	21—31	·793	·900	·862	·844	·906	·822	·8184	·7948	·8447
August	1—10	·793	·900	·862	·723	·962	·891	·7642	·9348	·8753
	11—20	·708	·831	·947	·678	·845	·852	·6950	·8379	·9167
	21—31	·637	·724	·710	·837	·941	·796	·7453	·8482	·7518
September	1—10	·676	·835	·907	·700	·879	·895	·6889	·8568	·9017
	11—20	·756	·703	·792	·720	·916	·907	·7415	·8285	·8535
	21—30	·466	·610	·618	·910	·968	·954	·7466	·8734	·8548
July	1—31	·7513	·8076	·8415	·8105	·8605	·8092	·7755	·8335	·8259
August	1—31	·7174	·8284	·8661	·7589	·9310	·8493	·7360	·8843	·8596
September	1—30	·6160	·7424	·8211	·7907	·9272	·9198	·7264	·8462	·8744
July 1—September	30	·7100	·7963	·8410	·7854	·9124	·8675	·7449	·8602	·8557

The evidence is now rather conflicting. In about half the cases the correlation with a lag of 1 day is higher, while in the other, correlations with a lag of 2 days show the greater value.

Up to 1895, there was only one reading available for Naraj, taken at 6-0 A.M. For the subsequent period the Naraj readings used were the average of 3 daily readings taken at 6-0 A.M., 12 noon and 6-0 P.M., and may be centred at 12-0 noon*. Sambalpur records were all single readings. Unfortunately I have not been able to ascertain the time at which these daily readings at Sambalpur were taken. In the case of single day readings in India, 6-A.M. local time was the usual hour of observation up to about 30 or 40 years ago, but 8-0 A.M. or 10-0-A.M. is probably more usual at the present time. The actual lag, of course, would depend on the actual hour of observation. I am giving below a table corresponding to various hours (Table 215).

Table 215.—Lag between Gauge readings.

Sambalpur Reading.	Naraj Reading.											
	Same day.			1 day Lag.			2 days Lag.			3 days Lag.		
	6 A.M.	12 Noon.	6 P.M.	6 A.M.	12 Noon.	6 P.M.	6 A.M.	12 Noon.	6 P.M.	6 A.M.	12 Noon.	6 P.M.
6 A.M. ...	0	6	12	24	30	36	48	54	60	72	78	84
8 A.M. ...	−2	4	10	22	28	34	46	52	58	70	76	82
10 A.M. ...	−4	2	8	20	26	32	44	50	56	68	74	80
12 Noon ...	−6	0	6	18	24	30	42	48	54	66	72	78

I shall give an example of the use of the coefficient of correlation in the construction of prediction formulae. Let us consider August. We have altogether 691 daily readings at Sambalpur. Choosing a lag of one day we can correlate the daily readings at Sambalpur on the first day with the daily (average of 3 readings) at Naraj on the next day. The actual Correlation Table (cross-chart) is given in Table 216. The constants are given below :—

Mean Height at Sambalpur (1st day) $= \overline{S} = 410{\cdot}97$ ft.

Mean Height at Naraj (2nd day) $= \overline{N} = 80{\cdot}90$ ft.

Standard Deviation (Sambalpur) $= \sigma_x = 5{\cdot}161$ ft.

Standard Deviation (Naraj) $= \sigma_y = 4{\cdot}792$ ft.

Coefficient of Correlation $= r = +0{\cdot}8140$

$\pm 0{\cdot}0086.$

The regression equation is given by

$$(N - \overline{N}) = r \cdot \frac{\sigma_y}{\sigma_x} (S - \overline{S}),$$

Thus $N = 0{\cdot}756\ (S) - 229{\cdot}88$ ft.

where N and S are the levels at Naraj and Sambalpur respectively.

The observed mean values are shown in Table 217.

*The difference in the time of the Naraj reading introduces some heterogeneity in the data, which however, cannot be eliminated. As the readings prior to 1895 cover only 4 years (1883—86) out of the total of 24 years, the net effect on the lag will be small, of the order of one hour only, and may be neglected.

Table 216.—Dot-chart for correlation between Naraj and Sambalpur Gauges (1 day lag).

Naraj Gauge (Base=70 feet.)	−2	−1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Totals.
24	..	..	..	..	..	..	..	1	..																				
23																													
22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	3	1				
21	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	2	..	..	1						
20	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	1	4	1	1						
19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	2	2	1	..	..	2	..	..	..	1		
18	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	2	..	4	1	1	..	4	1	1						
17	..	..	..	..	..	..	..	..	..	..	..	1	5	1	1	3	7	6	2	5	1	1	1	1						
16	..	..	..	..	..	..	..	..	..	1	..	2	1	10	5	3	4	3	1	1	1	..	2							
15	..	..	..	..	1	1	..	..	..	..	3	1	3	11	7	5	2	3	..	..	..	..	2							
14	..	..	..	..	..	..	1	..	2	..	4	7	9	4	5	6	3	..	1	..	..	..	..	..	..	..	..	..	r = ·8149	
13	..	..	..	1	..	..	..	1	4	3	3	6	13	9	2	3	1	1	3	..	..	..	..	..	..	..	..	..	S_x = 5·161	
12	..	..	..	..	1	..	1	1	6	9	8	6	13	5	2	3	..	3	..	..	..	..	..	..	..	..	..	..	S_y = 4·792	
11	..	..	..	1	..	..	2	3	7	5	6	4	8	4	..	..	1	..	..	..	..	..	..	..	..	..	..	..	$\bar{N}$ = 80·90	
10	1	..	1	1	1	2	1	4	9	8	8	5	6	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	$\bar{S}$ = 410·97	
9	..	..	..	3	2	..	10	7	6	7	9	7	1	..	..	1														
8	..	..	..	..	1	12	18	17	6	6	3	3	1	..	1															
7	..	..	..	4	10	24	14	5	11	7	..	1	..	..	..															
6	..	2	3	18	21	8	2	4	4	7	..	..	..	1	2															
5	..	3	..	5	3	..	..	1	..	2																				
4	1	5	1	..	..	..	..	..	..	..	1																			
3	1	5	..	..	..	1																								
Totals.	3	15	5	33	40	48	50	44	55	55	45	43	62	48	26	26	20	21	10	9	6	9	7	9	1	—	—	1	691	

Sambalpur Gauge (Base=403·04).

Table 217.—The observed mean height at Naraj against the height at Sambalpur.

Sambalpur Base=70.	Naraj.	Sambalpur Base=70.	Naraj.	Sambalpur Base=70.	Naraj.
—2	75·9	8	80·9	18	89·0
—1	74·1	9	81·6	19	88·8
0	76·3	10	82·9	20	86·7
1	76·7	11	83·9	21	90·0
2	76·8	12	83·9	22	92·0
3	77·3	13	84·5	23	
4	78·4	14	85·8	24	
5	78·8	15	86·1	25	95·0
6	78·5	16	85·9		
7	79·3	17	87·4		

On the available evidence namely practically an equal division of the higher correlation between the results for 1 day and 2 days lag, it looks likely that the optimum lag would be given by the value lying midway between the two intervals. If we assume the gauge readings at Sambalpur to have been taken at 6 A.M., these two intervals are 30 and 54 hours, and the mean value is 42 hours. (For 10 A.M. observations, the mean value would be 38 hours, for 8·0 A.M. 40 hours, and for 12·0 noon 36 hours). In the absence of fuller information I shall work on the basis of 6 A.M. observations which gives an optimum lag of about 42 hours. The average velocity of the peak of the flood would on this basis work out as 180 miles in 42 hours or about 4·3 miles per hour or 6·3 ft. per sec.

For a closer study of the problem Sambalpur readings of values greater than 23·7 feet (which are of special importance in flood studies) were selected and the correlations with heights at Naraj for various intervals were worked out. The lag in each case was taken to be that corresponding to 6·0 A.M. observations at Sambalpur. (If the hour of observation is assumed to be 10·0 A.M. or any other hour, a suitable correction will have to be applied.)

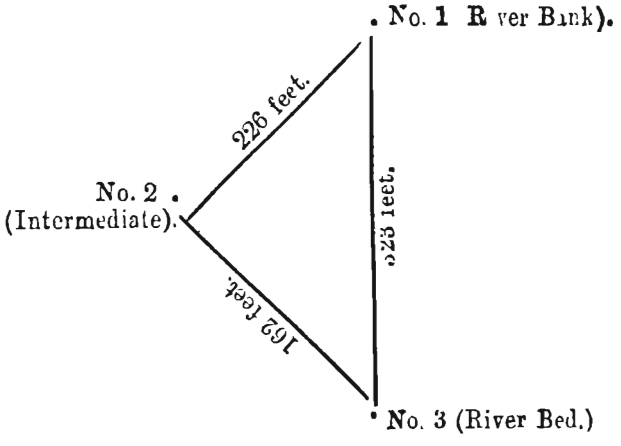
The results are given below. The size of the sample is given within brackets in each case.

Table 218.—Mahanadi river Gauge : Readings at Naraj and Sambalpur. Correlation with selected data (above 23·7 ft.) at Sambalpur and different periods of lag.

Naraj Readings on—	Lag in hours.	Sambalpur Readings (1st day) at 8·0 A.M.			
		July.	August.	September.	July—September.
2nd day ... 12·0 noon	30	0·471(87)	0·581(168)	...	...
6·0 P.M.	36	·485(51)	...	...	...
3rd day ... 6·0 A.M.	48	·486(63)	0·634(162)	0·669(50)	...
12·0 noon	54	·458(87)	0·716(168)	0·788(50)	0·757(305)
6·0 P.M.	60	...	0·531(163)	...	...
4th day ... 12·0 noon	78	·362(87)	0·459(166)	...	...

For this selected data the magnitude of the correlation is smaller. This, of course, was to be expected. A new but interesting result which comes out is the tendency for the maximum correlation to occur with a shorter lag in July. This implies, of course, a greater flood velocity in July. If this is a real effect, and it does look like one, it probably indicates a retardation of flood velocity in August or September owing to the backing up of water, i.e., owing to a decrease in the effective fall of the river level.

For stringently selected data, less than one-sixth of the whole material, correlations of 0·75 and 0·78 are distinctly encouraging. The importance of readings of the river level at Sambalpur for purposes of forecasting the flood level at Naraj cannot be emphasized too much. Daily readings used to be taken so far back as 1883. But we have been able to recover the data for only 1883-86, and then after a big gap for the period for 1907-12, 1914-16, and finally 1920-29. It is unlikely that the daily readings were discontinued in the interval. They were, however, not available in the office of the Irrigation Department at Cuttack. My assistant Babu Sudhir Kumar Banerjee who made specific enquiries on this point was told that records for Sambalpur were not filed before 1906 as it was outside the Province of Bihar and Orissa at that time. It is a pity that such a purely administrative view of the matter had been allowed to prevail in this case. For, so far as floods in Orissa are concerned, records of the height of the Mahanadi at Sambalpur are far more important than the records of any other single factor (gauge reading or rainfall) in Orissa. A most careful search should certainly be made for the missing data, and an attempt should also be made to ascertain the exact hour of observation for the available readings at Sambalpur. There is one further complication which deserves notice at this point. I find from the letter no. 9083, dated Sambalpur, 17th October 1914 of the Executive Engineer, Sambalpur Division, that there are no less than 3 gauges on the Mahanadi at Sambalpur. They are all located near one another, but it is still important to be definite as to the particular gauge at which the readings were taken. The accompanying sketch shows the position of the 3 gauges. The figures denote the distances in feet from one gauge to another.



However with the available material we can construct a number of useful prediction formulæ. Required constants are given below in Table 219.

Table 219.—Mahanadi : Selected records above 23·7 ft. at Sambalpur (all available years).

	July—September.	August—September
Sambalpur : Mean Height in ft.	27·37	27·43
Naraj : „ „ „	85·02	85·44
Sambalpur : Standard Deviation in ft.	2·817	2·643
Naraj : „ „ „	2·962	2·734
Coefficient of correlation (r)	+0·6145	+0·7572
Coefficient of Regression (b)	+0·6464	+0·7834
Size of sample (n)	305	218

For the period July—September, and for heights of the river over 23·7 feet at Sambalpur, we have,

$$N = 85\ 02 + 0{\cdot}6464\ (S - 27{\cdot}37)$$
$$= 64{\cdot}16 + 0{\cdot}6464\ S$$

where N = Height at Naraj in feet
and S = Height in Sambalpur in feet.

Also for the two months of August and September, and river levels greater than 23·7 feet at Sambalpur we get

$$N = 85{\cdot}23 + 0{\cdot}7831\ (S - 27{\cdot}43)$$
$$= 63{\cdot}74 + 0{\cdot}7831\ S$$

where N and S are respectively the heights of the Mahanad at Naraj and Sambalpur.*

In July and August a rise of one foot at Sambalpur causes a rise of 0·78 ft. or about 9 inches at Naraj.

The cross-chart for August for the selected data of readings above 23·7 feet at Sambalpur is shown in Table 220. The mean values are given below in Table 221.

Table 221.—Gauge height at Naraj corresponding to heights at Sambalpur.

Sambalpur.	Naraj.	Sambalpur.	Naraj.
1	2	3	4
24·0	83·1 (24)	31·5	87·8 (4)
24·5	83·5 (15)	32·0	87·2 (5)
25·0	84·2 (13)	32·5	88·2 (5)
25·5	83·4 (12)	33·0	.....
26·0	84·4 (14)	33·5	89·2 (6)
26·5	85·7 (17)	34·0	89·7 (3)
27·0	85·2 (11)	34·5	91·0 (1)
27·5	84·4 (11)	35·0	92·0 (1)
28·0	86·2 (9)	35·5	.....
28·5	85·0 (6)	36·0	.....
29·0	85·2 (4)	36·5	.....
29·5	87·5 (4)	37·0	.....
30·0	86·8 (5)	37·5	.....
30·5	85·5 (2)	38·0	91·0 (1)
31·0	88·4 (5)	...	.....

N. B.—The numbers within brackets give the size of samples.

*Mr. Shaw, in his typewritten note of 20th December 1938, states that the formula for relationship between Sambalpur and Naraj gauges does not work out sufficiently accurate for our purpose and better results are obtained by direct comparison of recent list of comparative readings. The margin of error is great as the large tributary Tel and many other small streams intervene between Sambalpur and Naraj and the distribution and timing of rainfall make a big variation.

Table 229.—Naraj and Sambalpur Gauge—August 2-day lag.

Naraj gauge height.	24·0	24·5	25·0	25·5	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	31·5	32·0	32·5	33·0	33·5	34·0	34·5	35·0	35·5	36·0	36·5	37·0	37·5	38·0	Totals.
92	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1							
91	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1	..	1	2	1	..	..	..	..	..	..	1	
90	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2										
89	..	..	..	..	..	..	..	..	1	..	..	1	..	..	1	2	1	..	..	1										
88	..	..	..	..	1	..	..	..	..	..	.	1	2	..	1	1	1	.	..	1										
87	1	1	1	..	..	1	3	1	3	1	..	1	1	1	2	..	1	2	..	1	1									
86	2	1	3	..	2	3	2	1	2	1	3	1	1	..	..	..	..	1												
85	5	4	3	4	2	3	2	3	2	2	..	..	1	..	..	1														
84	3	3	2	2	5	..	2	4	1	1	0	..	..	1																
83	5	1	1	2	3	..	2	1	..	1	1																			
82	4	1	1	3	1																									
81	2	1	2	1	..	..	..	1	..	.	..	..	..	..	..	..	1													
80																														
79	1																													
78																														
77																														
76																														
75	1	2																												
Totals.	24	15	13	12	14	7	11	11	9	6	4	4	5	2	5	4	5	5	0	6	3	1	1	—	—	—	—	—	1	168

Sambalpur gauge height.

Correlation between gauge readings below Naraj.

The correlations between the levels of a river channel at different places in the Delta are of interest in throwing considerable light on the course of the flood in the lower reaches of the Delta. Such correlations deserve careful study. I shall consider here one special case. Table 223 gives the maximum heights reached at different places in each year during the period 1887—1926. Correlations between such maximum heights have been worked out for various places, and are shown in Table 222.

The distances between different gauges are of interest in this connexion. I am giving below a few particulars.

The Suk Pyka takes off about eight miles from Jobra. Kulsai is situated in the 24th mile, Jaipur in the 29th mile, Taldanda in the 44th mile of the Taldanda canal. Paradip is at the tail of this canal which is 51¼ miles long, and is thus about 52 miles from Jobra.

Bellevue gauge is two miles 500 feet from the head of City Protective Embankment at Biranasi, and Lalbagh gauge is 900 feet from Bellevue, (Executive Engineer, Mahanadi Division, letter no. 8455-S., Cuttack, 14th—16th November, 1914), while Lalbagh is about 5¾ miles from Naraj on the Katjuri.

The off-take of Surua is about 3¾ miles from Lalbagh, and twelve miles further down is Gobindapur where the Daib takes off to the south. The head of the Daib is thus about 15¾ miles from Lalbagh, and 21½ miles from Naraj.

Karmanga gauge is located at the head of the Kundal (opposite Daib left embankment 1st mile) which takes off about three and quarter miles from Gobindapur (Thomson, page 11) and 24¼ miles from Naraj. Mundilo at the outfall of Biloakhye is opposite 7½ miles, Daib left embankment and is thus 9½ miles from Karmonga or about 38¾ miles from Naraj. Debidol is in the 15th mile of Daib left or 14 miles from Karmanga or 36¼ miles from Naraj.

On the left or north side of the Beropa weir is Chowdwar the head lock of High Level Canal Range 1, which is 17½ miles from Goil bank and 12 miles from Naraj. The Kendrapara canal starts from Jagatpur which is situated on the right or south side of the Beropa weir.

Rameswar is situated near the place where the Chota Ganguti used to take off to the north about 12 miles below Choudar. Gopalpur is situated at the place where the united waters of the Bura Ganguti and the Kimiria join the Beropa and is about 28 miles from Jobra. Indupur is the place near which the Beropa (taking together all its divided waters and the Kimiria branch of the Brahmini) joins the main stream of the Brahmini, and is about 36 miles from Chowdar.

Kendupatna is situated on the Chittartola and is about 16 miles from Jobra. Bosepur lies on the Noona about 12 miles below the place where it bifurcates from the Chittartola and is in the 31st mile of the Kendrapara canal. Marsaghai is in the 40th mile of the Kendrapara canal (Thomson, page 4) where the Chittartola and Noona unite again.

Table 222.—Correlation between maximum readings at different gauges in the same year in the Mahanadi Delta.

Serial no.	Gauges.	n.	Co-efficient of correlation.	Distance in miles (approx.)	Average height (feet).		Standard deviation (feet).		Period. (Omitted years mentioned within brackets.)
					First Gauge.	Second Gauge.	First Gauge.	Second Gauge.	
1	Naraj (1) × Bellevue (2) ..	39	+·8850	5½	87·90	78·40	2·69	2·67	1887—1926(1897).
2	,, × Jhinkiria	33	+·7798	9	88·24	51·66	2·49	1·53	1891—1926 (1899, 1914, 1915).
3	,, × Karmanga (2) ..	35	+·5964	24¾	87·92	46·26	2·72	2·57	1890—1926 (1914, 1915).
4	,, × Mundilo (2) ..	18	+·7463	31½	88·84	42·39	2·20	1·25	1907—1926 (1914, 1915.)
5	,, × Debidol (2) ..	34	+·5517	38¾	88·06	24·03	2·65	3·69	1890—1926 (1914, 1915).
6	,, × Jobra (2)	39	+·8850	10	87·81	71·77	2·77	2·05	1891—1926 (1897).
7	Jobra (1) × Sukpyka (2) ..	35	+·7450	8	71·91	58·25	2·11	2·11	1891—1926 (1897).
8	,, × Kulsai (2) ..	35	+·8965	23	71·91	37·26	2·11	3·26	1891—1926 (1897).
9	,, × Jaipur (2) ..	35	+·9058	26	71·91	30·96	2·11	3·16	1891—1926 (1897, 1900, 1919).
10	,, × Taldanda (2) ..	32	+·8316	41	71·85	14·71	2·17	2·42	1893—1926 (1897, 1912).
11	,, × Paradip (2) ..	29	+·9000	48½	72·18	8·33	2·16	2·01	1893—1926 (1897, 1912—15).
12	,, × Kendupatna (2) ..	33	+·9518	17½	71·89	46·39	2·16	2·65	1892—1926 (1897, 1919).
13	,, × Bosepur (2) ..	32	+·7481	22½	71·92	26·11	2·09	0·89	1892—1926 (1897, 1902, 1920).
14	,, × Marsaghai (2) ..	34	+·6692	40½	71·91	20·74	2·14	1·64	1892—1926 (1897).
15	,, × Rameswar (2) ..	27	+·7487	12½					1900—1926.
16	,, × Gopalpur (2) ..	35	+·6032	32½	71·87	49·63	1·99	2·60	1888—1926 (1889, 1897, 1915, 1916).
17	,, × Indupur (2) ..	36	+·5186	40½	71·89	30·42	2·10	2·19	1889—1926 (1897, 1899).

The correlations given in Table 222 decrease generally with increasing distance in each river channel, but there are big differences between different channels. For example, the Mahanadi, on the whole, shows much higher correlations than the other system, while correlations in the Katjuri-Daib are much lower. Correlations in the Beropa naturally enough have the lowest value, since the height in the lower portions of this river is determined to some extent by the level of the Brahmini.

In the Noona, the gauge at Bosepur shows a remarkably low standard deviation indicating that the level at this point is far more steady than the evel at other places.

The rather low value of the correlation (+0·7450) between Jobra and Sukpyka indicates probably the variable partition of the water into the different channels. The high value between Naraj and Mundilo is, of course, partly spurious, as it is based on only 18 years (1907—1926) during which flood levels were on the whole considerably above the general average.

Table 223.—Maximum gauge readings in the same year

Year.	(1) Naraj.	(2) Jobra.	(3) Sukpyka.	(4) Kulsai.	(5) Taldanda.	(6) Jajpur.	(7) Paradip.	(8) Kendra-para.	(9) Bosepur.
1887	82·50	71·17	..	..	..	..	..	..	..
88	85·80	70·20	..	..	..	..	..	..	..
89	86·75	71·00	..	..	..	..	..	..	..
90	83·00	69·70	..	..	..	..	..	..	..
91	87·10	71·64	56·05	32·51	..	30·86	..	..	..
92	91·50	73·78	55·38	39·05	17·30	35·30	..	49·70	26·17
93	87·75	70·00	58·05	32·61	10·00	29·30	8·80	40·50	26·10
94	89·40	72·29	57·75	37·17	15·35	36·40	10·00	48·20	26·20
95	90·55	72·02	58·02	40·45	16·10	34·57	11·00	49·70	25·80
96	92·10	75·00	59·20	41·16	17·75	34·41	12·10	47·00	26·40
98	85·30	69·57	56·30	32·70	12·41	26·70	6·00	42·40	25·00
99	82·10	68·35	53·89	31·80	12·49	25·10	3·60	41·20	24·10
1900	88·80	72·35	60·30	39·70	Nil	32·70	9·00	48·20	26·70
01	87·30	70·90	57·08	33·00	13·20	23·40	6·08	44·50	26·10
02	83·90	69·20	55·29	32·50	9·61	21·99	5·20	38·80	..
03	82·75	69·25	55·28	31·52	10·53	26·54	6·90	43·00	24·35
04	88·10	72·30	59·18	38·87	12·20	31·66	7·30	47·30	26·00
05	81·10	68·90	55·62	33·13	11·60	25·99	6·70	43·29	24·50
06	86·65	70·00	56·08	35·00	12·50	27·90	6·90	45·30	24·60
07	89·70	72·45	58·09	39·30	15·90	31·40	9·50	47·30	27·00
08	89·40	71·10	57·30	36·40	13·60	29·10	8·40	45·20	26·80
09	87·35	70·00	56·60	34·60	12·14	27·60	7·40	43·20	25·80
10	90·25	73·40	59·70	40·40	16·50	32·60	10·30	48·50	26·40
11	91·30	75·00	62·10	41·92	18·05	34·20	10·70	49·75	26·90
12	88·50	69·50	60·50	35·01	12·50	27·77	..	43·80	25·80
13	88·40	71·20	59·10	38·30	15·22	30·00	..	47·10	26·80
14	90·10	73·40	60·04	40·30	16·86	33·10	..	48·90	27·10
15	88·80	72·15	59·30	39·10	15·84	32·30	..	47·80	26·90
16	83·00	69·20	56·20	34·70	11·78	27·55	5·90	44·00	25·40
17	86·80	73·00	60·58	39·01	16·70	32·91	8·70	47·00	27·00
18	89·08	73·60	60·08	40·25	16·20	32·58	8·50	48·00	26·80
19	90·28	73·00	60·08	40·00	Nil	32·78	9·20	..	27·00
20	91·88	74·00	61·40	41·20	17·80	35·86	10·70	49·30	..
21	87·20	71·30	59·88	37·25	14·40	32·32	7·10	46·20	26·40
22	86·50	70·50	57·58	35·60	13·30	29·86	7·50	45·10	25·40
23	87·80	71·20	59·08	37·00	15·00	31·66	7·80	46·70	26·30
24	86·70	70·50	58·08	35·50	13·40	29·96	9·00	44·95	24·60
25	91·30	75·00	61·33	41·00	16·80	34·56	10·90	49·30	27·15
26	91·85	75·40	61·83	45·25	17·50	34·66	11·20	49·90	27·50

at different places in the Mahanadi Delta.

(10) Marshaghai.	(11) Rameswar.	(12) Bellevue.	(13) Daib.	(14) Karmanga.	(15) Debidol.	(16) Mundilo.	(17) Indupur.
..	..	78·80	..	..	..	..	..
..	..	76·80	..	..	..	..	..
..	..	78·00	..	..	..	..	25·70
..	..	..	..	47·70	..	..	23·10
..	..	76·53	..	48·60	20·35	..	23·00
..	..	83·00	49·80	49·21	22·55	..	25·60
23·00	..	78·23	53·80	51·85	22·18	..	23·80
21·40	..	80·00	57·30	50·93	22·67	..	28·70
21·60	..	81·00	53·00	50·73	22·18	..	25·30
21·70	..	82·87	51·90	48·79	23·65	..	28·30
23·30	..	75·60	51·70	49·26	10·20	..	..
19·90	..	76·80	50·34	44·37	10·50	..	22·60
18·50	..	72·80	49·71	37·20	16·40	..	..
22·40	49·90	80·00	51·84	46·00	26·90	..	24·40
21·60	49·15	77·12	51·59	45·40	22·00	..	25·40
20·30	46·70	74·50	49·39	43·86	19·91	..	25·30
19·90	45·80	74·50	48·84	43·35	19·39	..	22·90
20·90	51·70	79·60	52·09	46·14	24·23	..	24·60
19·70	45·50	75·00	49·38	43·60	20·80	..	21·70
20·70	46·80	74·50	51·00	44·80	21·40	..	24·70
18·20	50·90	79·20	52·59	46·30	23·40	41·70	30·00
17·20	48·80	78·20	52·34	46·10	23·13	41·20	24·70
16·30	46·80	77·18	51·59	45·70	21·30	40·20	24·60
21·90	52·70	80·02	56·24	47·00	23·70	43·20	24·00
23·30	45·90	83·30	53·50	47·00	24·90	43·80	25·30
21·40	47·00	75·40	50·60	44·64	20·00	40·90	23·30
21·00	49·70	78·07	53·20	45·83	22·30	42·50	27·60
21·70	52·00	80·10	Nil	..	..	..	25·50
21·10	50·70	78·80	Nil	..	..	..	20·20
18·90	46·20	74·80	49·30	43·75	26·00	40·55	21·60
21·10	51·35	79·85	52·70	46·75	29·55	43·80	25·30
20·90	51·20	79·30	52·20	46·50	29·50	43·20	24·00
21·40	52·30	79·80	52·39	45·50	29·00	43·30	25·00
22·20	52·60	82·85	52·84	47·00	29·90	43·33	30·00
20·10	51·20	76·90	51·50	45·75	27·83	42·20	24·40
19·00	49·10	76·30	50·84	45·00	27·15	42·50	23·40
22·20	51·60	78·15	51·64	45·75	28·20	42·10	26·60
18·80	46·90	77·00	50·34	44·75	26·80	40·70	21·20
21·40	54·00	81·30	52·59	47·00	29·60	43·40	24·80
22·20	53·60	82·85	52·59	47·05	30·00	44·70	28·70

PART V.—ANALYTIC STUDY OF THE BRAHMINI.

CHAPTER 30.—MONSOON RAINFALL IN THE BRAHMINI BASIN.

We shall now consider the rainfall in the Brahmini basin which has been divided for this purpose into two sections I and II which cover respectively the lower and upper reaches of the river and which have been described in greater detail in Chapter 6.

The monthly averages of daily rainfall in July, August, September for the two sections (Br. I and Br. II) of the Brahmini catchment area are given in Tables 224—225. The seasonal averages for the whole period of 92 days are given in column (5) of Tables 224—225. In the case of the Brahmini catchment, the average rainfall does exhibit certain peculiarities which require notice.

In Section I the tendency was for the average rainfall to increase for about 12 years from 1891 to 1902. It was then fairly steady for about 6 years between 1903 and 1908, after which a tendency to decrease set in which persisted for about 10 years from 1909 to 1918. From 1919 the rainfall steadily increased for 9 years from 1919 to 1928.

In Section II, rainfall increased from 1895 to 1904, was steady from 1905 to 1914, decreased again up to 1918, and has been increasing since then. The trend in Section II is not strictly identical with that in Section I, but both possess similar features. The rainfall tendency up to 1918 was of a broadly parabolic type in both sections with its minimum at 1918. Since then the rainfall increased appreciably in both sections up to 1928.

Table 224.—Average daily rainfall in inches for each month from July to September.

Brahmini Catchment, Section I, 1891—1928.

Year.	July.	August.	September.	July—September.
1892	·48	·20	·42	·37
93	·28	·28	·30	·31
94	·54	·23	·21	·33
95	·20	·28	·13	·20
96	·65	·46	·12	·41
97	·32	·43	·22	·32
98	·20	·30	·32	·30
99	·27	·19	·10	·19
1900	·32	·49	·53	·44
01	·28	·24	·18	·23
02	·62	·29	·14	·35
03	·43	·44	·22	·3.
04	·45	·49	·28	·41
05	·39	·25	·36	·33
06	·46	·30	·32	·36
07	·22	·58	·23	·34
08	·47	·77	·23	·50
09	·51	·35	·23	·36
1910	·47	·46	·33	·42
11	·22	·37	·31	·30
12	·49	·48	·25	·41
13	·58	·40	·20	·39
14	·49	·33	·40	·41
15	·35	·29	·33	·92

Table 224 (*concld.*).

Year.	July.	August.	September.	July—September.
1916	·30	·39	·20	·30
17	·40	·38	·33	·37
18	·22	·15	·17	·18
19	·46	·60	·16	·41
1920	·79	·35	·24	·46
21	·39	·28	·43	·36
22	·59	·26	·31	·39
23	·38	·31	·28	·32
24	·31	·35	·27	·31
25	·59	·44	·30	·44
26	·38	·74	·39	·51
27	·56	·49	·18	·42
28	·55	·26	·22	·55

Table 225.—Average daily rainfall in inches for each month from July to September.

Brahmini Catchment, Section II, 1891—1928.

Year.	July.	August.	September.	July—September.
1891	0·45	0·37	0·31	0·34
92	·46	·40	·15	·34
93	·31	·31	·43	·35
94	·64	·60	·19	·37
95	·50	·44	·23	·39
96	·70	·41	·11	·41
97	·50	·60	·27	·40
98	·63	·48	·34	·48
99	·54	·38	·04	·32
1900	·43	·60	·57	·53
01	·36	·66	·34	·45
02	·79	·36	·36	·50
03	·39	·49	·26	·38
04	·53	·52	·11	·39
05	·50	·33	·38	·40
06	·57	·29	·32	·39
07	·33	·88	·14	·46
08	·55	·75	·33	·51
09	·55	·44	·35	·44
1910	·37	·44	·26	·36
11	·25	·53	·34	·37
12	·54	·48	·17	·39
13	·58	·51	·14	·41
14	·50	·49	·29	·43
15	·35	·28	·25	·40
16	·24	·41	·23	·30
17	·51	·43	·33	·42
18	·24	·25	·21	·23
19	·46	·20	·20	·29
1920	1·20	·63	·19	·68
21	·47	·59	·26	·40
22	·59	·42	·36	·46
23	·58	·82	·13	·51
24	·52	·35	·43	·37
25	·69	·47	·23	·53
26	·53	·60	·42	·44
27	·69	·54	·19	·49
28	·52	·33	·23	·63

The average rainfall in each year for the Brahmini Catchment as a whole for the period 1891—1928 is given in Table 226.

Table 226.—Mean daily rainfall in the whole Brahmini Catchment (1891—1928).

Year.	No. of stations.	Mean rainfall (July—Sept.) in inches.	Year.	No. of stations.	Mean rainfall (July—Sept.) in inches.
1891	4	0".36	1910	18	0".38
92	5	·33	11	17	·34
93	8	·36	12	17	·40
94	8	·34	13	16	·40
95	8	·41	14	16	·42
96	8	·41	15	20	·36
97	8	·37	16	21	·30
98	8	·41	17	22	·40
99	8	·27	18	22	·21
1900	8	·50	19	22	·34
01	7	·42	1920	22	·58
02	8	·46	21	21	·38
03	11	·37	22	22	·43
04	15	·40	23	20	·42
05	15	·37	24	22	·34
06	17	·38	25	22	·49
07	17	·41	26	22	·47
08	17	·51	27	22	·46
09	18	·41	28	22	·59

Tables 227—228 give the average rainfall for each date from July 1 to September 30 in sections I and II of the Brahmini Catchment. The general features are similar in both sections. The average rainfall increases slowly as the season advances, attains a fairly steady value in the last week of July and the first week of August, and then begins to decrease at first slowly and then more rapidly in September.

Table 227.—Average rainfall in inches for each date from 1st July to 30th September

Brahmini Catchment—Section I, 1891—1928.

July	1 ..	0·35	August	1 ..	0·58	September	1	0·39
	2 ..	0·32		2 ..	·52		2	·36
	3 ..	0·39		3 ..	·33		3	·31
	4 ..	0·40		4 ..	·34		4	·34
	5 ..	0·36		5 ..	·36		5	·39
	6 ..	0·36		6 ..	·42		6	·37
	7 ..	0·24		7 ..	·43		7	·44
	8 ..	0·34		8 ..	·44		8	·30
	9 ..	0·41		9 ..	·32		9	·31
	10 ..	0·45		10 ..	·22		10	·28
	11 ..	0·42		11 ..	·27		11	·25
	12 ..	0·56		12 ..	·33		12	·30
	13 ..	0·48		13 ..	·39		13	·31
	14 ..	0·36		14 ..	·32		14	·35
	15 ..	0·40		15 ..	·34		15	·24
	16 ..	0·36		16 ..	·46		16	·19
	17 ..	0·42		17 ..	·48		17	·22
	18 ..	0·32		18 ..	·33		18	·26
	19 ..	0·31		19 ..	·43		19	·17

Table 227 (*concld.*).

20 ..	0·46	20 ..	·41	20	·21
21 ..	0·35	21 ..	·39	21	·19
22 ..	0·46	22 ..	·44	22	·23
23 ..	0·47	23 ..	·41	23	·28
24 ..	0·63	24 ..	·34	24	·26
25 ..	0·61	25 ..	·36	25	·27
26 ..	0·53	26 ..	·30	26	·16
27 ..	0·48	27 ..	·33	27	·19
28 ..	0·43	28 ..	·38	28	·22
29 ..	0·41	29 ..	·39	29	·14
30 ..	0·51	30 ..	·31	30	·13
31 ..	0·54	31 ..	·32		

Table 228.—Average rainfall in inches for each date from 1st July to 30th September

Brahmini Catchment—Section II, 1891—1928.

July	1 ..	0·39	August	1 ..	0·59	September	1	0·46
	2 ..	·31		2 ..	·48		2	·33
	3 ..	·51		3 ..	·50		3	·30
	4 ..	·44		4 ..	·36		4	·46
	5 ..	·58		5 ..	·54		5	·39
	6 ..	·51		6 ..	·66		6	·40
	7 ..	·56		7 ..	·70		7	·27
	8 ..	·47		8 ..	·47		8	·25
	9 ..	·47		9 ..	·41		9	·32
	10 ..	·47		10 ..	·36		10	·28
	11 ..	·55		11 ..	·42		11	·26
	12 ..	·49		12 ..	·41		12	·27
	13 ..	·46		13 ..	·53		13	·28
	14 ..	·44		14 ..	·56		14	·31
	15 ..	·49		15 ..	·43		15	·28
	16 ..	·49		16 ..	·50		16	·29
	17 ..	·40		17 ..	·54		17	·22
	18 ..	·37		18 ..	·50		18	·21
	19 ..	·44		19 ..	·60		19	·21
	20 ..	·69		20 ..	·55		20	·22
	21 ..	·68		21 ..	·48		21	·22
	22 ..	·54		22 ..	·51		22	·24
	23 ..	·42		23 ..	·53		23	·23
	24 ..	·63		24 ..	·46		24	·24
	25 ..	·62		25 ..	·44		25	·23
	26 ..	·60		26 ..	·32		26	·16
	27 ..	·58		27 ..	·38		27	·13
	28 ..	·49		28 ..	·37		28	·10
	29 ..	·56		29 ..	·43		29	·12
	30 ...	·55		30 ..	·39		30	·13
	31 ..	·59		31 ..	·33			

CHAPTER 31.—THE FREQUENCY DISTRIBUTION OF INTENSITIES OF RAINFALL IN THE BRAHMINI BASIN.

The frequency distributions of different intensities of rainfall in July, August, September and for the combined period for the two sections of the Brahmini catchment are given in Tables 229—230. The distribution covers the 38 years 1891—1928, and for each range of rainfall gives the number of days on which the actual rainfall lay within each range. For example, in Section II, September, range 1·00″—1·20″, we find the figure 22. This indicates that on 22 days in 38 years the daily average rainfall was of an amount lying between 1·00″ and 1·20″.

In Section I the highest range is 5·50″—6·00″, and in Section II, 5·00″—5·50″, showing that so far as the maximum is concerned there is not much difference between the two sections.

The accumulated totals are given in Table 231. The portion beyond 1·00″ were drawn on a large scale for each section and were graduated by a free hand curve. The graduated values divided by 38 give the probability (per season) which is shown in Table 232. From this table we can find directly the probability of occurrence (in number of days per season) on which the average rainfall is likely to reach or exceed any assigned value.

Table 229.—Frequency distribution of rainfall intensities in July, August, September and combined period July—September (1891—1928).

Brahmini Catchment—Section I.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	115	98	173	386
—·01	201	290	299	790
—·2	164	157	162	483
—·3	145	129	129	403
—·4	112	105	108	325
—·5	80	79	68	227
—·6	70	53	41	164
—·7	49	50	26	125
—·8	44	44	14	102
—·9	26	26	21	73
—1·0	23	28	16	67
—1·2	33	26	21	80
—1·4	27	20	13	60
—1·6	21	16	6	43
—1·8	8	10	7	25
—2·0	9	3	2	14
—2·5	9	6	3	18
—3·0	1	4	..	5
—3·5	7	1	1	9
—4·0	2	..	..	2
—4·5	..	1	..	1
—5·0	..	..	..	..
—5·5	1	..	..	1
—6·0	..	1	..	1

Table 230.—Frequency distributions of rainfall intensities in July, August and September and combined period July—September (1891—1928).

Brahmini Catchment—Section II.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	53	45	197	295
—·01	168	200	295	363
—·2	163	170	168	501
—·3	137	141	125	403
—·4	121	129	112	362
—·5	85	108	71	264
—·6	68	75	42	185
—·7	77	71	25	173

Table 230 (*concld.*).

—·8	59	50	15	124
—·9	51	39	21	111
—1·0	34	16	15	65
—1·2	58	48	22	128
—1·4	43	32	13	88
—1·6	15	20	6	41
—1·8	14	7	7	28
—2·0	6	3	2	11
—2·5	12	14	3	29
—3·0	8	4	..	12
—3·5	2	4	1	7
—4·0	..	..	..	..
—4·5	..	1	..	1
—5·0	3	1	..	4
—5·5	1	..	..	1
—6·0				

Table 231.—Accumulated frequencies of rainfall intensities for the period July—September (1891—1928).

Brahmini Catchment, Sections I and II.

Rainfall in inches in excess of	Br. I.	Br. II.	Rainfall in inches in excess of	Br. I.	Br. II.
·0	3404	3496			
·01	3018	3201			
·1	2228	2538	1·6	76	93
·2	1745	2037	1·8	51	65
·3	1342	1634	2·0	37	54
·4	1017	1272	2·5	19	25
·5	790	1008	3·0	14	13
·6	626	823	3·5	5	6
·7	501	650	4·0	3	6
·8	399	526	4·5	2	5
·9	326	415	5·0	2	1
1·0	259	350	5·5	1	
1·2	179	222			

Table 232.—Probability of occurrence (in number of days) of different intensities of rainfall in one season from July to September.

Brahmini Catchment Sections I and II, 1891—1929.

Rainfall in inches in excess of	Br. I.	Br. II.	Rainfall in inches in excess of	Br. I.	Br. II.
0·9	8·94	13·15	2·5	·42	·65
1·0	6·31	9·26	3·0	·26	·34
1·2	5·26	5·78	3·5	·15	·18
1·4	3·15	3·47	4·0	·10	·15
1·6	2·10	2·52	4·5	·05	·13
1·8	1·47	1·99	5·0	·05	·05
2·0	·78	1·15	5·5	·02	·02

In view of the importance of continued rainfall we have also investigated the moving averages from 2 to 10 days. For this purpose we decided to ignore lighter falls below 0·8". All daily rainfalls likely to yield an average of 0·8" for 2 or more consecutive number of days were specially marked, and the process of calculating moving average for 2, 3, 4 up to 10 consecutive days was completed with this selected material.

The results are given in Tables 233 and 234. The accumulated totals are given in Tables 235 and 236, and the per annum probability tables (which are obtained by dividing by 38) in Tables 237 and 238. It will be noticed that the probability of heavier rainfall occurring is much greater in section II.

Table 233.—Frequency distribution of average daily rainfall for 2—10 consecutive days (1891—1928).

Brahmini Catchment, Section I.

Range of Rainfall in inches.	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.	8 days.	9 days.	10 days.
1·0—1·1	38	30	24	39	22	17	16	27	23
—1·2	36	21	22	10	16	10	15	13	5
—1·3	25	21	11	17	10	7	13	4	4
—1·4	17	13	11	9	4	13	2	2	2
—1·5	15	10	7	7	7	4	2	2	3
—1·6	15	15	6	4	9	..	..	5	4
—1·7	6	4	6	2	..	1	2	4	
—1·8	2	5	5	1	..	..	5		
—1·9	0	5	1	6	..		1		
—2·0	6	1	..	..	1	4			
—2·1	3	4	3	..	..	1			
—2·2	4	2	..	..	1				
—2·3	5	2	2	..	3				
—2·4	..	..	2	1					
—2·5									
—2·6	..	..	..	2					
—2·7	1	1	..	1					
—2·8	..	2							
—2·9	..	..	2						
—3·0	..	2							
—3·1	1								
—3·2	1	..	1						
—3·3	1								
—3·4									
—3·5									
—3·6									
—3·7	..	1							
—3·8									
—3·9									
—4·0									
—4·1	1	1							

Table 234.—Frequency distribution of average daily rainfall for 2—10 consecutive days (1891—1928).

Brahmini Catchment, Section II.

Range of Rainfall in inches.	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.	8 days.	9 days.	10 days.
1·0—1·1	35	18	30	33	38	32	31	42	40
—1·2	22	21	27	31	22	20	31	28	20
—1·3	22	18	21	16	19	26	24	13	6
—1·4	16	18	15	13	16	15	4	5	6
—1·5	11	13	13	9	9	3	2	1	6
—1·6	11	17	7	8	8	4	4	7	6
—1·7	14	12	4	5	4	3	3	6	2
—1·8	10	16	8	4	1	1	4	..	1
—1·9	6	7	7	3	..	1	3	2	1
—2·0	10	7	4	1	2	4	..	1	2
—2·1	3	3	3	2	1	1	3	3	2
—2·2	3	4	1	1	1	2	3	1	
—2·3	3	2	3	1	3	4			
—2·4	2	7	..	1	1				
—2·5	3	4	..	..	2				
—2·6	2	4	..	2	1				
—2·7	..	3	..	..	1				
—2·8	..	1	..	2					
—2·9	2	1	2	1					
—3·0	..	2	..	1					
—3·1	1	..	1						
—3·2	..	..	1						
—3·3	3	..	1						
—3·4	1	..	1						
—3·5									
—3·6									
—3·7									
—3·8	..	2							
—3·9	1								
—4·0									
—4·1	1	1							
—4·2	2	1							
—4·3									
4·3—5·8	2	2							

Table 235.—Accumulated totals : Frequency distribution of average daily rainfall for 2—10 consecutive days.

Brahmini Catchment, Section I, 1891—1928.

Rainfall equalled or exceeding (in inches).	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.	8 days.	9 days.	10 days.
1·0	183	140	103	94	73	57	56	57	46
1·1	145	110	79	60	51	40	40	30	23
1·2	109	89	57	50	35	30	25	17	18
1·3	84	68	46	33	25	23	12	13	14
1·4	67	55	35	24	21	10	10	11	12
1·5	52	45	28	17	14	6	8	9	4
1·6	37	30	22	13	5	6	8	4	
1·7	31	26	16	11	5	5	6		
1·8	29	21	11	10	5	5	1		
1·9	23	16	10	4	5	5			
2·0	17	15	10	4	4	1			
2·1	14	11	7	4	4				
2·2	10	9	7	4	3				
2·3	5	7	5	4					
2·4	5	7	3	3					
2·5	5	7	3	3					
2·6	5	7	3	1					
2·7	4	6	3						
2·8	4	4	3						
2·9	4	4	1						
3·0	4	2	1						
3·1	3	2	1						
3·2	2	2							
3·3	1	2							
3·4	1	2							
3·5	1	2							
3·6	1	2							
3·7	1	1							
3·8	1	1							
3·9	1	1							
4·0	1	1							

Table 236.—Accumulated total of frequency distribution of average daily rainfall for 2—10 consecutive days.

Brahmini Catchment, Section II, 1891—1928.

Rainfall equalled or exceeding (in inches.)	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.	8 days.	9 days.	10 days.
1·0	186	184	149	134	129	122	112	109	92
1·1	151	166	119	101	91	90	81	67	52
1·2	129	145	92	70	69	64	50	39	32
1·3	107	127	71	54	50	38	26	26	26
1·4	91	100	56	41	34	23	22	21	20
1·5	80	96	43	32	25	20	20	20	14
1·6	69	79	36	24	17	16	16	13	8
1·7	55	67	32	19	13	13	13	7	6
1·8	45	51	24	15	12	12	9	7	5
1·9	39	44	17	12	12	11	6	5	4
2·0	29	37	13	11	10	7	6	4	2
2·1	26	34	10	9	9	6	3	1	
2·2	23	30	9	8	8	4			
2·3	20	28	6	7	5				
2·4	18	21	6	6	4				
2·5	15	17	6	6	2				
2·6	13	13	6	4	1				
2·7	13	10	6	4					
2·8	13	9	6	2					
2·9	11	8	4	1					
3·0	11	6	4						
3·1	10	6	3						
3·2	10	6	2						
3·3	7	6	1						
3·4	6	6							
3·5	6	6							
3·6	6	6							
3·7	6	6							
3·8	6	4							
3·9	5	4							
4·0	5	4							
4·1	4	3							
4·2	2	2							
4·3	2	2							

Table 237.—Probability of occurrence of assigned daily rainfall for 2—10 consecutive days in number of days per monsoon season : July—September.

Brahmini Catchment, Section I.

Rainfall equalled or exceeding (in inches.)	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.	8 days.	9 days.	10 days.
1·0	4·81	3·68	2·71	2·47	1·92	1·50	1·47	1·50	1·21
1·1	3·81	2·89	2·08	1·60	1·34	1·05	1·05	·79	·68
1·2	2·87	2·34	1·53	1·24	·92	·79	·58	·50	·47
1·3	2·21	1·60	1·11	·89	·63	·50	·39	·34	·36
1·4	1·76	1·29	·92	·61	·45	·34	·29	·26	·29
1·5	1·34	1·03	·71	·45	·32	·26	·21	·21	·24
1·6	1·03	·82	·58	·34	·21	·18	·16	·13	
1·7	·84	·60	·45	·26	·14	·14	·12		
1·8	·68	·55	·34	·21	·12	·12	·11		
1·9	·53	·45	·29	·18	·11	·08			
2·0	·42	·37	·21	·13	·09	·07			
2·1	·32	·29	·18	·11	·09				
2·2	·26	·26	·16	·08	·08				
2·3	·18	·21	·14	·07					
2·4	·16	·18	·11	·06					
2·5	·13	·16	·08	·05					
2·6	·11	·14	·07	·03					
2·7	·09	·13	·05						
2·8	·08	·11	·03						
2·9	·07	·08	·03						
3·0	·07	·07	·03						
3·1	·05	·05	·03						
3·2	·05	·05							
3·3	·04	·04							
3·4	·03	·03							
3·5	·03	·03							
3·6	·03	·03							
3·7	·03	·03							
3·8	·03	·03							
3·9	·03	·03							
4·0	·03	·03							

Table 238.—Probability of occurrence of assigned daily rainfall for 2—10 consecutive days in number of days per monsoon season : July—September.

Brahmini Catchment, Section II.

Rainfall equalled or exceeding (in inches).	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.	8 days.	9 days.	10 days.
1·0	4·89	4·84	3·92	3·53	3·93	3·21	2·95	2·87	2·42
1·1	3·99	4·37	3·13	2·66	2·39	2·37	2·13	1·76	1·37
1·2	3·30	3·81	2·42	1·84	1·81	1·68	1·30	1·03	·95
1·3	2·81	3·34	1·87	1·42	1·30	1·00	·79	·74	·71
1·4	2·39	2·87	1·47	1·08	·89	·72	·61	·58	·50
1·5	2·11	2·53	1·18	·84	·61	·53	·48	·45	·34
1·6	1·81	2·08	·97	·63	·48	·42	·37	·34	·26
1·7	1·45	1·74	·79	·50	·38	·37	·28	·26	·18
1·8	1·21	1·30	·61	·42	·32	·29	·24	·18	·13
1·9	·97	1·18	·44	·34	·20	·24	·18	·13	·08
2·0	·79	·97	·34	·20	·26	·18	·13	·08	·05
2·1	·69	·92	·26	·23	·24	·16	·09	·03	
2·2	·61	·79	·21	·75	·18	·13			
2·3	·53	·66	·20	·16	·16				
2·4	·48	·55	·17	·14	·13				
2·5	·42	·45	·16	·13	·09				
2·6	·38	·37	·14	·11	·05				
2·7	·34	·34	·13	·08	·04				
2·8	·31	·29	·12	·06					
2·9	·20	·22	·11	·05					
3·0	·26	·20	·09						
3·1	·24	·18	·08						
3·2	·21	·16	·08						
3·3	·20	·14	·08						
3·4	·18	·13							
3·5	·17	·12							
3·6	·16	·12							
3·7	·14	·11							
3·8	·13	·11							
3·9	·12	·09							
4·0	·11	·08							
4·1	·09	·08							
4·2	·08	·06							

CHAPTER 32—LEVEL OF THE BRAHMINI AT JENAPUR.

The present chapter gives a statistical analysis of the daily readings (taken at 8 A.M.) of the height of the Brahmini river at Jenapur for the three monsoon months July, August and September for the period 1875—1929 inclusive. Records for 1889 and 1890 for all three months and September 1876 are missing altogether. Records for certain other days are also missing here and there, so that the total number of readings available is 4,723.

The mean height of the river for each day in July, August and September is given in Table 239 and is shown in graphical form in Chart 8. The number of years for which data are available is also shown against each date.

It will be noticed that the average height of the river gradually rises from about 57 ft. in the beginning of July to over 60 ft. in the middle of August, and then slowly decreases to about 59 ft. towards the end of September. The rise of more than 3 ft. in the first 6 or 7 weeks, and the subsequent fall of about 2 ft. in the next few weeks represent the seasonal fluctuation due to the progress of the monsoon.

A parabolic graduation of the data is also given and a short list of graduated values is given in Table 240. It will be noticed from Chart 8 and Table 240 that the graduated values are in satisfactory agreement with the observed averages.

The equation to the parabola is given below :—

$$Y = 60{\cdot}17\ 49 + 0{\cdot}01\ 43\ 76(x) - 0{\cdot}00\ 12\ 76(x^2).$$

Where Y = graduated height

x = Actual date — 15th August.

Table 239.—Daily averages of the level of the Brahmini at Jenapur : 1875-1929.

[*N.B.*—Height in feet. The number of years available is shown under (*n*).]

July.			August.			September.		
Date.	n.	Height.	Date.	n.	Height.	Date.	n.	Height.
1	49	56·9	1	53	60·2	1	52	62·0
2	49	57·4	2	53	59·9	2	52	61·1
3	49	57·4	3	53	60·0	3	52	59·3
4	49	57·5	4	53	59·9	4	52	59·0
5	49	57·6	5	52	59·7	5	52	60·2
6	49	57·7	6	53	59·3	6	51	59·1
7	49	57·6	7	53	59·0	7	51	59·3
8	50	57·8	8	53	61·1	8	51	59·4
9	50	57·8	9	51	60·2	9	51	59·4
10	50	57·7	10	53	59·8	10	51	58·7
11	51	58·0	11	51	59·8	11	49	60·6
12	50	58·1	12	53	59·7	12	50	60·4
13	51	58·4	13	53	61·5	13	50	60·4
14	52	58·4	14	52	61·4	14	50	60·1
15	52	58·2	15	52	59·8	15	51	60·0
16	52	58·3	16	51	60·0	16	51	59·5
17	50	58·5	17	52	60·1	17	51	58·2
18	51	58·6	18	53	60·2	18	50	58·2
19	51	58·7	19	52	60·0	19	50	58·2
20	51	58·5	20	53	60·1	20	51	58·1
21	52	58·7	21	52	60·4	21	51	57·9
22	52	58·7	22	52	60·5	22	50	59·2
23	52	58·9	23	51	60·7	23	51	59·0
24	53	59·0	24	51	60·5	24	50	58·0
25	53	59·4	25	52	60·3	25	50	58·1
26	53	59·7	26	53	60·3	26	51	59·4
27	53	59·5	27	53	59·8	27	49	59·5
28	52	59·6	28	53	59·7	28	50	59·3
29	52	59·8	29	53	61·2	29	51	59·0
30	53	60·0	30	52	59·5	30	50	58·7
31	52	59·9	31	51	59·3			

Table 240.—Graduated Height (in feet) of the Brahmini at Jenapur, 1875-1929.

Date.		Graduated height in feet.	Observed height in feet.
July	1	56·94	56·9
	6	57·55	57·7
	11	58·10	58·0
	16	58·59	58·3
	21	59·01	58·7
	26	59·37	59·7
	31	59·67	59·9
August	5	59·90	59·7
	10	60·07	59·8
	13	60·14	60·5
	15	60·17	59·8
	16	60·18	60·4
	17	60·19	60·1
	18	60·20	60·2
	19	60·21	60·0
	20	60·21	60·1
	25	60·19	60·3
	30	60·17	59·5
September	4	59·95	59·0
	9	59·63	59·4
	14	59·45	60·1
	19	59·11	58·2
	24	58·70	58·0
	29	58·23	59·0

In view of the fact that the average height of the river depends on the time of the season it has been thought advisable to analyse the data separately for each month. Table 241 gives the average height for each year separately for each month, and Chart 9 the corresponding graphs.

As the seasonal fluctuation is on the whole quite smooth and gradual we are justified in pooling together the data for all three months, and calculating the average height for the combined period of three months. These figures are given in col. (4) of Table 241, and are shown in a graphical form in Chart 9.

The details of the analysis of variance for the whole period 1875—1929 for July, August and September, and the combined monsoon period will be found in Table 242. In every case the fluctuations from one year to another appear to be far stronger than variations within the year. In other words, each year has an individual character of its own; it may be either a year of high river levels or one of low river levels, and more rarely of high levels at one time and low levels at another time in the same season.

As the different years are significantly differentiated from one another I next tried to find out whether there is any definite secular trend. For this purpose I fitted the best straight line to the data for the average river level in each of the three months July, August and September; and also for the combined period July—September. The equations to these straight lines are given just after Table 242.

Table 241.—Annual Average Height (in feet) of the Brahmini at Jenapur, 1875—1929.

Years.	July.		August.		September.		Combined.	
	n.	Height.	n.	Height.	n.	Height.	n.	Height.
1875	31	58·2±·44	31	59·3±·11	30	59·0±·23	92	58·8±·17
76	31	58·2±·38	31	59·4±·18	..	..	62	58·8±·21
77	31	56·8±·30	31	59·0±·35	30	57·8±·22	92	57·9±·18
78	31	55·7±·10	31	59·0±·24	30	57·5±·10	92	57·4±·14
79	31	58·0±·02	31	60·2±·58	30	58·3±·10	92	58·9±·21
80	31	57·5±·14	31	59·3±·17	30	58·1±·25	92	58·4±·12
81	31	60·5±·33	31	61·6±·17	30	57·2±·15	92	59·9±·18
82	31	59·6±·32	30	59·8±·24	30	56·6±·23	91	58·8±·20
83	31	58·6±·23	30	59·4±·38	30	58·9±·18	91	59·1±·16
84	30	58·0±·13	30	58·5±·16	29	60·2±·19	89	59·0±·11
85	31	59·3±·18	30	60·2±·22	30	59·3±·06	91	59·7±·10
86	31	58·8±·13	31	58·7±·17	30	58·5±·19	92	58·7±·09
87	31	58·3±·14	31	58·7±·21	30	57·6±·12	92	58·2±·10
88	31	58·1±·17	31	61·5±·40	30	57·9±·13	92	59·2±·19
89	No record.							
90	No record.							
91	31	57·6±·23	31	59·8±·21	30	59·3±·25	92	58·9±·13
92	31	59·9±·29	31	57·8±·11	30	58·2±·30	92	58·6±·15
93	31	58·2±·28	31	59·0±·38	30	60·7±·27	92	59·3±·17
94	31	60·2±·33	31	61·5±·49	30	59·2±·14	92	59·9±·17
95	31	58·9±·21	31	60·5±·12	30	57·8±·09	92	59·1±·12
96	31	60·6±·30	31	60·9±·40	30	57·2±·29	92	59·6±·21
97	31	57·7±·05	31	60·5±·22	30	58·2±·05	92	58·8±·12
98	31	58·4±·13	31	59·8±·22	5	58·4±·39	67	59·0±·13
99	31	58·7±·21	31	58·4±·13	30	57·9±·07	92	58·3±·09
1900	31	58·2±·25	31	61·2±·26	30	60·5±·32	92	60·1±·17
01	31	57·8±·08	31	59·4±·31	30	59·5±·33	92	58·9±·16
02	31	60·0±·28	31	58·6±·13	30	58·2±·30	92	59·0±·14
03	23	58·2±·20	31	58·2±·16	30	58·1±·09	84	58·2±·09
04	31	60·1±·34	31	60·6±·30	30	58·1±·21	92	59·6±·18
05	31	57·6±·12	31	56·6±·38	30	57·8±·25	92	57·3±·16
06	31	58·0±·28	31	58·0±·15	30	58·0±·31	92	58·0±·15
07	31	58·1±·17	31	62·0±·26	29	60·1±·31	91	60·2±·20
08	24	59·7±·20	31	62·9±·25	30	59·8±·18	85	60·9±·17
09	30	59·7±·20	28	60·2±·24	26	59·8±·18	84	60·4±·16
10	27	57·8±·26	30	59·9±·06	30	58·1±·22	88	58·5±·15
11	31	56·7±·23	31	60·4±·30	30	59·4±·18	92	58·8±·18
12	31	57·5±·23	31	60·1±·34	30	57·4±·40	92	58·4±·21
13	31	57·8±·46	31	60·8±·46	30	57·0±·14	92	58·5±·18
14	31	57·8±·42	30	59·7±·25	30	58·2±·19	92	58·4±·14
15	31	57·7±·21	31	57·0±·17	30	57·8±·13	92	57·5±·10
16	31	56·1±·24	31	59·2±·29	29	56·9±·18	91	57·4±·17
17	30	57·8±·17	31	60·8±·34	30	58·5±·15	92	59·0±·17
18	30	55·8±·19	31	59·0±·26	30	57·5±·29	92	57·4±·17
19	31	58·3±·37	31	61·7±·26	30	59·4±·41	92	59·8±·21
20	30	61·6±·50	31	62·7±·40	25	58·2±·30	87	60·9±·28
21	31	56·5±·35	31	60·6±·24	29	59·2±·26	91	58·8±·20
22	31	59·4±·37	31	59·4±·21	30	59·6±·25	92	59·5±·20
23	31	57·6±·30	31	62·7±·35	30	58·4±·15	92	59·6±·16
24	31	57·8±·33	31	58·8±·20	30	59·6±·13	92	58·7±·27
25	31	63·0±·14	31	60·7±·22	30	58·4±·50	92	60·7±·22
26	9	56·8±·36	31	61·1±·40	29	61·8±·23	69	60·8
27	14	60·7±·84	28	62·8±·40	29	57·9±·37	71	60·5±·33
28	31	59·1±·39	22	56·2±·25	30	57·4±·33	83	57·8±·21
29	31	60·6±·61	31	62·5±·37	30	57·6±·27	92	60·2±·29

Table 242.—Analysis of Variance : Height of the Brahmini at Jenapur.

Nature of variation.	Degrees of freedom.	Sum of squares.	Mean squares.
(1) July : 1875 to 1929.			
Total	1579	1114076	705·56
Within years	1527	817026	535·05
Between years	52	297050	5712·50
Linear Regression ..	1	4189	4189·00
Deviations from Lin. Reg. ..	51	292861	5742·37
(2) August : 1875 to 1929.			
Total	1621	1202280	741·69
Within years	1569	885139	..
Between years	52	317141	6098·87
Linear Regression ..	1	22907	22907·00
Deviations from Lin. Reg. ..	51	294234	5769·29
(3) September : 1875 to 1929.			
Total	1520	726256	477·80
Within years	1469	544246	370·49
Between years	51	182058	3569·76
Linear Regression ..	1	596	596·00
Deviation from Lin. Reg. ..	50	181462	3629·24
(4) Combined : 1875 to 1929.			
Total	4722	3261194	..
Within years	4670	2866468	613·80
Between years	52	394726	7590·9
Linear Regression ..	1	1944	1944·0
Deviation from Lin. Reg. ..	51	392782	..

Linear Regression Equations for secular trends are given below :

July, $J = 58{\cdot}4868 + {\cdot}010772\ (t-1902)$.

August, $J = 59{\cdot}9164 + {\cdot}024697\ (t-1902)$.

September, $J = 58{\cdot}5040 + {\cdot}004144\ (t-1902)$.

Combined, $J = 58{\cdot}9818 + {\cdot}013387\ (t-1902)$.

Where J = Height of Brahmini at Jenapur (in feet).

t = Year (from 1875 to 1929).

The actual change in feet per year is shown below :—

Table 243.—Rate of change of average annual height of Brahmini at Jenapur : 1875—1929.

Month	(n)	(b) in feet per year with P.E.
July	1580	$+{\cdot}0108 \pm 0029$.
August	1622	$+{\cdot}0247 \pm 0029$.
September	1521	$+{\cdot}0041 \pm 0025$.
Combined	4723	$+{\cdot}0139 \pm 0017$.

Comparing with the values of the probable error of "b" we notice that for September the change is not significant. The rise is statistically significant in other cases. The magnitude of the rise in the average height of the river is, however, extremely small. August shows the greatest change, but

even here we have a rise of only 0·0227 ft. per year, that is 0·247 ft. or about three inches in 10 years. For the month of July the rise is only 0·108 ft. or about 1·3 inches per 10 years. For the entire period of 53 years this represents a total rise of less than 7 inches.

It is clear then that the secular change for the entire period is extremely small. The residual variation (deviations from the Linear Regression, Table 242) is high, showing that the small secular trend is unable to account for the greater part of the fluctuations from year to year.

It has been suggested, however, that since about 1920 the level of the river has suffered a permanent change (*Orissa Flood Committee*, 1928, p. 29). I have, therefore, analysed the data separately for the period 1915—1929. Details of analysis will be found in Table 244.

Table 244.—Analysis of variance : Height of the Brahmini at Jenapur.

Nature of variation.	Degrees of freedom.	Sum of squares.	Mean square.
(1) July : 1915—1929.			
Total	422	507705	1203·09
Within years	408	343073	840·87
Between years	14	164632	11759·43
Linear Regression ..	1	51201	51201·00
Deviation from Lin. Reg. ..	13	113431	8725·46
(2) August : 1915 to 1929.			
Total	452	423075	936·01
Within years	438	262466	599·24
Between years	14	160609	11472·07
Linear Regression ..	1	16369	16369·00
Deviation from Lin. Reg. ..	13	144240	11095·38
(3) September : 1915 to 1929.			
Total	440	283233	643·71
Within years	426	220668	518·00
Between years	14	62565	4468·93
Linear Regression ..	1	2300	2300·00
Deviations from Lin. Reg. ..	13	60265	4635·77
(4) Combined : 1915 to 1929.			
Total	1316	1312417	997·28
Within years	1302	1138072	874·10
Between years	14	174345	12453·21
Linear Regression ..	1	53212	53212·00
Deviation from Lin. Reg. ..	13	121133	9317·92

The rate of change during this period is shown in Table 245.

Table 245.—Rate of change of average height of Brahmini at Jenapur, 1915—1929.

Month	(n)	(b) in ft. per year & P. E.
July	423	0·2563±·0215.
August	453	±·0220.
September	441	·0526±·0185.
Combined	1317	·1477±·0132.

The magnitude of the change is also now much greater. For July there appears to be a rise of over 3 inches per year, or about 3 feet 10 inches during

the period 1915 to 1929. The combined rate of rise is just about 1½ inches per year, which represents a total rise of about 2 feet 3 inches in 15 years.

The persistent rise during 1915 to 1929 cannot, therefore, be considered a chance fluctuation. I do not think, however, that we shall be justified in inferring that a permanent change in the bed of river has taken place. It is known that distinct periods (extending over a number of years) of persistent increase (or decrease) of rainfall occur from time to time without any permanent change in the character of the average rainfall. It is possible that the rise in the average height of the river during 1915 to 1929 is associated with one such period of increasing rainfall. The analysis of rainfall in the Brahmini catchment supports this view, and this point has been discussed more fully in Chapter 39.

It is interesting to note that just as 1915—1929 appears to be a period of persistent rise, the period 1908—1915 appears to be one of persistent decrease in the average height of the river. The details of the analysis of variance for the period 1908—1918* will be found in Table 246.

Table 246.—Analysis of variance.

Brahmini : Jenapur gauge.

Nature of variation.	Degrees of freedom.	Sum of squares.	Mean squares.
(1) July : 1908 to 1918.			
Total	326	166573	510·96
Within years	316	125029	395·66
Between years	10	41544	4154·40
Linear Regression ..	1	19806	19806·00
Deviation from Lin. Reg. ..	9	21738	2415·33
(2) August : 1908 to 1918.			
Total	335	243641	727·29
Within years	325	179678	552 86
Between years ..	10	63963	6396 63
Linear Regression ..	1	6052	6052·00
Deviation from Lin. Reg. ..	9	57911	6434·55
(3) September : 1908 to 1918.			
Total	321	127788	394·41
Within years	314	95676	304·70
Between years	10	32112	3211·20
Linear Regression ..	1	13486	13486·00
Deviation from Lin. Reg. ..	9	18626	2069·55
(4) Combined : 1908 to 1918.			
Total	986	636984	645·37
Within years	977	581168	594·85
Between years	10	55816	5581.60
Linear Regression ..	1	53809	53809.00
Deviation from Lin Reg ..	9	2007	223·00

Again with the single exception of September all the other rates of change are significant.

*I have taken the period 1908—1918 to minimise the magnitude of the rate of fall. For 1908—1918, the rate of fall would be larger.

The rate of fall during 1908—1918 is given in Table 247.

Table 247.—Rate of change of the height of Brahmini at Jenapur : 1908—1918.

Month.	n	b in ft. per year with p. e.
July	327	−0·2515±·0273
August	336	−·1344±·0307
September	325	−·2045±·0221
Combined	988	−·2334±·0163

All rates of change are definitely significant. The magnitude of the fall in average height is also considerable. For July, it exceeds 3 inches per year on an average.

In view of the persistent change in opposite directions during two periods extending over 10 and 15 years respectively, it is clearly not possible to assert that only the latter change is of a permanent character.

The question of the nature of fluctuations from year to year is of some interest in this connection. The standard deviations for each month as well as for the combined period are given in Table 248.

Fluctuations in July appear to have increased slightly in recent years. This has also caused a small increase in the magnitude of the fluctuations for the combined period of three months. The fluctuations in August on the other hand have decreased while in September remain practically unaffected. On the whole the nature of the fluctuations (as measured by the standard deviation) has not changed appreciably.

Table 248.—Standard Deviations in feet of Fluctuations in the height of the Brahmini at Jenapur.

Year.	July.		August.		September.		Combined.	
	n.	S. D.	n.	S. D.	n.	S. D.	n.	S. D.
1875	31	3·69±·32	31	0·94±·08	30	1·83±·16	92	2·46±·17
76	31	3·12±·27	31	1·45±·12	..	..	62	2·50±·15
77	31	2·48±·21	31	2·92±·25	30	1·76±·15	92	2·59±·18
78	31	1·55±·13	31	1·96±·17	30	0·84±·07	92	2·05±·14
79	31	0·17±·01	31	4·82±·41	30	0·81±·07	92	2·06±·21
80	31	1·14±·10	31	1·39±·12	30	2·07±·18	92	1·73±·12
81	31	2·73±·23	31	1·41±·12	30	1·20±·10	92	2·59±·18
82	31	2·63±·23	30	1·95±·17	30	1·89±·16	91	2·81±·20
83	31	1·91±·16	30	3·09±·26	30	1·50±·13	91	2·27±·16
84	30	1·05±·09	30	1·32±·11	29	1·55±·13	89	1·58±·11
85	31	1·48±·13	30	1·79±·15	30	0·46±·04	91	1·41±·10
86	31	1·11±·10	31	1·43±·12	30	1·51±·13	92	1·33±·09
87	31	1·13±·10	31	1·74±·15	30	1·01±·09	92	1·39±·10
88	31	1·43±·12	31	3·31±·28	30	1·06±·09	92	2·71±·19
				No record.				
91	31	1·90±·16	31	1·71±·15	30	2·04±·18	92	1·90±·13
92	31	2·43±·21	31	0·92±·79	30	2·40±·21	92	2·14±·15

Table 248—(*concld*).

Years.	July.		August.		September.		Combined.	
	n.	S. D.	n.	S. D.	n.	S. D.	n.	S. D.
93	31	2·32±·20	31	3·10±·27	30	2·23±·19	92	2·45±·17
94	31	2·75±·24	31	4·06±·35	30	1·12±·10	92	2·39±·16
95	31	1·72±·15	31	1·00±·09	30	0·76±·07	92	1·67±·12
96	31	3·25±·28	31	3·29±·28	30	2·33±·20	92	3·00±·21
97	31	0·40±·03	31	1·83±·16	30	0·42±·04	92	1·66±·12
98	31	1·06±·09	31	1·79±·15	5	1·29±·28	67	1·60±·13
99	31	1·76±·15	31	1·09±·09	30	0·53±·05	92	1·25±·09
1900	31	2·05±·18	31	2·16±·19	30	2·58±·22	92	2·39±·17
01	31	0·71±·06	31	2·58±·22	30	2·70±·23	92	2·30±·16
02	31	2·31±·20	31	1·06±·09	30	2·42±·21	92	2·08±·15
03	23	1·67±·16	31	1·31±·11	30	0·70±·06	84	1·24±·96
04	31	2·83±·24	31	2·47±·21	30	1·70±·15	92	2·58±·18
05	31	0·99±·08	31	3·16±·27	30	2·02±·18	92	2·28±·16
06	31	2·35±·20	31	1·24±·11	30	2·48±·22	92	2·07±·15
07	31	1·43±·12	31	3·18±·27	29	2·46±·21	91	2·91±·21
08	24	1·47±·14	31	2·04±·17	30	1·43±·12	85	2·26±·12
09	30	1·66±·14	28	1·86±·16	26	1·35±·13	84	2·13±·11
10	27	2·04±·19	30	0·45±·04	30	1·76±·15	88	2·02±·14
11	31	1·86±·16	31	2·51±·21	30	1·43±·12	92	2·53±·18
12	31	1·94±·17	31	2·80±·24	30	3·27±·28	92	2·96±·21
13	31	3·82±·33	31	3·81±·33	30	1·10±·09	92	3·56±·25
14	31	1·01±·09	30	2·04±·17	30	1·56±·14	92	1·96±·14
15	31	1·71±·14	31	1·40±·12	30	1·07±·09	92	1·45±·10
16	31	1·96±·17	31	2·36±·20	29	1·41±·12	91	2·36±·17
17	30	1·41±·13	31	2·77±·24	30	1·20±·10	92	2·44±·17
18	30	1·52±·13	31	2·13±·18	30	2·32±·20	92	2·46±·17
19	31	3·09±·26	31	2·14±·18	30	3·34±·29	92	2·90±·21
20	30	4·04±·35	31	3·27±·28	25	2·26±·22	87	3·93±·20
21	31	2·89±·25	31	1·96±·17	29	2·04±·18	91	2·90±·20
22	31	3·07±·26	31	1·76±·15	30	2·01±·17	92	2·33±·16
23	31	2·48±·21	31	2·90±·25	30	1·18±·10	92	3·23±·23
24	31	2·69±·23	31	1·64±·14	30	1·05±·09	92	2·04±·14
25	31	1·13±·10	31	1·81±·15	30	4·05±·35	92	3·20±·16
26	9	1·62±·26	31	3·30±·28	29	1·84±·16	69	2·98±·17
27	14	4·64±·59	28	3·13±·28	29	2·97±·26	71	4·04±·23
28	31	3·26±·28	22	1·75±·18	30	2·68±·23	83	2·90±·15
29	31	5·01±·45	31	3·06±·26	30	2·21±·19	92	4·12±·29

CHAPTER 33.—THE FREQUENCY DISTRIBUTION OF THE HEIGHT OF THE BRAHMINI AT JENAPUR.

I shall now consider the frequency of occurrence of different heights of the river. A complete frequency distribution for each month separately as well as for the monsoon period of 3 months, grouped in intervals of 0·5 feet (6 inches), is given in Table 249. The graph for the combined period is shown in Chart 10.

As the frequency distributions for each month on the whole show similar characteristics, the discussion has been confined to the combined period of three months.

The frequency distribution presents certain peculiarities. At first the rise is gradual and rather slow. This continues up to a height of about 56·2 feet. The frequency then increases very suddenly, in big jumps, to about 58·7 feet. After which there is a precipitous drop to the range 58·8—59·2 feet and 59·3—59·8 feet. Beyond 60 feet the drop is more gradual, although between 61·3 feet and 63·3 feet the readings are abnormally high.

The nature of the frequency distribution indicates the existence of appreciable discontinuities in the volume of discharge at different heights of the river level. For example at about 59 feet the volume of the discharge probably increases very suddenly.

The irregular character of the frequency distribution made the task of graduation extremely difficult. After a large number of trials, Pearson's Type VI was used for graduating the readings for the whole range. The constants and equation for the Type VI curve are given in Table 250 and the graph is shown in Chart 10. The observed and graduated values are given in Table 251. The fit is not satisfactory, but considering the nature of the material is not unreasonable.

Table 249.—Frequency Distribution of the Height of the Brahmini at Jenapur gauge (1375—1929).

Range in feet.	Mid-point.	July.	August.	September.	July—Sept. Combined.
52·8—53·2	53·0	4	0	1	5
53·3—53·7	53·5	12	4	5	21
53·8—54·2	54·0	17	2	14	33
54·3—54·7	54·5	43	8	16	67
54·8—55·2	55·0	50	8	24	82
55·3—55·7	55·5	59	10	47	116
55·8—56·2	56·0	55	27	63	145
56·3—56·7	56·5	111	58	90	259
56·8—57·2	57·0	127	72	115	314
57·3—57·7	57·5	166	106	164	436
57·8—58·2	58·0	179	130	202	511
58·3—58·7	58·5	222	193	234	649
58·8—59·2	59·0	94	137	112	343
59·3—59·7	59·5	89	138	109	336
59·8—60·2	60·0	58	108	66	232
60·3—60·7	60·5	42	115	55	212
60·8—61·2	61·0	43	87	41	171
61·3—61·7	61·5	27	56	45	128
61·8—62·2	62·0	29	66	15	110
62·3—62·7	62·5	32	49	27	108
62·8—63·2	63·0	27	53	21	101
63·3—63·7	63·5	14	54	17	85
63·8—64·2	64·0	14	22	9	45
64·3—64·7	64·5	11	26	8	45
64·8—65·2	65·0	11	23	9	43
65·3—65·7	65·5	8	18	5	31
65·8—66·2	66·0	9	8	4	21
66·3—66·7	66·5	9	8	0	17

Table 249—(*concld.*).

Range in feet.	Mid-point.	July.	August.	September.	July—Sept. Combined.
66·8—67·2	67·0	2	10	1	13
67·3—67·7	67·5	3	5	0	8
67·8—68·2	68·0	4	4	..	8
68·3—68·7	68·5	3	5	..	8
68·8—69·2	69·0	1	4	..	5
69·3—69·7	69·5	1	4	..	5
69·8—70·2	70·0	4	1	..	5
70·3—70·7	70·5	..	1	..	1

Table 250.—Constants for Pearson Curve of Type VI : Height of the Brahmini at Jenapur.

Period : Combined (July, August, September), 1875—1929.

Range : 52·8—70·7 feet N=4719.

Grouping unit=0·5 feet.

Observed moments.

$\mu_2 =$ 26·523152
$\mu_3 =+$ 129·921708
$\mu_4 =$ 3154·383700

$\beta_1 =$ 0·904666
$\beta_2 =$ 4·483986

S. D. = 2·575032

Equation to curve.

$y = y_0 (x-a) y = y_0 (x-a) q^2 x - q^1$

Origin at	—	7·04601
Curve starts at		52·88979
Mean	=	59·00509
Mode	=	57·87330
r	=	−60·935056
a	=	+119·8716
q_1	=	+68·155344
q_2	=	+5·220288
log y_0	=	141·428667

Table 251.—Observed and Graduated Frequencies (Type VI curve): Height of the Brahmini at Jenapur.

Period : July—September, 1875—1929, N=4719.

Range in feet.	Frequencies.		Range in feet.	Frequencies.	
	Observed.	Graduated.		Observed.	Graduated.
53·3—53·7	26	4·0	62·3—62·7	108	112·5
53·8—54·2	33	18·5	62·8—63·2	101	89·0
54·3—54·7	67	50·5	63·3—63·7	85	69·5
54·8—55·2	82	103·5	63·8—64·2	45	56·0
55·3—55·7	116	168·5	64·3—64·7	45	38·5
55·8—56·2	145	260·5	64·8—65·2	43	28·5
56·3—56·7	259	319·0	65·3—65·7	31	21·0
56·8—57·2	314	367·5	65·8—66·2	21	16·5
57·3—57·7	436	404·5	66·3—66·7	17	14·0
57·8—58·2	511	399·5	66·8—67·2	13	11·5
58·3—58·7	649	386·5	67·3—67·7	8	8·5
58·8—59·2	343	362·0	67·8—68·2	8	6·5
59·3—59·7	336	329·0	68·3—68·7	8	5·0
59·8—60·2	232	287·5	68·8—69·2	5	2·5
60·3—60·7	212	245·0	69·3—69·7	5	2·5
60·8—61·2	171	216·0	69·8—70·2	5	1·5
61·3—61·7	128	172·0	Beyond 70·2	1	1·0
61·8—62·2	110	140·5			

As the higher levels are of greater interest in connection with floods the frequencies beyond 58·2 feet were graduated separately by a Pearson Type I curve. The constants, etc., will be found in Tables 252 and 253

Table 252.—Constants for Pearson Type I curve : Height of the Brahmini at Jenapur.

Period : Combined (July, August, September) 1875—1929.

Range :— 59·2 feet to 70·7 feet. N=2081.

Grouping unit=0·5 feet.

Observed moments.	Equation of curve.
$\mu_2 = +\ 18{\cdot}817015$	$Y = Y_0 \left(1+\frac{x}{A_1}\right)^{m_1} \left(1-\frac{x}{A_2}\right)^{m_2}$
$\mu_3 = +\ 108{\cdot}197191$	
$\mu_4 = +1640{\cdot}681799$	Origin at 61·196
$\beta_1 = 1{\cdot}757032$	Mean at 61·196
$\beta_2 = 4{\cdot}633645$	Start of curve at 58·853849
	$\log Y_0 = 2{\cdot}204758$
S. D. $= 2{\cdot}16895$	$r = 5{\cdot}619145$
	$A_1 = +\ 4{\cdot}684302$
	$A_2 = +26{\cdot}589381$
	$m_1 = -\ 0{\cdot}158339$
	$m_2 = +\ 3{\cdot}777484$

Table 253.—Ordinates of Pearson Type I curve : Height of the Brahmini at Jenapur.

Period : Combined (July, August, September), 1875—1929.

Grouping Unit=0·5. N=2081.

x=Height in feet.	Ordinates.	x=Height in feet.	Ordinates.
59·2	368·8	66·7	17·60
59·7	282·1	67·2	13·56
60·2	230·12	67·7	10·26
60·7	191·35	68·2	7·64
61·2	160·23	68·7	5·54
61·7	134·4	69·2	3·93
62·2	112·7	69·7	2·67
62·7	94·26	70·2	1·75
63·2	78·52	70·7	1·10
63·7	65·03	71·2	0·63
64·2	53·52	71·7	0·269
64·7	43·72	72·2	0·160
65·2	35·41	72·7	0·063
65·7	28·39	73·2	0·018
66·2	22·50		

Observed and graduated values are given in Table 254.

Table 254.—Observed and Graduated Frequencies (Pearson Type I curve) : Height of the Brahmini at Jenapur.

Combined period :—July—September, 1875—1929.

Range : 59·3—70·7 feet. Grouping unit=0·5 feet. N=1748.

Range in feet.	Frequency of heights of the Brahmini in feet.		Range in feet.	Frequency of heights of the Brahmini in feet.	
	Observed.	Graduated.		Observed.	Graduated.
59·3—59·7	336	315	66·3—66·7	17	19·5
59·8—60·2	232	250	66·8—67·2	13	14·5
60·3—60·7	212	205	67·3—67·7	8	11·0
60·8—61·2	171	172	67·8—68·2	8	9·00
61·3—61·7	128	146	68·3—68·7	8	6·00
61·8—62·2	110	122·5	68·8—69·2	5	4·10
62·3—62·7	108	103	69·3—69·7	5	3·00
62·8—63·2	101	85·5	69·8—70·2	5	2·00
63·3—63·7	85	75	70·3—70·8	1	1·40
63·8—64·2	45	58	70·8—71·2	0	0·85
64·3—64·7	45	47·5	71·3—71·8	0	0·38
64·8—65·2	43	39	71·8—72·2	0	0·18
65·3—65·7	31	32	72·3—72·8	0	0·09
65·8—66·2	21	25·5			
				1748	1748·00

The graduation is now excellent, and the graduated values may be safely used for calculating the probability of occurrence of readings equal to or greater than any assigned magnitude. This is given in Table 255. In column (3) of this table will be found (n) the number of days per year on which the level of the Brahmini at Jenapur is likely to be equal to or exceed the height given in column (1).

Table 255.—Probability of occurrence of assigned heights of the Brahmini at Jenapur.

(1) Assigned level in feet.	(2) Graduated Totals.	(3) n=number of days per year.	(1) Assigned level in feet.	(2) Graduated Totals.	(3) n=number of days per year.
59·2	1748·0	34·0784	66·2	72·0	1·4037
59·7	1433·0	27·9373	66·7	52·5	1·0235
60·2	1183·0	23·0634	67·2	38·0	0·7408
60·7	978·0	19·0668	67·7	27·0	0·5264
61·2	806·0	15·7135	68·2	18·0	0·3509
61·7	660·0	12·8671	68·7	12·0	0·2339
62·2	537·5	10·4789	69·2	7·9	0·1540
62·7	434·5	8·4709	69·7	4·9	0·0955
63·2	349·0	6·8040	70·2	2·9	0·0565
63·7	274·0	5·3418	70·7	1·5	0·0292
64·2	216·0	4·2111	71·2	0·65	0·0127
64·7	168·5	3·2850	71·7	0·27	0·0052
65·2	129·5	2·5247	72·2	0·09	0·0017
65·7	97·5	1·9008			

For example, for an assigned height of 65·2 feet we notice that n= 2·5247. For 10 years, multiplying 2·524 by 10 we get 25·2 approximately.

Hence we conclude that on 25 days in 10 years the level is likely to be equal to or exceed 65·2 feet.

One other interesting point in connexion with the present graduation may be mentioned here. A curve of Pearson Type 1 has a theoretical upper limit to the range. In the present case this limit is located at 74·49 feet. In other words, the present graduation suggests that the height of the river cannot exceed 74·49 feet.

Frequency of year—maximum Levels of the Brahmini.

Owing to the fact that high (or low) readings are apt to be crowded into the same year, Table 255 will not give correctly the probability of occurrence of floods of a given magnitude for the highest floods in each month or in each year. For this purpose it is necessary to examine the maximum heights in each month or in each year. Such single-day maximum readings for each year are given in Table 256.

Table 256.—Year—Maximum Height of the Brahmini at Jenapur for one day.

Year.	July.		August.		September.		Combined.	Date.
1875	65·3	(17)	61·5	(22)	62·6	(19)	65·3	(J. 17)
1876	63·2		62·3	(1)	....		63·2	(J.)
1877	65·6	(15)	65·6	(17)	61·5	(3)	65·6	(J. 15)
1878	59·5	(30)	66·3	(18)	59·3	(1)	66·3	(A. 18)
1879	61·2	(18)	65·5	(11)	62·4	(18)	65·5	(A. 11)
1880	61·0	(2)	62·6	(12)	64·7	(6)	64·7	(S. 6)
1881	68·3	(18)	64·8	(3)	60·4	(13)	68·3	(J. 18)
1882	66·6	(25)	64·4	(7)	58·5	(28)	66·6	(J 25)
1883	62·7	(1)	68·6	(2)	62·3	(10)	68·6	(A. 2)
1884	61·1	(11)	60·6	(22)	65·4	(7)	65·4	(S. 7)
1885	62·2	(26)	65·1	(25)	64·9	(24)	65·1	(A. 25)
1886	63·6	(31)	60·8	(1)	62·2	(21)	63·6	(J. 31)
1887	62·5	(13)	62·2	(4)	59·3	(17)	62·5	(J. 13)
1888	61·3	(23)	69·2	(29)	59·9	(22)	69·2	(A. 29)
1891	61·1	(28)	62·9	(4)	65·1	(13)	65·1	(S. 13)
1892	65·8	(13)	60·4	(6)	61·0	(10)	65·8	(J. 13)
1893	60·9	(18)	63·1	(4)	65·9	(14)	65·9	(S. 14)
1894	69·3	(26)	63·6	(7)	60·3	(1)	69·3	(J. 26)
1895	64·6	(1)	65·6	(1)	59·6	(1)	65·6	(S. 1)
1896	68·3	(23)	66·0	(3)	59·4	(2)	68·3	(J. 23)
1897	60·3	(18)	64·6	(24)	59·8	(10)	64·6	(A. 24)
1898	61·9	(20)	62·7	(10)	60·2	(2)	62·7	(A. 10)
1899	63·3	(15)	60·0	(28)	58·7	(26)	63·3	(J. 15)
1900	63·2	(15)	67·4	(1)	65·0	(24)	67·4	(A. 1)
1901	59·5	(10)	67·2	(27)	66·0	(5)	67·2	(A. 27)
1902	66·4	(28)	61·4	(9)	61·7	(12)	66·4	(J. 28)
1903	62·3	(25)	62·0	(9)	59·0	(8)	62·3	(J. 25)
1904	66·5	(10)	66·8	(16)	60·7	(2)	66·8	(A. 16)
1905	60·1	(21)	58·8	(3)	62·4	(17)	62·4	(S. 17)
1906	66·9	(29)	60·9	(11)	65·9	(15)	66·9	(J. 29)
1907	61·4	(6)	69·9	(21)	64·8	(2)	69·9	(A. 21)
1908	62·7	(24)	67·0	(25)	63·1	(2)	67·0	(A. 25)
1909	63·5	(19)	65·7	(3)	62·5	(24)	65·7	(A. 3)
1910	62·1	(5)	65·6	(15)	61·6	(11)	65·6	(A. 15)
1911	61·0	(10)	67·2	(24)	62·3	(14)	67·2	(A. 24)
1912	62·2	(30)	67·3	(18)	64·3	(12)	67·3	(A. 18)
1913	66·7	(27)	69·5	(1)	60·2	(1)	69·5	(A. 1)
1914	59·7	(27)	66·5	(6)	62·4	(5)	66·5	(A. 6)
1915	62·3	(30)	58·9	(3)	59·4	(18)	62·3	(J. 30)
1916	59·0	(30)	64·9	(17)	58·8	(27)	64·9	(A. 17)

Table 256—*concld.*

Year.	July		August.		September.		Combined.	Date.
1917	62·0	(14)	66·2	(2)	61·7	(22)	66·2	(A. 2)
1918	59·5	(11)	63·8	(25)	62·5	(8)	63·8	(A. 25)
1919	62·9	(8)	65·0	(14)	67·0	(2)	67·0	(S. 2)
1920	70·1	(23)	69·6	(9)	62·1	(15)	70·1	(J. 23)
1921	67·3	(31)	64·6	(1)	63·3	(2)	67·3	(J. 31)
1922	62·2	(30)	63·7	(22)	68·2	(9)	68·2	(S. 9)
1923	63·7	(28)	69·1	(19)	61·3	(2)	69·1	(A. 19)
1924	61·4	(30)	63·6	(7)	62·4	(19)	63·6	(A. 7)
1925	65·8	(1)	66·8	(23)	66·0	(7)	66·8	(A. 23)
1926	58·8	(30)	70·6	(17)	65·2	(4)	70·6	(A. 17)
1927	70·1	(31)	69·4	(20)	63·4	(8)	70·1	(J. 31)
1928	65·4	(24)	59·0	(27)	65·7	(3)	65·7	(S. 3)
1929	70·2	(31)	67·5	(1)	63·7	(11)	70·2	(J. 31)

N. B.—The number within brackets under each month shows the actual date of the maximum. For the combined period J, A, and S denote July, August, and September respectively.

It is also possible to calculate not merely the single-day maximum, but the highest average in each year for 2 consecutive days, for 3 consecutive days, etc. Such averages of maximum for 2, 3, 4, and 5 consecutive days in each year are given in Tables 257—260 for each month separately as well as for the whole season.

Table 257.—Year—Maximum Heights of the Brahmini at Jenapur : Average of 2 consecutive days.

Year.	July.		August.		September.		Combined.	Date.
1875	64·3	(18)	61·4	(22)	62·0	(20)	64·3	(J. 18)
1876	63·3	(31)	62·8	(1)	..		63·3	(J. 31)
1877	64·8	(15)	64·7	(17)	60·2	(10)	64·8	(J. 15)
1878	59·0	(31)	63·7	(19)	59·8	(1)	63·7	(A. 19)
1879	60·8	(19)	65·4	(12)	59·4	(26)	65·4	(A. 12)
1880	60·4	(3)	62·5	(12)	64·1	(6)	64·1	(S. 6)
1881	67·5	(19)	64·4	(4)	60·0	(14)	67·5	(J. 19)
1882	66·0	(26)	64·0	(8)	57·8	(13)	66·0	(J. 26)
1883	61·5	(2)	67·0	(3)	61·9	(11)	67·0	(A. 3)
1884	60·3	(12)	60·5	(6)	63·8	(7)	63·8	(S. 7)
1885	62·6	(26)	64·8	(26)	63·7	(25)	64·8	(A. 26)
1886	62·9	(31)	62·2	(1)	61·6	(21)	62·9	(J. 31)
1887	61·5	(13)	62·1	(5)	59·2	(18)	62·1	(A. 5)
1888	61·0	(23)	60·1	(30)	59·4	(18)	60·1	(A. 30)
1891	61·0	(28)	62·7	(16)	64·1	(13)	64·1	(S. 13)
1892	65·1	(14)	59·8	(7)	60·4	(10)	65·1	(J. 14)
1893	60·8	(19)	62·9	(5)	65·7	(14)	65·7	(S. 14)
1894	67·3	(26)	63·5	(8)	60·1	(2)	67·3	(J. 26)
1895	63·2	(2)	64·6	(9)	60·1	(1)	64·6	(A. 9)
1896	68·3	(24)	65·0	(4)	59·2	(2)	68·3	(J. 24)
1897	59·8	(18)	64·1	(25)	59·6	(9)	64·1	(A. 25)
1898	61·1	(21)	62·4	(10)	59·4	(2)	62·4	(A. 10)
1899	62·3	(16)	60·0	(29)	58·6	(27)	62·3	(J. 16)
1900	62·8	(15)	65·2	(22)	65·0	(25)	65·2	(A. 22)
1901	58·9	(11)	66·4	(27)	65·0	(5)	66·4	(A. 27)
1902	65·8	(30)	60·7	(10)	58·6	(6)	65·8	(J. 30)
1903	62·4	(25)	61·0	(9)	58·6	(7)	62·4	(J. 25)
1904	66·4	(11)	66·4	(16)	60 5	(2)	66·4	(J. 11& A. 16)
1905	60·0	(22)	58·6	(3)	62·0	(17)	62·0	(S. 17)
1906	65·5	(30)	60·5	(11)	65·6	(15)	65·6	(S. 15)
1907	61·2	(6)	68·9	(21)	64·2	(2)	68·9	(A. 21)
1908	62·7	(24)	66·1	(26)	63·9	(1)	66·1	(A. 26)
1909	63·4	(19)	65·0	(4)	60·2	(1)	65·0	(A. 4)
1910	61·0	(30)	65·2	(16)	60·3	(9)	65·2	(A. 16)
1911	60·6	(11)	65·8	(24)	62·0	(14)	65·8	(A. 24)
1912	61·4	(31)	67·0	(18)	63·7	(8)	67·0	(A. 18)
1913	66·7	(28)	69·5	(2)	61·7	(1)	69·5	(A. 2)
1914	59·4	(30)	65·8	(7)	61·6	(5)	65·8	(A. 7)
1915	61·9	(30)	58·9	(5)	59·0	(16)	61·9	(J. 30)
1916	58·9	(30)	64·2	(18)	58·7	(22)	64·2	(A. 18)
1917	61·5	(14)	65·4	(3)	60·0	(22)	65·4	(A. 3)
1918	58·8	(12)	63·2	(26)	61·7	(9)	63·2	(A. 26)
1919	62·7	(9)	64·7	(15)	65·9	(3)	65·9	(S. 3)
1920	70·0	(23)	68·8	(9)	62·0	(16)	70·0	(J. 23)
1921	65·7	(31)	65·9	(1)	63·1	(3)	65·9	(A. 1)
1922	64·7	(31)	62·9	(22)	62·0	(26)	64·7	(J. 31)
1923	63·5	(28)	67·7	(20)	61·1	(3)	67·7	(A. 20)
1924	61·2	(31)	63·4	(7)	61·8	(20)	63·4	(A. 7)
1925	65·1	(29)	60·4	(24)	65·3	(8)	66·4	(A. 24)
1926	58·7	(31)	69·3	(18)	65·0	(4)	69·3	(A. 18)
1927	67·4	(31)	69·6	(1)	62·9	(1)	69·6	(A. 1)
1928	64·8	(28)	58·8	(27)	64·3	(4)	64·8	(J. 28)
1929	69·7	(31)	68·8	(1)	63·4	(12)	69·7	(J. 31)

N.B.—(1) The figures give the maximum value of the average height for 2 consecutive days in each year.

(2) The number within brackets under each month gives the date of occurrence (last day) of the maximum average value.

(3) The entries in the last column (under combined) give the date of occurrence (last day) of the maximum for the whole season ; and J, A, S, denote July, August and September, respectively.

Table 258.—Year—Maximum Heights of the Brahmini at Jenapur : Average of 3 consecutive days.

Year.	July.		August.		September.		Combined.	Date.
1875	63·6	(18)	61·0	(2)	61·5	(21)	63·6	(J. 18)
1876	62·4	(21)	62·8	(1)	No record.		62·8	(A. 1)
1877	64·2	(16)	63·7	(18)	59·7	(11)	64·2	(J. 16)
1878	58·8	(31)	62·9	(20)	59·2	(1)	62·9	(A. 20)
1879	60·4	(19)	65·0	(13)	59·7	(18)	65·0	(A. 13)
1880	59·7	(3)	62·1	(13)	63·7	(7)	63·7	(S. 7)
1881	66·6	(19)	60·1	(26)	59·4	(14)	66·6	(J. 19)
1882	64·8	(29)	63·2	(9)	57·8	(14)	64·8	(J. 29)
1883	60·6	(23)	66·9	(4)	61·8	(12)	66·9	(A. 4)
1884	59·3	(13)	60·1	(23)	64·0	(8)	64·0	(S. 8)
1885	62·0	(26)	64·3	(27)	63·1	(26)	64·3	(A. 27)
1886	62·7	(31)	61·2	(2)	61·5	(22)	62·7	(J. 13)
1887	61·1	(14)	61·3	(6)	58·9	(18)	61·3	(A. 6)
1888	60·5	(23)	66·5	(30)	62·0	(1)	66·5	(A. 30)
1891	60·8	(28)	62·5	(16)	63·1	(14)	63·1	(S. 14)
1892	63·8	(15)	59·4	(7)	60·1	(11)	63·8	(J. 15)
1893	60·3	(20)	62·9	(5)	65·2	(15)	65·2	(S. 15)
1894	66·8	(27)	63·5	(8)	60·1	(3)	66·8	(J. 27)
1895	62·0	(3)	64·2	(10)	60·0	(1)	64·2	(A. 10)
1896	67·2	(25)	64·2	(5)	58·9	(3)	67·2	(J. 25)
1897	59·1	(18)	63·9	(25)	59·7	(10)	63·9	(A. 25)
1898	60·4	(21)	62·2	(11)	59·2	(3)	62·2	(A. 11)
1899	61·4	(9)	59·6	(29)	58·7	(1)	61·4	(J. 9)
1900	62·8	(15)	64·9	(22)	64·7	(26)	64·9	(A. 22)
1901	58·4	(11)	65·7	(27)	65·0	(6)	65·7	(A. 27)
1902	66 0	(30)	60·2	(11)	59·0	(7)	66·0	(J. 30)
1903	61·3	(26)	60·5	(10)	58·8	(8)	61·3	(J. 26)
1904	65·6	(11)	65·2	(17)	60·1	(3)	65·6	(J. 11)
1905	59·4	(23)	58·3	(4)	62·2	(18)	62·2	(S. 18)
1906	64·0	(31)	60·4	(13)	64·6	(16)	64·6	(S. 16)
1907	60·3	(7)	68·1	(22)	64·3	(3)	68·1	(A. 22)
1908	62·4	(24)	65·6	(26)	63·6	(1)	65·6	(A. 26)
1909	62·6	(20)	64·3	(4)	60·7	(2)	64·3	(A. 4)
1910	60·9	(30)	64·8	(16)	60·2	(10)	64·8	(A. 16)
1911	60·1	(12)	65·2	(25)	61·7	(15)	65·2	(A. 25)
1912	61·0	(31)	63·4	(18)	63·5	(9)	65·4	(A. 18)
1913	66·5	(28)	68·7	(3)	61·9	(1)	68·7	(A. 3)
1914	59·2	(30)	65·5	(7)	61·2	(6)	65·5	(A. 7)
1915	61·0	(31)	58·6	(26)	58·8	(16)	61·0	(J. 31)
1916	58·7	(30)	63·8	(18)	58·4	(23)	63·8	(A. 18)
1917	61·0	(14)	64·5	(3)	60·5	(23)	64·5	(A. 3)
1918	58·0	(13)	62·7	(26)	61·2	(9)	62·7	(A. 26)
1919	61·8	(10)	64·2	(25)	65·2	(3)	65·2	(S. 3)
1920	59·5	(24)	68·3	(10)	61·7	(16)	69·5	(J. 24)
1921	63·8	(31)	65·3	(1)	62·8	(3)	65·3	(A. 1)
1922	64·1	(31)	63·4	(1)	62·0	(26)	64·1	(J. 31)
1923	62·8	(29)	67·0	(20)	60·9	(3)	67·0	(A. 20)
1924	61·1	(31)	62·7	(8)	61·5	(20)	62·7	(A. 8)
1925	64·9	(29)	65·3	(25)	65·4	(9)	65·4	(S. 9)
1926	58·7	(31)	68·0	(19)	64·8	(5)	68·0	(A. 19)
1927	65·9	(27)	68·2	(2)	63·4	(1)	68·2	(A. 2)
1928	64·5	(28)	58·4	(28)	63·5	(4)	64·5	(J. 28)
1929	68·6	(31)	68·9	(1)	62·8	(12)	68·9	(A. 1)

N.B.—(1) The figures give the maximum value of the average height for 3 consecutive days in each year.

(2) The number within brackets under each month gives the date of occurrence (last day) of the maximum average value.

(3) The entries in the last column (under combined) give the date of occurrence (last day) of the maximum for the whole season.

Table 259.—Year—Maximum Heights of the Brahmini at Jenapur : Average of 4 consecutive days.

Year.	July.	August.	September.	Combined.	Date.
1875	63·0 (18)	60·7 (3)	61·0 (22)	63·0	(J. 18)
1876	62·1 (22)	62·1 (2)	..	62·1	(J. 22) & (A. 2)
1877	63·2 (17)	63·1 (17)	59·7 (12)	63·2	(J. 17)
1878	58·6 (31)	62·7 (20)	58·8 (2)	62·7	(A. 20)
1879	69·1 (19)	64·6 (13)	59·7 (19)	64·6	(A. 13)
1880	59·2 (4)	61·8 (13)	62·8 (8)	62·8	(S. 8)
1881	65·5 (20)	63·2 (26)	59·6 (1)	65·5	(J. 20)
1882	63·8 (27)	62·3 (24)	57·7 (15)	63·8	(J. 27)
1883	60·4 (24)	60·0 (5)	61·8 (13)	66·0	(A. 5)
1884	59·1 (28)	59·9 (24)	63·8 (9)	63·8	(S. 9)
1885	62·0 (26)	63·6 (28)	62·7 (27)	63·6	(A. 28)
1886	61·8 (31)	60·8 (3)	61·2 (23)	61·8	(J. 31)
1887	60·8 (15)	60·8 (7)	58·8 (19)	60·8	(J. 15) & (A. 7)
1888	60·3 (23)	65·7 (30)	63·8 (1)	65·7	(A. 30)
1891	60·3 (29)	62·2 (17)	62·1 (15)	62·2	(A. 17)
1892	62·8 (15)	59·2 (8)	59·8 (12)	62·8	(J. 15)
1893	60·1 (21)	62·2 (12)	64·8 (16)	64·8	(S. 16)
1894	66·2 (28)	63·2 (8)	60·0 (4)	66·2	(J. 28)
1895	61·1 (4)	63·7 (11)	59·8 (2)	63·7	(A. 11)
1896	66·3 (26)	63·8 (5)	58·7 (18)	66·3	(J. 26)
1897	58·9 (18)	64·0 (24)	59·5 (10)	64·0	(A. 24)
1898	60·0 (22)	62·0 (12)	58·8 (4)	62·0	(A. 12)
1899	61·1 (10)	59·5 (29)	58·8 (1)	61·1	(J. 10)
1900	61·9 (16)	64·2 (22)	64·6 (27)	64·6	(S. 27)
1901	58·2 (29)	65·1 (28)	64·6 (7)	65·1	(A. 28)
1902	64·4 (31)	60·0 (12)	59·2 (8)	64·4	(J. 31)
1903	60·6 (26)	60·0 (11)	58·8 (9)	60·6	(J. 26)
1904	65·0 (12)	64·4 (17)	59·9 (3)	65·0	(J. 12)
1905	58·7 (24)	58·2 (5)	61·7 (19)	61·7	(S. 19)
1906	62·9 (31)	60·3 (13)	63·4 (17)	63·4	(S. 17)
1907	59·8 (7)	67·4 (23)	64·0 (4)	67·4	(A. 23)
1908	62·1 (24)	65·1 (26)	63·4 (1)	65·1	(A. 26)
1909	61·9 (21)	63·9 (4)	60·9 (2)	63·9	(A. 4)
1910	60·6 (31)	64·2 (17)	60·6 (11)	64·2	(A. 17)
1911	59·7 (13)	64·4 (25)	60·9 (16)	64·4	(A. 25)
1912	61·0 (31)	63·8 (19)	62·8 (10)	63·8	(A. 19)
1913	65·6 (29)	67·2 (4)	61·5 (1)	67·2	(A. 4)
1914	59·0 (30)	64·8 (8)	60·9 (7)	64·8	(A. 8)
1915	60·0 (31)	58·6 (26)	58·7 (18)	60·0	(J. 31)
1916	58·6 (30)	63·4 (18)	58·2 (24)	63·4	(A. 18)
1917	60·3 (15)	63·9 (4)	60·2 (23)	63·9	(A. 4)
1918	57·6 (14)	62·3 (27)	60·8 (10)	62·3	(A. 27)
1919	61·0 (11)	64·0 (25)	64·6 (4)	64·6	(S. 4)
1920	69·0 (25)	67·5 (10)	61·6 (16)	69·0	(J 25)
1921	63·2 (31)	64·7 (2)	62·6 (4)	64·7	(A. 2)
1922	63·3 (31)	63·2 (1)	61·7 (27)	63·3	(J. 31)
1923	62·4 (30)	66·4 (20)	60·6 (4)	66·4	(A. 20)
1924	61·1 (31)	62·0 (8)	61·4 (20)	62·0	(A. 8)
1925	64·5 (30)	64·7 (25)	65·0 (10)	65·0	(S. 10)
1926	58·4 (31)	66·8 (20)	64·6 (6)	66·8	(A. 20)
1927	65·1 (28)	67·3 (2)	62·9 (2)	67·3	(A. 2)
1928	63·9 (28)	59·2 (1)	62·6 (5)	63·9	(J. 28)
1929	67·9 (31)	68·4 (1)	62·5 (13)	68·4	(A. 1)

N.B.—(1) The figures give the maximum value of the average height for 4 consecutive days in each year.

(2) The number within brackets under each month gives the date of occurrence (last day) of the maximum average value.

(3) The entries in the last column (under combined) give the date of occurrence (last day) of the maximum for the whole season.

Table 260.—Year—Maximum Heights of the Brahmini at Jenapur : Average of 5 consecutive days.

Year.	July.		August.		September.		Combined.	Date.
1875	62·3	(19)	60·6	(4)	60·7	(23)	62·3	(J. 19)
76	61·5	(23)	61·5	(3)	..		61·5	(J. 23) & (A. 3)
77	62·0	(18)	61·0	(17)	59·8	(13)	62·0	(J. 18)
78	58·2	(31)	61·8	(21)	58·5	(3)	61·8	(A. 21)
79	60·0	(19)	64·2	(14)	59·5	(19)	64·2	(A. 14)
80	59·0	(5)	61·5	(14)	62·2	(8)	62·2	(S. 8)
81	64·3	(21)	62·8	(27)	59·8	(1)	64·3	(J..21)
82	62·9	(28)	61·8	(25)	57·6	(16)	62·9	(J. 28)
83	60·2	(24)	65·3	(6)	61·6	(13)	65·3	(A. 6)
84	58·9	(28)	60·1	(6)	63·4	(9)	63·4	(S. 9)
85	61·7	(26)	63·1	(28)	62·4	(28)	63·1	(A. 28)
86	60·9	(31)	60·7	(4)	60·9	(23)	60·9	(S. 23) & (J. 31)
87	60·3	(16)	60·6	(14)	58·7	(20)	60·6	(A. 14)
88	60·1	(24)	65·3	(30)	63·3	(1)	65·3	(A. 30)
91	59·8	(29)	61·9	(17)	61·4	(15)	61·9	(A. 17)
92	62·0	(16)	59·0	(9)	59·6	(13)	62·0	(J. 16)
93	60·2	(22)	61·8	(12)	64·1	(17)	64 1	(S. 17)
94	64·5	(29)	63 0	(8)	59·9	(4)	64·5	(J. 29)
95	60·4	(5)	63·1	(12)	59·7	(3)	63·1	(A. 12)
96	65·6	(27)	63·2	(6)	58·7	(18)	65 6	(J. 27)
97	58·6	(18)	63·9	(25)	59·4	(11)	63·9	(A. 25)
98	59·5	(23)	61 8	(13)	58·4	(5)	61·8	(A. 13)
99	60·5	(11)	59·4	(30)	59·0	(1)	60·5	(J. 11)
1900	61 8	(17)	63 7	(23)	64·2	(27)	64·2	(S. 27)
01	58·1	(29)	64·3	(29)	64·5	(8)	64·5	(S. 8)
02	63·3	(31)	59·9	(13)	59·1	(9)	63·3	(J. 31)
03	60·0	(27)	59·5	(12)	58·7	(10)	60·0	(J. 27)
04	64·1	(13)	63 6	(18)	59·9	(3)	64·1	(J. 13)
05	58·3	(25)	58 2	(6)	61·1	(20)	61·1	(S. 20)
06	61·5	(31)	60·0	(14)	62·3	(17)	62·3	(S. 17)
07	59·4	(7)	66·6	(24)	63·7	(5)	66·6	(A. 24)
08	61·9	(24)	65·1	(26)	63·3	(1)	65·1	(A. 26)
09	61·3	(21)	63·5	(5)	61·0	(3)	63·5	(A. 5)
10	60·3	(31)	63·5	(18)	60·6	(12)	63·5	(A. 18)
11	59·6	(14)	64 5	(24)	60·6	(16)	64·5	(A. 24)
12	60·7	(31)	63·6	(20)	62·2	(11)	63·6	(A. 20)
13	64·5	(29)	66·1	(5)	61·1	(1)	66·1	(A. 5)
14	58·9	(30)	64·0	(9)	60·4	(8)	64·0	(A. 9)
15	59·7	(31)	58·5	(26)	58·7	(18)	59·7	(J. 31)
16	58·5	(31)	62·9	(19)	58·2	(25)	62·9	(A. 19)
17	60·6	(16)	63·4	(5)	60·0	(25)	63·4	(A. 5)
18	57·0	(14)	61·9	(28)	60·5	(10)	61·9	(A. 28)
19	60·4	(12)	63·9	(26)	63·8	(1)	63·9	(A. 26)
20	68·7	(25)	66·8	(10)	61·6	(16)	68·7	(J. 25)
21	61·9	(31)	63·8	(3)	62·4	(5)	63·8	(A. 3)
22	62·7	(31)	62·8	(1)	61·3	(23)	62·8	(A. 1)
23	62·1	(31)	65·9	(20)	60·3	(5)	65 9	(A. 20)
24	69·9	(31)	61·4	(9)	63·2	(20)	63·2	(S. 20)
25	61·0	(31)	64·2	(25)	64·6	(11)	64·6	(S. 11)
26	57·9	(31)	66·0	(20)	64·5	(6)	66·0	(A. 20)
27	64·0	(28)	66·5	(3)	62·9	(3)	66·5	(A. 3)
28	63·5	(28)	60·2	(1)	61·9	(6)	63·5	(J. 28)
29	67·3	(31)	67·8	(1)	62·0	(14)	67·8	(A. 1)

N.B.—(1) The figures give the maximum value of the average height for 5 consecutive days in each year.

(2) The number within brackets under each month gives the date of occurrence (last day) of the maximum average value.

(3) The entries in the last column (under combined) give the date of occurrence (last day) of the maximum for the whole season.

The above data for the whole season have been classified in the form of frequency distributions of year—maximum heights of the Brahmini at Jenapur for single-day, 2-day, 3-day, 4-day, or 5-day of averages in Table 261.

Table 261.—Frequency Distribution of Year—maximum heights of the Brahmini at Jenapur : 1875-1929.

[*N.B.*—For 2, 3, 4 and 5 days the figures refer to the heighest average of 2, 3, 4, 5 consecutive days respectively.]

Range in feet.	1-day.	2-day.	3-day.	4-day.	5-day.
59·3—59·7	..	..	...	..	1
59·8—60·2	..	..	...	1	1
60·3—60·7	..	..	..	1	2
60·8—61·2	..	..	1	2	2
61·3—61·7	..	..	3	1	1
61·8—62·2		3	2	5	7
62·3—62·7	5	3	3	2	2
62·8—63·2	1	3	3	4	6
63·3—63·7	3	2	2	5	7
63·8—64·2	1	5	7	8	7
64·3—64·7	2	3	5	6	6
64·8—65·2	3	8	7	6	1
65·3—65·7	8	4	7	2	3
65·8—66·2	3	6	1	2	3
66·3—66·7	4	3	2	2	2
66·8—67·2	7	2	4	2	..
67·3—67·7	3	3	..	2	..
67·8—68·2	1	..	3	..	1
68·3—68·7	3	1	1	1	1
68·8—69·2	2	2	1	1	
69·3—69·7	2	4	1		
69·8—70·2	4	1			
70·3—70·7	1				

The accumulated totals from the data given in Table 261 are given in Table 262. These give the total number of years in which the river level stood higher than any assigned value. It will be noticed that as the number of days over which the average is taken is increased the number of years for any given maximum steadily decreases. This is, of course, just what is to be expected.

Table 262.--Accumulated Totals of Year—maximum Heights of the Brahmini at Jenapur : 1875—1929.

[*N.B.*—For 2, 3, 4, and 5 days, the figures refer to the highest average of 2, 3, 4 and 5 consecutive days respectively.]

Height (in feet) in excess of	1-day.	2-day.	3-day.	4-day.	5-day.
59·3	..	..	..	..	53
59·8	..	..	..	53	52
60·3	..	..	..	52	51
60·8	..	..	53	51	49
61·3	..	..	52	49	47
61·8	..	53	49	48	46
62·3	53	50	47	43	39
62·8	48	47	44	41	37
63·3	47	44	41	37	31
63·8	44	42	39	32	24
64·3	43	37	32	24	17
64·8	41	34	27	18	11
65·3	38	26	20	12	10
65·8	30	22	13	10	7
66·3	27	16	12	8	4
66·8	23	13	10	6	2
67·3	16	11	6	4	2
67·8	13	8	6	2	2
68·3	12	8	3	2	1
68·8	9	7	2	1	0
69·3	7	5	1	0	0
69·8	5	1	0	0	0
70·3	1	0	0	0	0

In Table 263 the above data are shown in the form of percentages. This table will serve as a rough probability table. For any assigned maximum (i.e. single-day or average of 2, 3, 4, or 5 days) this table will give the number of years per century in which the river level is likely to exceed any assigned height. For example, we find that the single-day maximum is likely to exceed the height 67·3 feet in just about 30 years in a century.

Table 263.—Observed Percentage Accumulated Totals of Year—maximum Heights of the Brahmini at Jenapur : 1875—1929.

[*N.B.*—The number gives the number of years in a century in which the assigned height will be exceeded ; and the figures for 2, 3, 4, 5 days refer to highest average of 2, 3, 4,-5 days respectively.]

Height (in feet) in excess of	1-day.	2-day.	3-day.	4-day.	5-day.
59·3	..	..	..	..	100·00
59·8	..	..	..	100·00	98·11
60·3	..	..	..	98·11	96·23
60·8	..	..	100·00	96·23	92·45
61·3	..	..	98·11	92·45	88·66
61·8	..	100·00	92·45	90·57	80·79
62·3	100·00	94·34	88·68	81·13	73·58
62·8	90·57	88·68	83·01	77·36	69·81
63·3	88·68	83·02	77·36	69·81	58·49
63·8	83·02	79·24	73·58	60·37	45·28
64·3	81·13	69·81	60·37	45·28	32·08
64·8	77·36	64·15	50·94	33·96	20·75
65·3	71·70	49·06	37·74	22·64	18·87
65·8	56·60	41·51	24·53	18·87	13·20
66·3	50·98	30·19	22·64	15·09	7·55
66·8	43·40	24·53	18·87	11·32	3·77
67·3	30·19	20·75	11·32	7·55	3·77
67·8	24·53	15·09	11·32	3·77	3·77
68·3	22·64	15·09	5·66	3·77	1·89
68·8	16·98	13·21	3·77	1·89	
69·3	13·21	9·43	1·89		
69·8	9·43	1·89			
70·3	1·89				

The observed accumulated totals given in Table 262 were next graduated by drawing free-hand curves. Graduated values were read off from the free-hand curves and are given in Table 264. For the upper range (beyond 64·2 feet) the curves were actually drawn on a large scale in order to reduce errors of interpolation, etc.

Table 264.—Graduated Accumulated Totals of Year—maximum Heights of the Brahmini at Jenapur : 1875—1929.

Height (in feet) in excess of	1-day.	2-day.	3-day.	4-day.	5 day.
59·3	..	..	..	..	53·00
59·8	..	..	..	53·00	52·50
60·3	..	..	..	52·16	51·00
60·8	..	..	53·00	50·05	49·40
61·3	..	53·00	51·65	49·60	47·25
61·8	..	51·75	50·10	47·50	44·60
62·3	53·00	50·00	48·00	44·66	41·25
62·8	49·50	47·50	45·50	41·00	37·00
63·3	47·25	44·75	42·13	36·75	31·05
63·8	44·60	41·40	38·33	31·50	23·75
64·3	41·75	37·75	33·40	24·00	17·00
64·8	38·40	32·75	27·10	18·00	12·41
65·3	34·75	27·33	20·66	13·26	9·10
65·8	30·50	21·16	14·84	10·00	6·41
66·3	26·00	16·50	11·22	7·22	4·41
66·8	21·50	13·00	8·64	5·18	2·92
67·3	17·25	10·42	6·41	3·60	1·96
67·8	13·60	8·40	4·58	2·44	1·25
68·3	10·70	6·75	3·00	1·68	0·90
68·8	8·40	5·32	1·95	1·10	0·50
69·3	6·50	4·20	1·22	0·58	0·22
69·7	4·80	2·92	0·78	0·29	0·05
70·3	3·50	2·10	0·41	0·16	
70·8	2·50	1·42	0·21	0·04	
71·3	1·60	0·86	0·05		
71·8	0·90	0·40			
72·3	0·50	0·18			
72·8	0·25				

The graduated data given in Table 264 were then reduced to the percentage form in Table 265, which is our graduated probability table. Table 265 will give the probable number of years (in a century) in which the river level will exceed any assigned height.

Table 265.—Graduated Probability Table for Year—maximum Heights of the Brahmini at Jenapur in number of years per century.

[*N.B.*—The figures give the number of years in a century in which any assigned level is likely to be exceeded. The figures for 2, 3, 4, 5 days refer to the highest average height for 2, 3, 4, 5 consecutive days respectively.]

Height (in feet) in excess of	1-day.	2-day.	3-day.	4-day.	5-day.
59·3	..	..	..	..	100·00
59·8	..	..	..	100·00	99·07
60·3	..	..	..	98·42	96·24
60·8	..	..	100·00	94·44	93·22
61·3	..	100·00	97·46	93·60	89·16
61·8	..	97·65	94·54	89 63	84·16
62·3	100·00	94·35	90·58	84·27	97·84
62·8	93·40	89·63	85·86	77·37	69·82
63·3	89·15	84·44	79·50	69·35	58·59
63·8	84·15	78·12	72·33	59·44	44·82
64·3	78·77	71·23	63·02	45·28	32·08
64·8	72·45	61·79	51·13	33·96	23·42
65·3	65·56	51·57	38·98	25·62	17·17
65·8	57·55	39·92	28·00	18·87	12·09
66·3	49·06	31·13	21·17	13·62	8·32
66·8	40·57	24·53	16·30	9·77	5·51
67·3	32·55	19·66	12·09	6·79	3·70
67·8	25·66	15·85	8·64	4·60	2·36
68·3	20·19	12·74	5·66	3·17	1·70
68·8	15·85	10·04	3·68	2·08	0·94
69·3	12·26	7·93	2·30	1·09	0·42
69·8	9·06	5·51	1·47	0·55	0·09
70·3	6·60	3·96	0·77	0·30	
70·8	4·72	2·68	0·40	0·08	
71·3	3·02	1·62	0·09		
71·8	1·70	0·75			
72·3	0·94	0·34			
72·8	0·47				

For example, we find that the average of 5 consecutive days is likely to exceed the height 66·8 feet only on 5 or 6 occasions in a century (n=5·51).

Finally I have converted Table 265 into a reciprocal form in Table 266. This table gives the number of years (y) in which any assigned level is likely to be exceeded at least once. For example, we find from this table that the 2-day maximum is likely to be greater than 66·8 feet about once in 4 years (y=4·18). The averages of 5 consecutive days, on the other hand, will exceed the same value only once in 18 years (y=18·15).

Table 266.—Reciprocal Probability Table for Year—maximum Heights of the Brahmini at Jenapur.

[*N.B.*—The figures give the number of years in which the assigned level is likely to be exceeded; and the figures for 5, 4, 3, 2 days refer to highest average height for 5, 4, 3, 2 consecutive days respectively.

Height (in feet) exceeded.	5-day.	4-day.	3-day.	2-day.	1-day.
59·3	1·00				
59·8	1·01	1·00			
60·3	1·04	1·02			
60·8	1·07	1·06	1·00		
61·3	1·12	1·07	1·03	1·00	
61·8	1·19	1·12	1·06	1·02	
62·3	1·28	1·19	1·10	1·06	1·00
62·8	1·43	1·29	1·16	1·12	1·07
63·3	1·71	1·44	1·26	1·18	1·12
63·8	2·23	1·68	1·38	1·28	1·19
64·3	3·12	2·21	1·59	1·40	1·27
64·8	4·27	2·94	1·96	1·62	1·38
65·3	5·82	4·00	2·57	1·94	1·53
65·8	8·27	5·30	3·57	2·51	1·74
66·3	12·02	7·34	4·72	3·21	2·04
66·8	18·15	10·24	6·13	4·08	2·46
67·3	27·03	14·73	8·27	5·09	3·07
67·8	42·37	21·74	11·57	6·31	3·90
68·3	58·82	31·55	17·67	7·85	4·95
68·8	106·38	48·08	27·17	9·96	6·31
69·3	238·10	91·74	43·48	12·61	8·16
69·8	1111·11	181·82	68·03	18·15	11·04
70·3	..	333·33	129·87	25·25	15·15
70·8	..	1250·00	250·00	37·31	21·19
71·3	..	..	1111·11	61·73	33·11
71·8	..	..	..	133·33	58·82
72·3	..	..	..	294·12	106·38

N.B.—Beyond the observed range, i.e., beyond 70·7 the table should be used with caution.

Frequency Distribution of Average Heights for consecutive days.

For purposes of flood study, the occurrence of an exceptionally high river level for a short time only is less important than the continuance of even a moderately high level above the danger point for a number of days. In order to gain some idea regarding such persistence of high levels for a number of consecutive days, the moving averages for 2, 3, 4 and 5 consecutive days were directly calculated; and the frequency distributions for the average of 2, 3, 4, and 5 consecutive days are given in Tables 267—270.

The accumulated totals for the combined period July—September are given in table 271. Dividing the figures by 55 (the number of years of experience) we get the observed probability of occurrence (in number of days per monsoon season, July 1—September 30) of different river levels for 2, 3, 4, or 5 consecutive days (Table 272).

Table 267.—Frequency Distribution of Heights of the Brahmini at Jenapur (1875—1929) Average level for 2 consecutive days.

Range in feet.	July.	August.	September.	July—September.
52·75—53·25	2	..	..	2
—53·75	6	1	3	10
—54·25	13	1	17	31
—54·75	28	9	10	47
—55·25	43	5	21	69
—55·75	52	10	42	104
—56·25	47	27	63	137
—56·75	97	41	77	215
—57·25	133	77	120	330
—57·75	174	97	173	444
—58·25	214	141	225	580
—58·75	167	170	210	547
—59·25	118	131	122	371
—59·75	67	142	99	308
—60·25	62	123	77	262
—60·75	52	116	45	213
—61·25	51	92	43	186
—61·75	36	68	43	147
—62·25	24	59	28	111
—62·75	24	68	21	113
—63·25	22	48	16	86
—63·75	17	29	16	62
—64·25	9	38	18	65
—64·75	18	22	5	45
—65·25	9	26	7	42
—65·75	5	13	6	24
—66·25	6	11	1	18
—66·75	7	11	..	18
—67·25	2	2	..	4
—67·75	8	8	..	16
—68·25	..	5	..	5
—68·75	1	1	..	2
—69·25	..	5	..	5
—69·75	2	3	..	5
—70·25	1	..	..	1

Table 268.—Frequency distribution of heights of the Brahmini at Jenapur (1875—1929) Average level for 3 consecutive days.

Range in feet.	July.	August.	September.	July—September.
52·75—53·25	..	..	..	..
—53·75	5	..	3	8
—54·25	10	..	13	23
—54·75	24	8	12	44
—55·25	39	6	16	61
—55·75	44	7	34	85
—56·25	49	22	55	126
—56·75	76	44	78	198
—57·25	124	58	116	298
—57·75	185	106	170	461
—58·25	235	158	229	622
—58·75	168	157	210	535
—59·25	89	126	133	348

Table 268—*concld.*

Range in feet.	July.	August.	September.	July—September.
—59·75	82	130	93	305
—60·25	64	142	84	290
—60·75	47	116	53	216
—61·25	42	94	42	178
—61·75	38	77	40	155
—62·25	18	61	27	106
—62·75	27	68	22	117
—63·25	22	47	22	91
—63·75	15	36	20	71
—64·25	21	42	8	71
—64·75	8	21	7	36
—65·25	3	19	9	31
—65·75	9	18	1	28
—66·25	5	6	..	11
—66·75	4	9	..	13
—67·25	5	10	..	15
—67·75	1	2	..	3
—68·25	..	5	..	5
—68·75	2	2	..	4
—69·25	1	1	..	2
69·25—69·75	1	..	..	1

Table 269.—Frequency distribution of heights of the Brahmini at Jenapur (1875—1929). Average level for 4 consecutive days.

Range in feet.	July.	August.	September.	July—September.
52·75—53·25	1	..	..	1
—53·75	3	..	..	3
—54·25	8	..	3	11
—54·75	17	4	11	32
—55·25	34	9	11	54
—55·75	47	7	14	68
—56·25	45	16	25	86
—56·75	71	35	54	160
—57·25	121	64	70	255
—57·75	203	111	100	414
—58·25	220	157	186	563
—58·75	95	148	219	462
—59·25	63	116	209	388
—59·75	55	145	120	321
—60·25	44	136	114	294
—60·75	88	115	81	284
—61·25	66	101	63	230
—61·75	45	76	46	167
—62·25	33	77	48	158
—62·75	29	52	29	110
—63·25	27	59	25	111
—63·75	30	36	19	85
—64·25	22	29	14	65
—64·75	11	29	13	53
—65·25	16	22	7	45
—65·75	5	14	2	21
—66·25	9	7	..	16
—66·75	4	8	..	12
—67·25	2	6	..	8
—67·75	5	5	..	10
—68·25	2	..	..	2
—68·75	..	1	..	1
—69·25	1	..	..	1
—69·75	2	..	..	2
—70·25	1	..	..	1

Table 270.—Frequency distribution of heights of the Brahmini at Jenapur (1875—1929): Average level for 5 consecutive days.

Range in feet,	July.	August.	September.	July—September
53·25—53·75	2	..	3	5
—54·25	9	..	12	21
—54·75	8	2	10	20
—55·25	36	9	15	60
—55·75	38	8	19	65
—56·25	43	11	51	105
—56·75	60	31	75	166
—57·25	103	56	86	246
—57·75	196	113	152	461
—58·25	222	151	289	662
—58·75	151	142	179	472
—59·25	104	113	136	353
—59·75	87	159	112	358
—60·25	63	129	87	279
—60·75	40	113	62	215
—61·25	34	111	50	195
—61·75	30	81	38	149
—62·25	34	61	36	131
—62·75	16	68	18	102
—63·25	17	53	21	91
—63·75	14	39	12	65
—64·25	12	30	19	61
—64·75	10	25	4	39
—65·25	2	14	..	16
—65·75	3	15	..	18
—66·25	2	14	..	16
—66·75	2	7	..	9
—67·25	2	1	..	3
—67·75	2	1	..	3
—68·25	..	1	..	1
—68·75	2	..	..	2
—69·25				
—69·75				

Table 271.—Accumulated totals of frequency distributions of heights of the Brahmini at Jenapur (1875—1929): Average level for 2, 3, 4 and 5 consecutive days for the combined period, July—September.

Height (in feet) in excess of	2 days.	3 days.	4 days.	5 days.
52·75	4625	4558	4494	4389
53·25	4623	4558	4493	4389
53·75	4613	4550	4490	4384
54·25	4582	4527	4479	4363
54·75	4535	4483	4447	4343
55·25	4466	4422	4393	4283
55·75	4362	4337	4325	4218
56·25	4225	4211	4239	4113
56·75	4010	4013	4079	3947
57·25	3680	3715	3824	3701
57·75	3236	3254	3410	3240
58·25	2656	2632	2847	2578
58·75	2109	2097	2385	2106
59·25	1738	1749	1997	1753
59·75	1430	1444	1676	1395
60·25	1168	1154	1382	1116

Table 271—*concld.*

Height (in feet) in excess of	2 days.	3 days.	4 days.	5 days.
60·75	955	938	1098	901
61·25	769	760	868	706
61·75	622	605	701	557
62·25	511	499	543	426
62·75	398	382	433	324
63·25	312	291	322	233
63·75	250	220	237	168
64·25	185	149	172	107
64·75	140	113	119	68
65·25	98	82	74	52
65·75	74	54	53	34
66·25	56	43	37	18
66·75	38	30	25	9
67·25	34	15	17	6
67·75	18	12	7	3
68·25	13	7	5	2
68·75	11	3	4	
69·25	6	1	3	
69·75	1	..	1	

Table 272.—Probability of occurrence of assigned heights of the Brahmini at Jonapur : Average level for 2, 3, 4, 5 consecutive days (in number of days per monsoon season, July—September).

Height (in feet) in excess of	2 days.	3 days.	4 days.	5 days.
52·75	84·09	82·87	81·71	79·80
53·25	84·05	82·87	81·69	79·80
53·75	83·87	82·73	81·64	79·71
54·25	83·31	82·31	81·44	79·33
54·75	82·45	81·51	80·85	78·96
55·25	81·20	80·40	79·87	77·87
55·75	79·31	78·85	78·64	76·69
56·25	76·82	76·56	77·07	74·78
56·75	72·91	72·90	74·16	71·76
57·25	66·91	67·55	69·53	67·29
57·75	58·84	59·16	62·00	58·91
58·25	48·29	47·85	51·40	46·87
58·75	38·35	38·13	43·36	38·29
59·25	31·60	31·80	36·31	31·87
59·75	26·00	31·71	30·47	25·36
60·25	21·24	20·98	25·13	20·29
60·75	17·36	17·05	19·96	16·38
61·25	13·98	13·82	15·71	12·83
61·75	11·31	11·00	12·75	10·13
62·25	9·29	9·07	9·87	7·75
62·75	7·24	6·95	7·87	5·89
63·25	5·67	5·29	5·85	4·24
63·75	4·54	4·00	4·31	3·05
64·25	3·36	2·71	3·13	1·95
64·75	2·55	2·05	2·16	1·24
65·25	1·78	1·49	1·35	·95
65·75	1·35	·98	·96	·62
66·25	1·02	·78	·67	·33
66·75	·69	·54	·45	·16
67·25	·62	·27	·31	·11
67·75	·33	·22	·13	·05
68·25	·24	·13	·09	·04
68·75	·20	·05	·07	
69·25	·11	·02	·05	
69·75	·02		·02	

In view of the importance of the subject I decided to extend the analysis up to 10 consecutive days. The upper range alone is of interest to us. I, therefore, decided to work with only such values in the 5 days totals as were likely to lead to an average gauge height of over 62 feet for 6, 7, 8, 9, or 10 consecutive days.

The frequency distribution for levels above 62 feet are given in Table 273, the accumulated totals in Table 274, and the probability of occurrence of different (observed) heights in Table 275.

Regarding the accumulated totals of frequencies of average heights for 2—10 consecutive days the curves evidently belong to a single family. I believe it will be possible to represent the whole family of curves by a single function with the number of days as one of its parameters. I regret I have not had time to examine this point in greater detail.

Table 273.—Frequency distribution of heights of the Brahmini at Jenapur (1875—1929) Average level for 6, 7, 8, 9 and 10 consecutive days.

Range in feet.	6 days.	7 days.	8 days.	9 days.	10 days.
62—62·4	55	46	60	71	83
62·8	67	76	64	55	53
63·2	58	60	54	62	62
63·6	58	51	51	26	40
64·0	39	28	24	29	25
64·4	20	23	20	20	26
64·8	19	22	22	20	25
65·2	24	21	19	16	15
65·6	17	14	10	12	10
66·0	7	9	6	4	9
66·4	8	5	4	6	3
66·8	3	1	5	3	1
67·2	2	3	1	2	2
67·6	3	2	1		
68·0	0				
68·4	1				

Table 274.—Accumulated totals of frequency distributions of heights of the Brahmini at Jenapur (1875—1929): Average level for 6, 7, 8, 9 and 10 consecutive days for the combined period, July—September.

Height (in feet) in excess of	6 days.	7 days.	8 days.	9 days.	10 days.
62·0	381	361	341	326	352
62·4	326	315	281	255	269
62·8	259	239	217	200	216
63·2	201	179	163	138	154
63·6	143	128	112	112	114
64·0	104	100	88	83	89
64·4	84	77	68	63	63
64·8	65	55	46	43	38
65·2	41	34	27	27	23
65·6	24	20	17	15	13
66·0	17	11	11	11	4
66·4	9	6	7	5	3
66·8	6	5	2	2	2
67·2	4	2	1		
67·6	1				
68·0	1				

Table 275.—Probability of Occurrence of Assigned Heights of the Brahmini at Jenapur : Average level for 6, 7, 8, 9, 10 consecutive days in number of days per monsoon season July—September.

Height (in feet) in excess of	6 days.	7 days.	8 days.	9 days.	10 days.
62·0	7·02	6·54	6·18	5·89	6·40
62·4	5·83	5·45	5·09	4·64	5·09
62·8	4·71	4·36	3·93	3·60	3·91
63·2	3·64	3·24	2·91	2·73	2·91
63·6	2·58	2·33	2·15	2·05	2·07
64·0	2·24	1·73	1·53	1·56	1·49
64·4	1·60	1·23	1·09	1·16	1·05
64·8	1·13	·82	·73	·80	·69
65·2	·65	·55	·49	·55	·38
65·6	·42	·36	·33	·36	·22
66·0	·22	·18	·22	·22	·11
66·4	·16	·15	·15	·11	·05
66·8	·15	·09	·05	·03	
67·2	·09	·04			
67·6	·05				
68·0	·04				

CHAPTER 34—CORRELATION BETWEEN RAINFALL AND THE LEVEL OF THE BRAHMINI AT JENAPUR.

The Orissa Flood Committee (1928) laid great emphasis on the high average level of the Brahmini at Jenapur, and concluded "firstly, that the Brahmini has deteriorated, secondly, that the deterioration took place suddenly and not as the result of normal deltaic action and thirdly, that it took place in 1920" (Page 29).

I shall now consider how far the tendency towards increasing river levels shown in recent years can be explained on the basis of an increasing rainfall. For this purpose I have formed the regression equation for gauge height as determined by the rainfall in the two sections of the Brahmini, choosing the whole period of 92 days (1st July—30th September) as the unit of time.

The two correlations between rainfall in each section and the height of the river at Jenapur for 37 seasonal (July 1st—September 30th) averages for the period 1892—1928, as also the correlation between the rainfall in the two sections were directly calculated.

Let us use x_1 and x_2 to represent the average daily rainfall in sections I and II respectively, and x_0 to represent the height of the river at Jenapur. We find directly—

Mean rainfall per day in section I = 0·3565″

Mean rainfall per day in section II = 0·4222″

Mean height of river level = 59·09′.

The standard deviations and correlations are :—

$s_1 = 1{\cdot}013$ ft. ... $r_{01} = +{\cdot}5658 \pm 0{\cdot}75$

$s_2 = 0{\cdot}0762$ inch ... $r_{02} = +{\cdot}4955 \pm {\cdot}083$

$s_0 = 0{\cdot}0866$ inch ... $r_{12} = +{\cdot}4573 \pm {\cdot}092$

With the help of the theory of multiple correlation (the numerical value of which is 0·6451 in this case) we next find the equation for x_0 in terms of x_1 and x_2. We have :—

$$X_0 = 5{\cdot}4171 x_1 + 3{\cdot}3115 x_2$$

where all variates are measured from corresponding mean values in terms of respective standard deviations.

Using ordinary units and writing J for x_0 (the height of the Brahmini at Jenapur) we get :—

$$J = 59{\cdot}09 \text{ ft.} + 5{\cdot}4171 (x_1 - 0{\cdot}3565″) + 3{\cdot}3115 (x_2 - 0{\cdot}4222″)$$

where J = Height of the river in feet.

x_1 = Actual average daily rainfall (in inch) in section I.

x_2 = " " " " " in section II.

The coefficients have a direct physical interpretation. For one inch rise in the average rainfall per day in section I of the Brahmini catchment the rise in the level of the river would be 5·42 ft. while the same intensity of rainfall in section II would cause a rise of only 3·31 ft. Thus the rainfall in the nearer section has, naturally enough, an appreciably greater effect on the level of the river.

The reconstructed values (i.e., those predicted on the basis of the rainfall) and the observed values of the average height of the Brahmini at Jenapur for the period 1892—1928 are given in Table 276 and shown in Chart 11.

It will be noticed that the recent rise in the river level since 1920 is on the whole very closely predicted by the reconstruction formula. In other words, the recent rise can be almost completely explained by increased rainfall in the catchment.

We can test this point further. Column (3) of Table 276 gives the difference between the observed and predicted values. These differences which have also been plotted in Chart 11 are practically random in character. In fact the straight line of best fit to these discrepancies is given by—

$$\Delta J = 0{\cdot}0916 - 0{\cdot}0149\ (y - 1910)$$

where ΔJ is the discrepancy in any year "y". The very slight trend of —·015 ft. per year is practically negligible.

We conclude, therefore, that the increase in the level of the Brahmini at Jenapur since 1920 may be ascribed to increased rainfall in the catchment, and does not indicate any rise of the bed of the river.

Table 276.—Observed and calculated mean heights of Brahmini river at Jenapur for the period 1st July—30th September, 1892—1928.

Year.	Observed.	Calculated.	Difference Obs.—Cal.	Year.	Observed.	Calculated.	Difference Obs.—Cal.
1892	58·6	58·89	—0·29	1911	58·8	58·61	+0·19
93	59·3	58·60	+0·70	12	58·4	59·24	—0·84
94	59·9	58·77	+1·13	13	58·5	59·23	—0·73
95	59·1	58·13	+0·97	14	58·4	59·40	—1·00
96	59·6	58·84	+0·76	15	57·5	58·82	—1·36
97	58·8	58·82	—0·02	16	57·4	58·38	—0·98
98	59·0	58·97	+0·03	17	59·0	59·15	—0·15
99	58·3	57·85	+0·45	18	57·4	57·49	—0·09
1900	60·1	59·90	+0·20	19	59·8	58·94	+0·86
01	58·9	58·49	+0·41	1920	60·9	60·56	+0·34
02	59·0	59 31	—0·31	21	58·8	59·03	—0·23
03	58·2	59·02	—0·82	22	59·5	59·39	+0·11
04	59·6	58·90	+0·70	23	59·6	59·18	+0·42
05	57·3	58·87	—1·57	24	58·7	58·66	+0·04
06	58·0	58·97	—0·97	25	60·7	59·90	+0·80
07	60·2	59·12	+1·08	26	60·8	59·98	+0·82
08	60·9	60·16	+0·74	27	60·5	59·66	+0·84
09	60·4	59·16	+1·24	28	57·8	59·74	—1·94
1910	58·5	59·23	—0·72				

The correlation between the average rainfall in the Brahmini catchment as a whole for each year and the average level of the river is $+0{\cdot}61 \pm {\cdot}07$ for the period 1891—1928 (38 years). The multiple correlation formula given above is, however, more satisfactory, and will give more reliable results.

PART VI.—ANALYTIC STUDY OF THE BAITARANI AND THE SALINDI.

CHAPTER 35.—RAINFALL IN THE BAITARANI CATCHMENT.

The monthly averages of daily rainfall in July, August and September for the Baitarani catchment for each year are given in Table 277. The tendencies in different months are not concordant and periods of increasing or decreasing rainfall follow one another in irregular succession.

The figures for the combined period are shown in Column (5) of Table 277. There was a period of about 9 years of decreasing rainfall from 1891 to 1899; a period of fairly steady rainfall up to 1916, and then a period of increasing rainfall from 1917 to 1927. This last period coincides with the period of increasing rainfall in the Brahmini basin, and indicates that in the whole Brahmini-Baitarani region the average seasonal rainfall increased appreciably during a period of about 11 years from 1917 to 1927.

Table 277.—Average daily rainfall in inches for each month from July-September.

Baitarani Catchment (1891—1928).

Year.	July.	August.	September.	July—September.
1891	0·35	0·53	0·56	0·49
92	0·28	0·22	0·45	·32
93	0·27	0·25	0·48	·33
94	0·61	0·28	0·19	·36
95	0·20	0·40	0·20	·27
96	0·62	0·46	0·24	·44
97	0·27	0·23	0·24	·25
98	0·19	0·40	0·20	·27
99	0·18	0·24	0·08	·17
1900	0·40	0·65	0·56	·54
01	0·28	0·36	0·25	·30
02	0·44	0·41	0·23	·36
03	0·48	0·30	0·43	·40
04	0·36	0·24	0·37	·32
05	0·37	0·16	0·37	·30
06	0·29	0·23	0·40	·30
07	0·19	0·77	0·16	·38
08	0·27	0·51	0·22	·33
09	0·52	0·32	0·35	·21
1910	0·38	0·28	0·37	·34
11	0·16	0·10	0·36	·40
12	0·51	0·43	0·19	·38
13	0·73	0·44	0·16	·35
14	0·51	0·31	0·50	·44
15	0·27	0·2●	0·32	·28
16	0·24	0·27	0·18	·23
17	0·25	0·32	0·22	·27
18	0·20	0·32	0·26	·26
19	0·32	0·53	0·11	·33
1920	0·80	0·41	0·21	·48
21	0·40	0·33	0·41	·38
22	0·42	0·35	0·30	·36
23	0·31	0·29	0·22	·27
24	0·31	0·32	0·24	·29
25	0·49	0·50	0·22	·40
26	0·38	0·70	0·46	·51
27	0·94	0·39	0·18	·51
1928	0·63	0·39	0·28	·43

The average rainfall in the Baitarani catchment for each date from the 1st July to 30th September will be found in Table 278. The general features are the same as in other catchments. There is an increase in the average rainfall towards the end of July and the first week of August, and then a gradual steady decline up to the end of September.

Table 278.—Average rainfall in inches for each date from 1st July to 30th September.

Baitarani catchment (1891—1928).

July		August		September	
1 ..	0·27	1 ..	0·54	1 ..	0·42
2 ..	0·33	2 ..	0·34	2 ..	0·27
3 ..	0·34	3 ..	0·40	3 ..	0·34
4 ..	0·22	4 ..	0·31	4 ..	0·32
5 ..	0·31	5 ..	0·29	5 ..	0·42
6 ..	0·33	6 ..	0·42	6 ..	0·40
7 ..	0·25	7 ..	0·46	7 ..	0·34
8 ..	0·37	8 ..	0·38	8 ..	0·28
9 ..	0·28	9 ..	0·28	9 ..	0·20
10 ..	0·36	10 ..	0·30	10 ..	0·27
11 ..	0·39	11 ..	0·29	11 ..	0·47
12 ..	0·56	12 ..	0·25	12 ..	0·54
13 ..	0·44	13 ..	0·41	13 ..	0·26
14 ..	0·37	14 ..	0·42	14 ..	0·44
15 ..	0·25	15 ..	0·30	15 ..	0·24
16 ..	0·29	16 ..	0·45	16 ..	0·21
17 ..	0·26	17 ..	0·44	17 ..	0·36
18 ..	0·24	18 ..	0·44	18 ..	0·26
19 ..	0·25	19 ..	0·33	19 ..	0·20
20 ..	0·42	20 ..	0·48	20 ..	0·17
21 ..	0·32	21 ..	0·39	21 ..	0·21
22 ..	0·44	22 ..	0·32	22 ..	0·20
23 ..	0·44	23 ..	0·34	23 ..	0·38
24 ..	0·53	24 ..	0·41	24 ..	0·30
25 ..	0·81	25 ..	0·34	25 ..	0·34
26 ..	0·41	26 ..	0·38	26 ..	0·17
27 ..	0·50	27 ..	0·29	27 ..	0·17
28 ..	0·52	28 ..	0·37	28 ..	0·27
29 ..	0·44	29 ..	0·33	29 ..	0·19
30 ..	0·56	30 ..	0·28	30 ..	0·19
31 ..	0·62	31 ..	0·39		

The frequency distributions of different intensities of daily average rainfall in the Baitarani catchment are given in Table 279. It will be noticed that the limiting range 6·50″—7·00″ occurred only once in the month of July. In August the daily average rainfall never exceeded 5·50″, and in September it never exceeded 4·00″. A rainfall of over 2·50″ occurred on an average less than once in each year.

Table 279.—Frequency distribution of rainfall intensities for July, August, September and combined period, July—September.

Baitarani Catchment (1891—1928).

Range of rainfall in inches.	July.	Aug.	Sept.	Combined.	Accumulated totals for the combined period.
Zero	166	144	235	545	3496
·01—0·1	252	262	274	788	2951
— ·2	185	185	162	532	2163
— ·3	136	127	127	390	1631
— ·4	88	107	79	274	1241
— ·5	62	60	52	183	967
— ·6	58	61	53	172	784
— ·7	38	42	35	115	612
— ·8	35	46	19	100	497
— ·9	29	25	14	68	397
—1·0	23	17	18	58	329
—1·2	25	30	20	75	271
—1·4	20	18	16	54	196
—1·6	9	7	10	26	142
—1·8	12	5	3	20	116
—2·0	13	11	2	26	96
—2·5	9	12	14	35	70
—3·0	8	6	5	19	35
—3·5	4	1	1	6	16
—4·0	1	1	1	3	10
—4·5	1	1	..	2	7
—5·0	1	0	..	1	5
—5·5	1	1	..	2	4
—6·0	0	..	..	..	2
—6·5	1	..	..	1	2
—7·0	1	..	..	1	1

The absolute single year maxima are given in Table 280, and the accumulated frequencies in Table 281. The records were carefully searched and the absolute maxima of the average of 2, 3, 4 and 5 consecutive days have also been compiled in Table 280.

It will be noticed from Table 281 that the limiting value, which is in the range 6·50″—7·00″ for 1 day, very rapidly declines as the number of days over which the average is taken is increased. For 5 consecutive days the limiting value lies between 3·00″ and 3·50″.

Table 280.—Maximum rainfall for single day and for 2, 3, 4 and 5 consecutive days and dates of occurrence.

Baitarani Catchment (1891—1928.)

Year.	1 day.	2 days.	3 days.	4 days.	5 days.
1891	4·40 (3 A)	2·75 (26 J)	2·13 (27 J)	1·81 (27 J)	1·40 (27 J)
92	2·17 (12 J)	1·61 (12 J)	1·22 (12 J)	0·93 (13 J)	0·81 (29 S)
93	2·85 (11 S)	2·73 (12 S)	1·97 (12 S)	1·58 (13 S)	1·28 (13 S)
94	3·27 (24 J)	3·26 (25 J)	2·57 (25 J)	1·93 (26 J)	1·54 (26 J)
95	2·78 (28 A)	1·81 (29 A)	1·44 (30 A)	1·12 (30 A)	0·99 (30 A)
96	3·00 (22 J)	2·44 (22 J)	2·03 (23 J)	1·68 (24 J)	1·41 (25 J)
97	1·86 (10 J)	1·30 (10 J)	1·04 (10 J)	0·87 (11 J)	0·83 (12 J)
98	2·96 (14 S)	2·14 (9 A)	1·65 (9 A)	1·39 (10 A)	1·13 (13 J)
99	1·21 (13 J)	1·05 (14 J)	0·83 (14 J)	0·68 (14 J)	0·60 (28 A)
1900	4·12 (13 J)	2·48 (19 J)	1·92 (18 S)	1·70 (19 S)	1·38 (20 S)

Table 280—*concld.*

Years.	1 day.	2 days.	3 days.	4 days.	5 days.
1901	2·49 (24 A)	1·91 (24 A)	1·41 (25 A)	1·16 (25 A)	0·95 (25 A)
02	2·53 (16 J)	1·71 (16 J)	1·35 (16 J)	1·06 (16 J)	0·91 (16 J)
03	2·39 (23 J)	1·59 (24 J)	1·31 (30 S)	1·15 (30 S)	1·04 (30 S)
04	2·46 (11 S)	2·34 (12 S)	1·75 (12 S)	1·43 (13 S)	1·24 (14 S)
05	2·33 (25 J)	1·67 (26 J)	1·23 (26 J)	0·98 (27 J)	0·80 (28 J)
06	2·64 (12 S)	1·92 (12 S)	1·50 (13 S)	1·18 (13 S)	0·98 (13 S)
07	5·34 (20 A)	3·69 (20 A)	2·79 (20 A)	2·25 (21 A)	1·82 (21 A)
08	1·41 (21 A)	1·22 (21 A)	0·89 (21 A)	0·70 (21 A)	0·78 (21 A)
09	2·31 (1 A)	1·63 (15 S)	1·23 (15 S)	1·05 (28 J)	1·03 (28 J)
1910	1·74 (27 J)	1·53 (3 J)	1·22 (4 J)	0·94 (4 J)	0·86 (8 S)
11	2·01 (18 S)	1·11 (18 S)	1·01 (11 S)	0·91 (11 S)	0·74 (11 S)
12	2·17 (28 J)	1·55 (29 A)	1·33 (30 A)	1·17 (28 J)	1·10 (29 J)
13	5·19 (25 J)	3·66 (31 J)	2·96 (1 A)	2·46 (1 A)	1·99 (1 A)
14	2·04 (14 S)	1·93 (15 S)	1·81 (15 S)	1·64 (16 S)	1·58 (17 S)
15	1·67 (6 J)	1·01 (6 J)	0·74 (7 J)	0·62 (28 J)	0·66 (29 J)
16	1·32 (3 J)	0·88 (4 J)	0·85 (15 A)	0·69 (16 A)	0·66 (17 A)
17	1·85 (10 J)	1·06 (11 J)	0·90 (12 J)	0·75 (13 J)	0·63 (13 J)
18	1·30 (6 S)	1·17 (6 S)	0·96 (6 S)	0·89 (6 S)	0·96 (6 S)
19	2·78 (7 A)	2·34 (7 A)	1·81 (7 A)	1·49 (8 A)	1·23 (9 A)
1920	3·42 (31 J)	2·55 (31 J)	1·83 (31 J)	1·62 (23 J)	1·43 (24 J)
21	2·07 (1 S)	1·58 (9 A)	1·12 (9 A)	0·95 (4 S)	0·97 (6 S)
22	3·19 (28 J)	1·90 (28 J)	1·37 (29 J)	1·08 (28 J)	0·99 (28 J)
23	1·49 (28 S)	1·10 (23 A)	0·84 (16 A)	0·76 (16 A)	0·69 (16 A)
24	1·92 (5 A)	1·65 (5 A)	1·29 (6 A)	1·04 (6 A)	0·86 (6 A)
25	2·69 (21 A)	2·27 (22 A)	1·70 (22 A)	1·35 (22 A)	1·12 (22 A)
26	3·76 (16 A)	2·81 (16 A)	2·50 (16 A)	2·21 (17 A)	1·83 (16 A)
27	6·58 (30 J)	6·36 (30 J)	4·35 (30 J)	3·29 (30 J)	2·71 (30 J)
28	2·95 (25 J)	2·38 (26 J)	1·89 (26 J)	1·49 (27 J)	1·34 (26 J)

(*The dates given indicate the end of the period*).

Table 281.—Accumulated totals : Frequency distribution of maximum rainfall intensities for single day and 2, 3, 4 and 5 consecutive days.

Baitarani Catchment (1891—1928).

Rainfall (in inches) exceeded.	1 day.	2 days.	3 days.	4 days.	5 days.
0	38	38	38	38	38
0·50	38	38	38	38	38
1·00	38	37	31	25	19
1·50	34	29	16	11	6
2·00	27	15	7	4	1
2·50	17	8	4	1	1
3·00	9	4	1	1	
3·50	6	3	1		
4·00	5	1	1		
4·50	3	1			
5·00	3	1			
5·50	1	1			
6·00	1	1			
6·50	1				

CHAPTER 36.—THE LEVEL OF THE BAITARANI AT AKHUAPADA.

The daily readings of the level of the Baitarani river at the gauge at Akhuapada are available for the 3 monsoon months July, August and September, for the period 1874—1929 inclusive. Records * for 1885 and 1886 were missing entirely, as also 1884 (1st July to 14th August), 1898 (7th to 30th September), 1900 (1st to 16th July), 1903 (1st to 8th July), and 1926 (1st to 11th July), as also about 73 isolated readings here and there. The total number of daily readings available was thus reduced to 4,791. The methods of analysis used in the case of the Naraj and the Jenapur gauges have been followed very closely.

The mean height of the Baitarani at Akhuapada for July, August and September separately for each year, as well as the mean height for the combined period July—September taken together in each year were calculated and are given in Tables 282—285. In Tables 282—284 column (1) gives the year, column (2) the number of days available, column (3) the mean height in feet with its probable error, and column (4) the standard deviation in feet with its probable error. The corresponding graphs are shown in Chart 12. The observed heights are joined by a continuous black line in ink, and are bordered in pencil on either side by two lines showing the range of the probable error of the mean height.

Table 282.—Mean level and standard deviation in feet of the Height of the Baitarani at Akhuapada for July.

Year.	Number of days.	Mean height and P. E.	S. D. and P. E.
1874	31	49·5±0·39	3·22±0·28
75	31	52·5± ·25	2·10± ·18
76	31	52·9± ·24	1·96± ·17
77	31	53·9± ·15	1·25± ·11
78	31	53·8± ·15	1·21± ·10
79	31	54·5± ·15	1·21± ·10
1880	31	55·2± ·12	0·99± ·08
81	31	57·7± ·31	2·55± ·22
82	31	56·6± ·16	1·33± ·11
83	28	57·0± ·17	1·35± ·12
87	31	56·3± ·11	0·92± ·08
88	31	56·0± ·08	0·69± ·06
89	31	56·0± ·04	0·37± ·03
1890	31	55·9± ·10	0·83± ·07
91	31	55·9± ·09	0·73± ·06
92	31	56·3± ·14	1·13± ·10
93	31	56·2± ·09	0·75± ·06
94	31	57·3± ·26	2·14± ·18
95	31	56·1± ·10	0·85± ·07
96	31	58·1± ·33	2·72± ·23
97	31	56·0± ·08	0·69± ·06
98	31	56·5± ·06	0·46± ·04
99	31	56·4± ·12	0·96± ·08
1900	15	56·1± ·09	0·51± ·06
01	31	56·2± ·04	0·35± ·03
02	31	57·1± ·23	1·87± ·16
03	23	56·4± ·09	0·64± ·06
04	31	57·6± ·27	2·19± ·19
05	31	56·3± ·06	0·49± ·04
06	31	56·7± ·08	0·63± ·05
07	30	56·6± ·08	0·69± ·06
08	30	56·3± ·18	1·43± ·12
09	30	56·5± ·14	1·10± ·10
1910	31	56·6± ·17	1·41± ·12
11	31	56·2± ·05	0·60± ·07
12	31	56·6± ·14	1·15± ·10
13	31	57·2± ·30	2·47± ·21

*These records were copied from the Ganga Register in the office of the Superintending Engineer, Orissa Circle, Cuttack by [illegible]

Table 282.—*concld.*

Year.	Number of days.	Mean height and P. E.	S. D. and P. E.
1914	31	56·7± ·13	1·05± ·09
15	31	56·3± ·07	0·55± ·05
16	31	56·4± ·05	0·43± ·04
17	31	56·9± ·05	0·45± ·04
18	31	56·6± ·08	0·65± ·06
19	31	56·4± ·09	0·78± ·07
20	31	58·1± ·30	2·44± ·21
21	31	56·5± ·12	1·01± ·09
22	28	56·9± ·17	1·32± ·12
23	31	56·9± ·07	0·54± ·05
24	30	56·3± ·09	0·77± ·07
25	29	56·6± ·03	0·21± ·02
26	20	56·5± ·07	0·48± ·05
27	30	56·6± ·27	2·16± ·19
28	31	57·3± ·20	2·38± ·20
1929	12	58·7± ·34	1·82± ·24

Table 283.—Mean level and standard deviation in feet of the Height of the Baitarani at Akhuapada for August.

Year.	Number of days.	Mean height and P. E.	S. D. and P. E.
1874	31	52·0±0·28	2·33± ·20
75	31	52·6± ·08	0·49± ·04
76	31	54·1± ·15	1·35± ·10
77	30	54·5± ·17	1·45± ·12
78	31	54·9± ·09	0·77± ·01
79	31	56·2± ·19	1·55± ·14
80	31	56·3± ·13	1·07± ·10
81	31	57·0± ·19	1·55± ·14
82	31	56·8± ·11	0·91± ·08
83	31	56·4± ·15	1·30± ·10
84	17	55·9± ·08	0·66± ·06
87	31	55·9± ·13	1·07± ·10
88	31	57·1± ·20	1·68± ·14
89	31	56·7± ·13	1·09± ·10
90	31	56·2± ·06	0·46± ·04
91	31	57·2± ·21	1·75± ·15
92	31	56·0± ·06	0·51± ·04
93	31	56·4± ·15	1·24± ·10
94	31	56·6± ·07	0·59± ·05
95	31	56·9± ·07	0·60± ·05
96	31	57·8± ·12	1·04± ·09
97	31	56·8± ·07	0·57± ·05
98	31	57·4± ·16	1·36± ·11
99	31	56·6± ..	.. ..
1900	31	58·0± ·20	1·69± ·14
01	31	56·7± ·15	1·30± ·10
02	31	56·4± ·05	0·46± ·04
03	31	56·4± ·15	1·25± ·10
04	31	57·4± ·17	1·43± ·12
05	31	56·0± ·11	0·88± ·08

Table 283—*concld.*

Year.	Number of days.	Mean height and P. E.	S. D. and P. E.
1906	31	56·7±0·10	0·87±0·08
07	30	58·6± ·25	2·11± ·18
08	29	58·3± ·14	1·19± ·10
09	30	56·7± ·19	1·59± ·14
10	30	56·6± ·07	0·56± ·05
11	31	56·7± ·11	0·93± ·08
12	31	57·2± ·17	1·41± ·12
13	27	55·5± ·26	2·15± ·18
14	31	56·6± ·09	0·73± ·06
15	31	56·2± ·10	0·85± ·07
16	31	56·6± ·11	0·93± ·08
17	31	57·4± ·12	1·01± ·09
18	31	56·7± ·08	0·63± ·04
19	31	57·6± ·10	0·83± ·07
1920	31	57·5± ·22	1·86± ·16
21	31	56·9± ·07	0·58± ·05
22	31	56·6± ·12	1·04± ·09
23	31	57·8± ·19	1·64± ·13
24	29	56·5± ·09	0·74± ·06
25	28	57·2± ·20	1·69± ·14
26	27	57·6± ·15	1·25± ·11
27	31	55·6± ·31	2·54± ·22
28	31	57·0± ·10	0·85± ·07
1929	31	57·3± ·11	0·92± ·08

Table 284.—Mean level and standard deviation in feet of the Height of the Baitarani at Akhuapada for September.

Year.	Number of days.	Mean height and P. E.	S. D. and P. E.
1874	30	50·2±0·11	0·63±0·08
75	30	53·8± ·06	0·63± ·04
76	30	55·3± ·18	1·53± ·13
77	30	54·3± ·17	1·45± ·12
78	30	54·3± ·05	0·43± ·04
79	30	55·5± ·07	0·59± ·05
1880	30	56·3± ·14	1·19± ·10
81	30	55·6± ·09	0·77± ·16
82	30	55·9± ·15	1·26± ·10
83	30	56·7± ·10	0·85± ·17
84	30	57·3± ·15	1·26± ·16
87	30	55·7± ·10	0·83± ·07
88	30	56·4± ·12	1·00± ·09
89	30	55·9± ·07	0·62± ·05
1890	30	56·3± ·13	1·10± ·09
91	30	56·9± ·14	1·17± ·10
92	30	56·5± ·08	0·71± ·06
93	30	57·6± ·22	1·79± ·16
94	30	56·2± ·09	0·75± ·06
95	30	56·2± ·04	0·29± ·03
96	30	56·8± ..	.. ..
97	30	56·5± ·07	0·57± ·05

Table 284—*concla.*

Year.	Number of days.	Mean height and P. E.	S. D. and P. E.
1898	6	56·2± 0·08	0·72± 0·06
99	30	56·4± 0·07	0·54± 0·05
1900	30	58·1± 0·28	2·28± 0·20
01	30	56·8± 0·14	1·18± 0·10
02	30	56·3± 0·09	0·77± 0·06
03	30	56·5± 0·10	0·82± 0·07
04	30	57·2±	
05	30	56·6± 0·09	0·80± 0·06
06	30	56·9± 0·26	2·17± 0·19
07	28	57·6± 0·33	2·74± 0·23
08	30	56·7± 0·12	1·04± 0·09
09	30	57·0± 0·16	1·35± 0·11
1910	30	56·3± 0·12	1·02± 0·09
11	30	56·9± 0·10	0·88± 0·07
12	30	57·1± 0·20	1·65± 0·14
13	29	53·4± 0·28	2·20± 0·20
14	30	57·0± 0·14	1·19± 0·10
15	30	56·6± 0·13	1·07± 0·10
16	30	56·3± 0·07	0·53± 0·05
17	30	56·5± 0·08	0·67± 0·06
18	30	56·6± 0·14	1·20± 0·10
19	30	56·4± 0·10	0·84± 0·07
1920	30	56·0± 0·12	1·04± 0·08
21	30	56·9± 0·10	0·82± 0·09
22	28	56·6± 0·05	0·42± 0·03
23	30	56·7± ..	.. ..
24	28	56·5± 0·03	0·21± 0·02
25	28	56·7± 0·08	0·69± 0·06
26	29	57·8± 0·19	1·54± 0·13
27	20	50·7± 0·25	2·05± 0·18
28	30	57·2± 0·14	1·15± 0·10
29	30	56·7± 0·09	0·75± 0·06

Table 285.—Mean level and standard deviation (in feet) of the Height of the Baitarani at Akhuapada for the combined period, July—September.

Year.	Mean height and P. E.	Graduated height.	S. D. and P. E.
1874	50·9± ·28		4·15± ·20
1875	53·0± ·15	..	2·22± ·11
76	54·1± ·19	..	2·82± ·13
77	54·3± ·17	..	2·52± ·12
78	54·3± ·11	..	1·63± ·08
79	55·4± ·15	..	2·22± ·11
1880	56·0± ·13	..	1·93± ·10
81	56·7± ·22	..	3·26± ·16
82	56·4± ·14	..	2·08± ·11
83	56·7± ·14	..	2·08± ·11
84	56·8± ·10	..	1·48± ·07
..	..	...	..
...	..	..	..
87	56·0± ·11	56·63	1·63± ·08
88	56·5± ·15	56·64	2·22± ·10
89	56·2± ·09	56·64	1·33± ·06

Table 285—*concld.*

Year.	Mean height and P. E.	Graduated height.	S. D. and P. E.
1890	56·2± ·10	56·65	1·48± ·07
91	56·7± ·15	56·65	2·22± ·10
92	56·3± ·10	56·65	1·48± ·07
93	56·7± ·16	56·66	2·37± ·12
94	56·7± ·16	56·66	2·37± ·12
95	56·4± ·07	56·67	1·03± ·05
96	57·6± ·20	56·67	2·97± ·14
97	56·4± ·07	56·67	1·03± ·05
98	56·9± ·11	56·68	1·63± ·08
99	56·5± ..	56·68	.. ..
1900	57·7± ·21	56·69	2·11± ·15
01	56·6± ·12	56·69	1·70± ·09
02	56·6± ·15	56·69	2·22± ·11
03	56·5± ·12	56·70	1·70± ·11
04	57·4± ·18	56·70	2·67± ·13
05	56·5± ·09	56·71	1·33± ·06
06	56·7± ·17	56·71	2·52± ·12
07	57·6± ·25	56·71	3·71± ·18
08	57·2± ·15	56·72	2·22± ·11
09	56·8± ·17	56·72	2·52± ·12
1910	56·5± ·19	56·72	2·82± ·14
11	56·6± ·09	56·73	1·33± ·06
12	57·0± ·17	56·73	2·52± ·12
13	55·4± ·28	56·74	4·15± ·20
14	56 8± ·12	56·74	1·78± ·09
15	56·4± ·10	56·74	1·48± ·07
16	56·4± ·08	56·75	1·19± ·06
17	56·4± ·09	56·75	1·33± ·06
18	56·6± ·11	56·76	1·63± ·08
19	56·8± ·09	56·76	1·33± ·06
1920	57·6± ·23	56·76	3·41± ·17
21	56·8± ·10	56·77	1·48± ·07
22	56·7± ·13	56·77	1·93± ·10
23	57·1±	56·78	
24	56·4± ·07	56·78	1·03± ·05
25	56·8± ·13	56·78	1·03± ·10
26	57·4± ·15	56·79	2·22± ·11
27	54·8± ·28	56·79	4·15± ·20
28	57·1± ·19	56·80	2·82± ·14
1929	57·3± ·21	56·80	3·11± ·15

Between 1874 and 1884 (11 years) there is a persistent and systematic upward trend which appears in the curves for all three months. Using the ordinary product-moment method, I find that the coefficient of correlation with time is + 0·9391. Although the size of the sample is small, only 11, the observed correlation is significant. For we find in Fisher's Table* that for n=9 (i.e. 11—2), and a level of significance of ·01 (i.e. odds of 100 to 1), for no real correlation the limiting value of r is 0·7348. The significance of + 0·9391 cannot therefore be doubted.

The regression line is given by :—

$$H=54·90+0·51\ (Y—1879).$$

where H=mean height in feet, and Y=year.

We conclude that between 1874 and 1884 there was a definite rise of about 6" inches per year in the mean level of the Baitarani at Akhuapada. Unfortunately the available rainfall data of this period are extremely meagre,

* "Statistical Methods for Research Workers" by R. A. Fisher, F. R. S., Table V(A), page 178 (3rd edition).

and it is not possible to investigate whether this rise represents merely the effect of a larger quantity of rainfall, or some kind of real change in the bed of the river. It is not improbable, however, that the gradual rise was due to the construction of the weir.

The data from 1887—1929 appear to be extremely steady. The straight line of best fit is given by :—

$$H = 56{\cdot}710 + 0{\cdot}004\ (Y - 1908).$$

where H=mean height in feet, and

Y=year.

It will be noticed that the average rise is only ·004 feet or less than $\frac{1}{20}$th inch per year, the total rise in 43 years being only 2" (two inches). The level of the river may, therefore, be considered to have remained steady in recent years.

A glance at Chart 12 will show that the fluctuations in height from year to year (1887—1929) are clearly of a sporadic character. Each year is usually clearly differentiated from other years, but there is no systematic trend from year to year (except the very small linear coefficient already discussed).

The mean heights for each date from July 1 to September 30 (with probable errors) are given in Table 286. Column (1) gives the date, column (2) the number of readings available, column (3) the observed mean height and its probable error, column (4) the graduated height, and column (5) the standard deviation with its probable error. In Chart 13 the mean heights are shown in black ink with the range of the probable error in the double pencil lines.

Graduation by a second order parabola gives the following equation :—

$$H = 56{\cdot}6145 + 0{\cdot}0008\ (D - \text{August } 15) - 0{\cdot}0005\ (D - \text{August } 15)^2.$$

where H=mean height in feet and

D=actual date.

The graduated values are given in column (4) of Table 286 and are shown in bold line in Chart 13. It will be noticed that the graduation is not fully adequate, and it is likely that a third-order parabola would give a better fit. I have not had time to investigate this point further.

Table 286.—Mean level and standard deviation (in feet) of the Height of the Baitarani at Akhuapada for each date from 1st July to 30th September, 1874-1919.

(1) Date.		(2) Number of years.	(3) Mean height and P. E.	(4) Graduated height.	(5) S. D. and P. E.
July	1 ..	49	55·7± 0·20	56·004	2·09± 0·14
	2 ..	49	55·7± 0·19	56·008	1·93± 0·13
	3 ..	49	55·6± 0·19	56·035	1·87± 0·13
	4 ..	49	55·4± 0·19	56·061	2·01± 0·13
	5 ..	49	55·5± 0·19	56·087	2·00± 0·13
	6 ..	47	55·8± 0·18	56·112	1·81± 0·13
	7 ..	49	55·7± 0·18	56·137	1·81± 0·13
	8 ..	48	55·7± 0·19	56·161	2·12± 0·13
	9 ..	49	55·9± 0·19	56·184	2·23± 0·13
	10 ..	49	55·9± 0·17	56·207	1·78± 0·12
	11 ..	49	56·0± 0·16	56·229	1·64± 0·11
	12 ..	50	56·2± 0·13	56·251	1·43± 0·09
	13 ..	50	56·3± 0·13	56·272	1·38± 0·09

Table 286—*contd.*

(1) Date.	(2) Number of years.	(3) Mean height and P. E.	(4) Graduated height.	(5) S. D. and P. E.
July 14 ..	49	56·2±0·13	56·293	1·37±0·09
15 ..	50	56·3±0·14	56·313	1·44±0·10
16 ..	50	56·3±0·15	56·332	1·54±0·11
17 ..	51	56·3±0·18	56·351	2·21±0·13
18 ..	50	56·3±0·16	56·369	1·71±0·11
19 ..	50	56·3±0·12	56·387	1·22±0·09
20 ..	52	56·3±0·13	56·404	1·33±0·09
21 ..	52	56·4±0·17	56·421	1·77±0·12
22 ..	52	56·4±0·16	56·436	1·69±0·11
23 ..	52	56·4±0·19	56·452	2·01±0·14
24 ..	52	56·7±0·20	56·466	2·27±0·14
25 ..	52	57·1±0·25	56·481	2·63±0·18
26 ..	52	57·0±0·19	56·494	2·22±0·13
27 ..	52	56·9±0·20	56·507	2·25±0·14
28 ..	51	56·8±0·17	56·520	1·82±0·12
29 ..	52	56·9±0·19	56·533	1·95±0·14
30 ..	52	56·9±0·12	56·544	1·28±0·08
31 ..	49	56·8±0·13	56·554	1·41±0·09
August 1 ..	52	56·6±0·17	56·564	1·79±0·12
2 ..	51	56·6±0·18	56·574	1·87±0·13
3 ..	52	56·6±0·15	56·583	1·60±0·11
4 ..	52	56·5±0·13	56·591	1·36±0·09
5 ..	52	56·3±0·14	56·598	1·44±0·10
6 ..	52	56·5±0·11	56·605	1·14±0·08
7 ..	53	56·6±0·16	56·612	1·68±0·11
8 ..	53	56·6±0·18	56·618	1·84±0·13
9 ..	53	56·7±0·15	56·623	1·56±0·11
10 ..	53	55·8±0·16	56·628	1·66±0·11
11 ..	53	56·6±0·15	56·332	1·59±0·10
12 ..	52	56·4±0·16	56·636	1·57±0·11
13 ..	53	56·5±0·16	56·639	1·58±0·11
14 ..	52	56·3±0·20	56·641	2·07±0·14
15 ..	53	56·4±0·16	56·645	1·65±0·11
16 ..	53	56·3±0·16	56·644	1·64±0·11
17 ..	52	56·5±0·17	56·644	1·73±0·12
18 ..	54	57·0±0·21	56·642	2·13±0·15
19 ..	54	56·9±0·19	56·640	1·96±0·13
20 ..	54	56·9±0·20	56·638	2·11±0·14
21 ..	54	56·7±0·19	56·634	1·94±0·13
22 ..	54	56·6±0·17	56·631	1·76±0·12
23 ..	54	56·8±0·17	56·626	1·72±0·12
24 ..	54	56·7±0·14	56·621	1·44±0·10
25 ..	54	56·6±0·14	56·616	1·51±0·10
26 ..	54	56·6±0·15	56·610	1·61±0·10
27 ..	54	56·4±0·14	56·603	1·44±0·10
28 ..	54	56·3±0·14	56·595	1·43±0·10
29 ..	54	56·3±0·08	56·588	0·85±0·05
30 ..	54	56·3±0·14	56·579	1·51±0·10
31 ..	50	56·2±0·14	56·570	1·49±0·10
September 1 ..	54	56·5±0·19	56·561	2·03±0·14
2 ..	54	56·6±0·19	56·550	2·01±0·14
3 ..	54	56·5±0·14	56·540	1·54±0·10
4 ..	53	56·5±0·16	56·528	1·70±0·12
5 ..	53	56·4±0·18	56·516	1·87±0·13
6 ..	53	56·6±0·22	56·504	1·86±0·16
7 ..	53	56·6±0·23	56·491	1·93±0·16
8 ..	53	56·4±0·17	56·477	1·74±0·12
9 ..	53	56·3±0·14	56·463	1·48±0·10

Table 286—*concld.*

(1) Date.	(2) Number of years.	(3) Mean height and P. E.	(4) Graduated height.	(5) S. D. and P. E.
Sept. 10 ..	53	56·1± 0·15	56·448	1·61± 0·10
11 ..	52	56·2± 0·17	56·432	1·75± 0·12
12 ..	53	56·3± 0·17	56·416	1·74± 0·12
13 ..	52	56·4± 0·21	56·400	2·17± 0·15
14 ..	53	56·3± 0·21	56·382	2·14± 0·15
15 ..	53	56·2± 0·17	56·365	1·83± 0·12
16 ..	53	56·0± 0·18	56·346	1·85± 0·13
17 ..	53	56·1± 0·18	56·327	1·87± 0·13
18 ..	51	56·4± 0·15	56·308	1·50± 0·10
19 ..	52	56·3± 0·16	56·288	1·62± 0·11
20 ..	53	56·0± 0·18	56·267	1·84± 0·13
21 ..	52	56·0± 0·14	56·246	1·39± 0·10
22 ..	52	56·1± 0·15	56·224	1·59± 0·10
23 ..	52	55·9± 0·17	56·201	1·75± 0·12
24 ..	51	55·9± 0·20	56·178	2·06± 0·14
25 ..	52	56·0± 0·20	56·155	2·02± 0·14
26 ..	51	56·2± 0·17	56·130	1·75± 0·12
27 ..	51	56·0± 0·19	56·106	1·99± 0·14
28 ..	52	55·8± 0·16	56·080	1·80± 0·11
29 ..	53	55·7± 0·18	56·644	1·89± 0·13
30 ..	51	55·9± 0·13	56·643	1·35± 0·09

The fluctuations in standard deviations for annual as well as daily means are given in column (4) of Tables 282—285 and col. (5) of Table 286 respectively. It will be noticed that there is no definite trend in either case. In other words the character of the fluctuations in rainfall for any particular year or for any particular date appears to have remained of the same type and do not show any progressive change with time.

CHAPTER 37.—THE FREQUENCY DISTRIBUTION OF GAUGE READINGS AT AKHUAPADA.

The frequency distribution of the height of the gauge readings at Akhuapada at intervals of 0·5 feet (6 inches) are shown in Table 287 and Chart 14.

The curves for July, August and September are very similar. In each case the distribution is nearly symmetrical showing that high and low levels tend to occur almost equally. All the curves rise very steeply near the mean, showing that mediocre values occur extremely frequently, and deviations from the average value are comparatively rare. There is a strong tendency for the level of the Baitarani to be maintained within rather narrow limits. In fact 2651 out of 4791 or 55·3 per cent of the readings lie between the narrow range of 55·75 and 57·25 feet (1·50 feet), and 3370 or 72·4 per cent between 55·25 and 57·75 (2·50 feet)

The frequency constants for the combined period are given in Table 288. The distribution is so steep that $\beta_1 = 0{\cdot}28$ and $\beta_2 = 8{\cdot}28$, which falls outside the Pearsonian family of curves.

Table 287.—Frequency distribution of daily Heights of the Baitarani at Akhuapada (1874—1929).

Range.	July.	August.	September.	July—Sept. Combined.
47·0—47·5	6	..	..	6
—48·0	4	..	..	4
—48·5	10	..	1	11
—49·0	4	..	12	16
—49·5	5	1	8	14
—50·0	6	1	6	13
—50·5	8	5	13	26
—51·0	4	0	2	6
—51·5	9	9	8	26
—52·0	12	6	9	27
—52·5	9	26	9	44
—53·0	8	22	18	48
—53·5	24	23	18	65
—54·0	39	30	30	99
—54·5	51	48	67	166
—55·0	59	56	68	183
—55·5	163	112	149	424
—56·0	329	236	245	810
—56·5	378	352	414	1144
—57·0	191	282	224	697
—57·5	109	173	113	395
—58·0	36	97	54	187
—58·5	26	61	32	119
—59·0	19	23	18	60
—59·5	16	25	23	64
—60·0	8	15	8	31
—60·5	9	8	8	25
—61·0	3	10	5	18
—61·5	4	7	4	15
—62·0	4	6	2	12
—62·5	7	2	..	9
—63·0	4	..	..	4
—63·5	6	2	4	12
—64·0	2	2	1	5
—64·5	1	..	1	2
—65·0	0	..	1	1
—65·5	2	..	..	2
—66·0	1	..	..	1

Table 288.—Frequency constants for daily Heights of the Baitarini at Akhuapada : Combined period July—Sept., 1874—1929.

Range	.. ..	57·25—65·75
N	.. ..	4791
Grouping unit	..	0·5
Mean	.. ..	56·3220
S. D.	.. ..	3·6688
μ_2	.. ..	13·359045
μ_3	.. ..	—25·052092
μ_4	.. ..	1477·760296
β_1	.. ..	0·2825
β_2	.. ..	8·2804

} in terms of grouping units.

As the graduation of the complete distribution by the Pearsonian system was not possible I decided to fit a smooth curve to the upper range of the data. For the combined period of July, August, and September, 941 readings between 57·25—66·25 were taken together and the frequency constants calculated which are given in Table 289. β_1 is now 4·61 and β_2 7·95 leading to Type I curve of the Pearsonian family. The equation to the curve is given below :—

$$y = y_0 \left(1+\frac{x}{a_1}\right)^{m_1} \left(1-\frac{x}{a_2}\right)^{m_2}$$

where, $y_0 = 90·343$

$a_1 = 2·108493$

$a_2 = 19·794480$

$m_1 = -0·646282$

$m_2 = 2·320701$

Origin at mode $= 59·56$

The observed and graduated values are given in Table 290. Although the goodness of fit is not brilliant ($x^2 = 29·23$ for 14 cells), the graduation is not unreasonable.

Table 289—Frequency constants : Height of the Baitarani at Akhuapada (Upper Range), 1874—1929.

Grouping Unit	..	·50
Range ..	Above	57·25
N	.. ..	941
Mean	.. ..	58·529
S. D.	.. ..	2·940
μ_2	.. ..	8·641205
μ_3	.. ..	54·543312
μ_4	.. ..	595·542006
β_1	.. ..	4·61
β_2	.. ..	7·95
Type	.. ..	Type I
No. of cells	..	14
x^2	.. ..	29·23
P (goodness of fit)	..	·006

} in grouping unit.

Table 290.—Observed and graduated frequency distribution of daily Heights of the Baitarani at Akhuapada above 57·25 feet combined period, July—September : 1874—1929.

Range in feet	Frequency.		Range in feet.	Frequency.	
	Observed.	Graduated.		Observed.	Graduated.
57·25—57·75	387	422	62·25	11	12
58·25	181	164	62·75	9	10
58·75	113	100	63·25	4	9
59·25	59	63	63·75	12	5
59·75	65	46	64·25	5	4
60·25	31	34	64·75	2	3
60·75	25	28	65·25	1	1
61·25	19	21	65·75	2	1
61·75	13	17	66·25	2	1

Accumulated totals were next formed for both observed and graduated values and Table 291 was constructed. Column (1) gives the assigned height to be equalled or exceeded, column (2) the observed acoumulated totals, and column (3) the graduated accumulated totals.

Multiplying by ·017857(*i.e.*$^1/_{56}$) we get the probability Table 292 for the number of days per monsoon season on which the assigned height is likely to be reached or sur passed.

The moving averages of the gauge readings for 2 days, 3 days, 4 days and 5 days were also directly calculated. The frequency distributions are given in Tables 293—296.

The accumulated totals for combined period as observed are given in Table 297 and the probability chart as obtained by free hand graduation is given in Table 298.

Table 291.—Accumulated totals : Frequency distribution of daily levels above 57·25 feet of the Baitarani at Akhuapada : 1874—1929.

Height equalled or exceeded	Accumulated totals.		Height equalled or exceeded.	Accumulated totals.	
	Observed.	Graduated.		Observed.	Graduated.
57·25	941	941	61·75	48	46
57·75	554	519	62·25	37	34
58·25	373	355	62·75	28	24
58·75	260	255	63·25	24	15
59·25	201	192	63·75	12	10
59·75	136	146	64·25	7	
60·25	105	112	64·75	5	
60·75	80	81	65·25	4	
61·25	61	63	65·75	2	

Table 292.—Probability of occurrence of assigned heights of the Baitarani at Akhuapada in number of days in one season (July—September) : 1874—1929.

Height equalled or exceeded.	Accumulated totals.		Height equalled or exceeded.	Accumulated totals.	
	Observed.	Graduated.		Observed.	Graduated.
57·25	16·8	16·8	61·75	0·9	0·8
57·75	9·9	9·3	62·25	0·7	0·6
58·25	6·7	6·3	62·75	0·5	0·4
58·75	4·6	4·6	63·25	0·4	0·3
59·25	3·6	3·4	63·75	0·2	0·2
59·75	2·4	2·6	64·25	0·1	
60·25	1·9	2·0	64·75	0·1	
60·75	1·4	1·5	65·25	0·1	
61·25	1·1	1·1	65·75		

Table 293.—Frequency distribution of average level of the Baitarani at Akhuapada for 2 consecutive days : 1874—1929.

Range.	July.	August.	September.	Combined.
47·5—48·0	4	..	..	4
48·5	4	..	..	4
49·0	6	..	1	7
49·5	5	..	8	13
50·0	2	..	8	10
50·5	5	2	13	20
51·0	6	2	7	15
51·5	6	3	7	16
52·0	6	4	2	12
52·5	13	11	11	35
53·0	5	24	9	38
53·5	7	20	16	43
54·0	23	14	15	52
54·5	46	33	27	106
55·0	33	34	53	120
55·5	67	58	81	206
56·0	157	117	149	423
56·5	316	235	253	804
57·0	371	332	399	1102
57·5	228	305	249	782
58·0	76	169	112	357
58·5	52	83	41	176
59·0	23	49	26	98
59·5	13	28	24	65
60·0	7	18	17	42
60·5	13	16	9	38
61·0	14	6	6	26
61·5	1	10	3	14
62·0	6	3	4	13
62·5	7	4	2	13
63·0	1	4	2	7
63·5	4	0	1	5
64·0	6	0	1	7
64·5	1	1	2	4
65·0	3	0	0	3
65·0—65·5	0	1	0	1

Table 294.—Frequency distribution of average level of the Baitarani at Akhuapada for 3 consecutive days : 1874—1929.

Range.	July.	August.	September.	Combined.
46·5—47·0	3	..	..	3
47·5	0	..	..	0
48·0	5	..	..	5
48·5	10	..	..	10
49·0	7	..	7	14
49·5	0	..	11	11
50·0	8	1	12	21
50·5	4	1	8	13
51·0	8	4	4	16
51·5	2	5	3	10
52·0	12	12	9	33
52·5	9	29	10	48
53·0	9	20	16	45
53·5	14	11	16	41
54·0	34	28	23	85

Table 294—*concld.*

Range.	July.	August.	September.	Combined.
54·5	34	35	38	107
55·0	65	57	83	205
55·5	152	94	138	384
56·0	312	233	234	779
56·5	358	384	392	1134
57·0	202	320	256	778
57·5	81	176	116	373
58·0	35	81	46	162
58·5	21	44	28	93
59·0	13	32	20	65
59·5	16	21	18	55
60·0	5	12	11	28
60·5	6	9	5	20
61·0	8	9	3	20
61·5	9	3	2	14
62·0	3	4	3	10
62·5	4	0	1	5
63·0	6	0	3	9
63·5	1	1	..	2
63 5—64·0	1	1	..	2

Table 295.—Frequency distribution of average level of the Baitarani at Akhuapada for 4 consecutive days: 1 874—1929.

Range.	July.	August.	September.	Combined.
47 0—47·5	3	..	..	3
48·0	5	..	..	5
48·5	10	..	..	10
49·0	7	..	4	11
49·5	0	..	15	15
50·0	5	..	10	15
50 5	3	1	7	11
51·0	6	3	5	14
51·5	6	7	4	17
52·0	10	11	7	28
52·5	7	17	10	34
53·0	9	19	17	45
53·5	14	11	11	36
54·0	29	30	30	89
54·5	32	25	32	89
55·0	63	47	85	195
55·5	138	99	150	387
56·0	308	245	236	789
56·5	365	350	410	1125
57·0	200	334	253	787
57·5	63	199	116	378
58·0	31	73	50	154
58·5	17	49	26	92
59·0	16	38	20	74
59·5	11	15	15	41
60·0	9	14	6	29
60·5	12	11	6	29
61·0	3	6	5	14
61·5	9	2	3	14
62·0	8	1	1	10
62·5	2	2	2	6
63·0	2	0	..	2
63·0—63·5	..	1	..	1

Table 296.– Frequency distribution of average level of the Baitarani at Akhuapada for 5 consecutive days : 1874—1929.

Range.	July.	August.	September.	Combined.
47·0—47·5	2	..	..	2
48·0	7	1	..	8
48·5	9	..	..	9
49·0	6	5	..	11
49·5	0	10	..	10
50·0	5	9	..	14
50·5	2	11	..	13
51·0	6	3	3	12
51·5	6	7	8	21
52·0	7	2	9	18
52·5	9	13	17	39
53·0	10	15	19	44
53·5	15	16	12	43
54·0	25	24	20	69
54·5	29	26	29	84
55·0	47	73	46	166
55·5	129	140	104	373
56·0	307	256	255	818
56·5	370	411	343	1124
57·0	181	259	345	785
57·5	59	110	164	333
58·0	30	47	87	164
58·5	23	32	60	115
59·0	6	19	20	45
59·5	15	12	21	48
60·0	15	4	19	38
60·5	6	8	5	19
61·0	10	5	2	17
61·5	5	3	1	9
62·0	4	2	2	8
62·5	3	..	3	6

Table 297.—Level of the Baitarani at Akhuapada : Accumulated totals of moving averages for 1, 2, 3, 4 and 5 days. (Combined period July—September.)

Height equalled or exceeded.	1 day.	2 days.	3 days.	4 days.	5 days.
47·0	4791	4681	4600	4549	4505
47·5	4785	4677	4597	4546	4463
48·0	4781	4666	4592	4541	4456
48·5	4770	4653	4582	4531	4446
49·0	4754	4643	4568	4520	4435
49·5	4740	4623	4557	4505	4425
50·0	4727	4608	4536	4490	4411
50·5	4701	4592	4523	4479	4398
51·0	4695	4580	4507	4465	4386
51·5	4669	4545	4497	4448	4365
52·0	4642	4507	4464	4420	4347
52·5	4598	4464	4416	4386	4308
53·0	4550	4412	4371	4341	4264
53·5	4485	4306	4330	4305	4221
54·0	4380	4186	4245	4216	4152
54·5	4220	3980	4138	4127	4068
55·0	4037	3557	3933	3932	3902
55·5	3613	2753	3549	3545	3529
56·0	2803	1651	2770	2756	2711
56·5	1659	869	1636	1631	1587

Table 297—*concld.*

Height equalled or exceeded.	1 day.	2 days.	3 days.	4 days.	5 days.
57·0	962	512	858	844	802
57·5	567	336	485	466	469
58·0	380	238	323	312	305
58·5	261	173	230	220	190
59·0	201	131	165	146	145
59·5	137	93	110	105	97
60·0	106	67	82	76	59
60·5	81	53	62	47	40
61·0	63	40	42	33	23
61·5	48	27	28	19	14
62·0	36	20	18	9	6
62·5	27	15	13	3	
63·0	23	8	4	1	
63·5	11	4	2		
64·0	6	1			
64·5	4				
65·0	3				
65·5	1				

Table 298.—Level of the Baitarani at Akhuapada : Probability of occurrence of an assigned height in number of days per monsoon season July—September, for single day and 2, 3, 4 and 5 consecutive days.

Height equalled or exceeded.	1 day.	2 days.	3 days.	4 days.	5 days.
47·0	85·44	83·62	82·09	81·18	79·70
48·0	85·18	83·09	81·82	80·91	79·39
49·0	84·64	82·55	81·37	80·45	79·02
50·0	83·95	82·00	80·77	79·98	78·54
51·0	83·37	81·16	80·30	79·43	77·95
52·0	83·10	79·71	78·86	78·32	76·93
53·0	80·09	76·89	77·32	76·87	75·37
54·0	75·36	71·07	73·89	73·70	72·64
55·0	64·52	49·16	63·37	63·25	63·02
56·0	29·62	15·52	29·21	29·12	28·34
57·0	10·12	6·00	8·66	8·32	8·37
58·0	4·66	3·09	4·11	3·93	3·39
59·0	2·45	1·66	1·96	1·87	1·73
60·0	1·45	·95	1·11	·84	·71
61·0	·86	·48	·50	·34	·25
62·0	·48	·27	·23	·05	
63·0	·20	·07	·04		
64·0	·07				

The absolute maximum readings for each year for 1 day, and averages of 2, 3, 4 and 5 consecutive days are shown in Table 299. The letter and figure within brackets, give the month and date ending the period in question. Thus for 5 days, in 1874 the figure 2A within brackets indicate that the period of 5 days extended over 29th July—2nd August, both days' inclusive.

The accumulated totals of the absolute year-maximum readings for 1, 2 3, 4 and 5 days' averages are given in Table 300.

Table 299.—Level of the Baitarani at Akhuapada : Maximum heights for 1, 2, 3, 4 and 5 consecutive days (July—September, 1874—1929).

Gauge height less 50 feet.

Years.	1 day.	2 days.	3 days.	4 days.	5 days.
1874	10· 5 (30 J)	9· 8 (30 J)	9·08 (31 J)	7.86 (1 A)	7·29 (2 A)
75	10· 5 (19 S)	9· 6 (17 J)	8· 9 (20 S)	7· 9 (21 S)	7· 4 (22 A)
76	10· 8 (3 S)	9 7 (3 S)	9· 2 (4 S)	8· 4 (5 S)	7· 9 (6 S)
77	9· 6 (4 S)	7· 5 (4 S)	7· 0 (4 S)	7· 1 (18 A)	6· 5 (18 A)
78	6· 6 (28 A)	5· 9 (17 A)	5· 8 (18 A)	5· 7 (18 A)	5· 6 (18 A)
79	10· 5 (10 A)	10· 1 (11 A)	9· 8 (11 A)	9· 6 (12 A)	8· 8 (13 A)
80	9· 9 (5 S)	9· 1 (6 S)	8· 5 (6 S)	8· 2 (7 S)	7· 9 (8 S)
81	15· 3 (17 J)	14· 5 (18 J)	13· 2 (18 J)	12· 2 (19 J)	11· 3 (20 J)
82	11· 2 (25 J)	9· 8 (26 J)	9· 2 (26 J)	8· 7 (27 J)	8· 3 (28 J)
83	11· 3 (1 J)	10· 3 (2 J)	9· 0 (3 J)	8 4 (4 J)	7· 8 (5 J)
84	11· 4 (7 S)	10· 8 (7 S)	10· 2 (8 S)	9· 8 (9 S)	9· 5 (10 S)
85					
86					
87	9· 0 (26 J)	8· 4 (26 J)	7· 9 (27 J)	7· 6 (27 J)	7· 5 (27 J)
88	11· 1 (24 A)	11 1 (25 A)	11· 1 (26 A)	10· 6 (27 A)	10· 3 (27 A)
89	10· 5 (18 A)	10· 0 (19 A)	9· 5 (19 A)	9· 0 (20 A)	8· 5 (21 A)
90	9· 0 (27 S)	8 7 (28 S)	8· 4 (28 S)	8· 1 (28 S)	7· 9 (29 S)
91	12· 4 (14 A)	12· 1 (15 A)	11· 4 (15 A)	10· 8 (16 A)	10· 3 (16 A)
92	8· 9 (13 J)	8· 8 (13 J)	8· 3 (14 J)	7· 8 (14 J)	7· 5 (15 J)
93	13· 3 (13 S)	12· 5 (13 S)	11· 9 (14 S)	11· 1 (15 S)	10· 4 (16 S)
94	14·33 (26 J)	13 63 (26 J)	13·15 (27 J)	12·05 (28 J)	11·14 (29 J)
95	8·18 (29 A)	7 99 (30 A)	7·70 (31 A)	7 49 (31 A)	7·32 (31 A)
96	15·46 (24 J)	14 28 (24 J)	13·72 (25 J)	12·87 (26 J)	12·32 (27 J)
97	7·60 (9 S) &(17 A)	7·53 (10 S)	7·47 (17 A)	7·35 (18 A)	7·20 (19 A)
98	11 35 (10 A)	10·46 (10 A)	10·59 (11 A)	10 05 (12 A)	9·46 (13 A)
99	9· 3 (15 J)	9· 0 (15 J)	8· 5 (16 J)	8· 0 (17 J)	7· 7 (18 J)
1900	14· 3 (25 S)	13 8 (25 S)	13· 1 (25 S)	12· 6 (26 S)	12· 1 (26 S)
01	11· 3 (26 A)	11 0 (26 A)	10· 0 (27 A)	9· 2 (28 A)	8· 8 (28 A)
02	11· 1 (17 J)	11 9 (17 J)	11· 1 (18 J)	10· 2 (18 J)	9· 5 (19 J)
03	8· 2 (24 J)	7· 9 (24 J)	7· 4 (30 S)	7· 3 (30 S)	7· 1 (30 S)
04	16· 0 (9 J)	14· 3 (9 J)	13· 1 (10 J)	12· 0 (11 J)	11· 1 (11 J)
05	7· 9 (14 J)	7 68 (16 S)	7·58 (16 S)	7·56 (16 S)	7·53 (17 S)
06	13· 9 (14 S)	13· 6 (14 S)	12· 3 (14 S)	11· 6 (15 S)	10· 8 (16 S)
07	16· 2 (29 A)	15· 1 (21 A)	14· 1 (21 A)	13· 3 (22 A)	12· 3 (23 A)
08	10· 8 (18 A)	10· 8 (18 A)	10· 8 (18 A)	10· 4 (19 A)	10· 1 (19 A)
09	11· 9 (2 A)	11· 5 (2 A)	10· 6 (3 A)	9· 9 (4 A)	9· 3 (5 A)
10	10· 6 (29 J)	10 0 (29 J)	9· 5 (30 J)	9· 2 (30 J)	8· 8 (31 J)
11	9· 3 (13 S)	9· 0 (13 S)	8· 8 (13 S)	8· 5 (14 S)	8· 3 (15 S)
12	11· 8 (7 S)	10· 6 (8 S)	10· 2 (9 S)	9· 7 (9 S)	9· 2 (9 S)
13	13· 5 (26 J)	13· 5 (26 J)	13· 5 (27 J)	12· 4 (28 J)	11· 3 (28 J)
14	10· 4 (16 S)	10· 1 (17 S)	9· 9 (17 S)	9· 6 (17 S)	9 3 (18 S)
15	8· 4 (17 S)	8 1 (18 S)	7· 7 (18 S)	7· 6 (18 S)	7· 6 (18 S)
16	7· 9 (21 A)	7· 8 (16 A)	7· 7 (17 A)	7· 6 (18 A)	7· 4 (18 A)
17	10· 1 (11 A)	9 9 (11 A)	9· 1 (12 A)	9· 0 (13 A)	8· 8 (14 A)
18	9· 7 (6 S)	9· 2 (7 S)	8· 6 (8 S)	8· 1 (8 S)	8· 0 (8 S)
19	10· 8 (9 A)	10· 6 (9 A)	9· 9 (9 A)	9· 4 (10 A)	9· 1 (11 A)
20	13· 6 (8 A)	12· 9 (24 J)	13· 0 (24 J)	12· 9 (24 J)	12· 5 (25 J)
21	8· 9 (29 J)	8· 4 (30 J)	8· 2 (31 J)	8· 2 (1 A)	8· 1 (1 A)
22	12· 1 (29 J)	10· 6 (30 J)	9· 6 (30 J)	9· 0 (31 J)	8· 5 (31 J)
23	12· 6 (18 A)	12· 4 (18 A)	11· 3 (19 A)	10· 6 (19 A)	10· 2 (19 A)
24	8· 2 (7 A)	8· 2 (7 A)	7· 6 (7 A)	7· 3 (8 A)	7· 1 (8 A)
25	14· 0 (23 A)	12· 2 (24 A)	11· 4 (24 A)	10· 2 (25 A)	9· 9 (26 A)
26	10· 0 (4 S)	9· 9 (5 S)	9· 6 (5 S)	9· 6 (21 A)	9· 4 (22 A)
27	14· 2 (25 J)	12· 2 (25 J)	11· 4 (26 J)	10· 6 (27 J)	9· 9 (27 J)
28	13· 3 (27 J)	13· 0 (27 J)	12· 1 (27 J)	11· 0 (28 J)	10· 2 (24 J)
29	12· 0 (31 J)	11· 3 (31 J)	10· 3 (31 J)	9· 9 (31 J)	10· 1 (31 J)

(Dates give the end of the period).

Table 300.—Level of the Baitarani at Akhuapada : Accumulated totals for Frequency distribution of maximum gauge-height for each year (1874—1929).

Height (in feet) exceeded.	1 day.	2 days.	3 days.	4 days.	5 days.
55·5	..	..	..	54	54
56·0	..	54	54	53	53
56·5	54	53	53	53	53
57·0	53	53	53	53	52
57·5	53	53	52	52	49
58·0	52	50	45	44	40
58·5	47	45	43	37	34
59·0	46	42	38	32	30
59·5	42	37	31	27	24
60·0	38	35	27	22	18
60·5	35	27	21	16	11
61·0	29	22	18	12	9
61·5	24	18	15	9	6
62·0	20	16	11	8	4
62·5	16	12	9	5	3
63·0	14	10	8	3	
63·5	14	8	3	1	
64·0	10	5	1		
64·5	6	4			
65·0	4	1			
65·5	4				
66·0	2				

The seasonal correlation between the average rainfall during each monsoon season and the average level of the Baitarani at Akhuapada for the 38 years 1891—1928 is $+ 0{\cdot}21 \pm {\cdot}11$ and is surprisingly small. In fact it is not significant. It will be remembered that the coefficients for the Mahanadi and the Brahmini are $+ 0{\cdot}72 \pm {\cdot}05$, and $+ 0{\cdot}61 \pm {\cdot}07$, respectively. The low value of the Baitarani coefficient cannot be explained by any instability of the river-bed, for we have already seen that since 1887 the average level has been remarkably steady.

The rainfall data for the Baitarani catchment, however, are not very satisfactory, and the low value of the correlation may be merely due to the uncertainty in the estimate of the rainfall. It is not possible to say anything more without further investigations.

CHAPTER 38.—THE LEVEL OF THE SALINDI AT RANDIA.

Table 301.—Frequency Distribution of the Height of the Salindi at Randia Gauge (1876—1929).

Range in feet.	July.	August.	September.	Combined.
38·5—39·5	17	..	..	17
—40·5	1	1	..	2
—41·5	1	..	..	1
—42·5	1	10	3	14
—43·5	23	12	9	44
—44·5	56	25	12	93
—45·5	180	52	29	261
—46·5	398	141	108	647
—47·5	353	351	414	1118
—48·5	156	331	400	887
—49·5	74	241	219	534
—50·5	56	164	130	350
—51·5	23	96	76	195
—52·5	23	62	58	143
—53·5	20	26	21	67
—54·5	8	20	19	47
—55·5	12	15	4	31
—56·5	4	4	3	11
—57·5	3	2	4	9
—58·5	2	..	0	2
—59·5	..	..	1	1

The data for the height of the river Salindi at Randia consists of daily readings for July, August and September for the period 1876—1921, 1925—29. Records for the 3 years 1922—24 were not available, as also July, 1884, 1914, 1925, and other readings here and there. The total number of daily readings available were in July 1411, in August 1553, and in September 1510 with a total of 4474.

The frequency distributions for each month and the combined period are given in Table 301. The mean values and standard deviations are given below in Table 302. (The mean values given in this table were directly calculated.)

Table 302.—Mean values and Standard Deviations of Gauge-height at Randia of the Salindi for July, August and September.

Period.	n.	Mean Height	Standard Deviation.
July	1411	47·1	2·35
August	1553	48·7	2·22
September	1510	48·5	2·12
July—September	4474	48·1	2·42

The accumulated totals of the frequencies for the combined period are given in Table 303.

Dividing by 50 (the approximate number of years of experience), we get the probability of occurrence (in number of days per monsoon season, July—September) of different heights of the Salindi at Randia, given in Table 304.

Table 303.—Height of the Salindi at Randia : Accumulated totals of frequency distribution (1876—1929).

Height in feet exceeded.	July.	August.	September.	Combined.
38·5	1411	..	..	4464
39·5	1394	1553	..	4457
40·5	1393	..	..	4455
41·5	1392	1552	1510	4454
42·5	1391	1542	1507	4440
43·5	1368	1530	1498	4396
44·5	1312	1505	1486	4303
45·5	1132	1453	1457	4042
46·5	734	1312	1349	3395
47·5	381	961	935	2277
48·5	225	630	535	1390
49·5	151	389	316	856
50·5	95	225	186	506
51·5	72	129	110	311
52·5	49	67	52	168
53·5	29	41	31	101
54·5	21	21	12	54
55·5	9	6	8	23
56·5	5	2	5	12
57·5	2	..	1	3
58·5	..	..	1	1
59·5				

Table 304.—Height of the Salindi at Randia : Probability occurrence of assigned Gauge-heights *in number of days per monsoon season of July—September, 1876—1929.*

Height in feet exceeded.	Frequency.	Height exceeded	Frequency.	Height exceeded.	Frequency.
38·5	89·28	47·5	80·84	52·5	3·26
39·5	89·14	46·5	67·90	53·5	2·02
40·5	89·10	47·5	45·54	54·5	1·08
41·5	89·08	48·5	27·80	55·5	·46
42·5	88·80	49·5	17·12	56·5	·24
43·5	87·92	50·5	10·12	57·5	·06
44·5	86·66	51·5	6·22	58·5	·02

The averages for each month (July, August, September) and the combined period July—September, for each year are given in Tables 305-306. There are minor oscillations of increasing or decreasing heights of the river in all the months, but there is no evidence of any persistent or regular change with time. The tendencies for different months are moreover not concordant.

In recent years, however, there is an increasing tendency shown in both the months of July and August which has imparted a decided upward tendency in the curve for the combined period. I believe that this upward trend is associated with one of a short period oscillation of increasing rainfall in the region drained by the Brahmini, Baitarani and the Salindi.

Table 305.—Level of the Salindi at Randia : Mean height of Gauge for July, August and September (1876—1929).

July.			August.			September.		
Years.	n.	Mean height	Years.	n.	Mean height.	Years.	n.	Mean height.
1876	31	47·0	1876	30	47·5	1876	30	49·5
77	31	47·6	77	31	48·8	77	30	48·4
78	28	45·7	78	31	48·1	78	30	46·6
79	30	46·1	79	31	47·9	79	30	48·0
80	31	47·1	80	31	49·4	80	30	49·6
81	31	50·3	81	31	50·5	81	30	48·0
82	25	47·6	82	27	48·2	82	26	48·6
83	25	48·3	83	27	48·6	83	26	48·9
84	..	..	84	20	47·8	84	30	49·6
85	31	47·0	85	31	49·0	85	30	49·0
86	31	47·4	86	31	48·6	86	20	47·7
87	31	48·1	87	31	49·0	87	30	48·7
88	31	45·9	88	31	47·8	88	30	48·3
89	31	46·0	89	31	48·9	89	30	48·7
90	31	46·9	90	31	47·8	90	30	48·3
91	31	46·4	91	31	49·7	91	30	50·1
92	31	44·8	92	31	43·6	92	30	44·6
93	31	44·3	93	31	45·6	93	30	46·6
94	31	49·6	94	31	48·7	94	30	47·8
95	31	47·5	95	31	48·8	95	30	48·3
96	31	49·4	96	31	50·1	96	30	49·7
97	31	47·7	97	31	49·7	97	30	48·6
98	20	47·1	98	31	49·6	98	30	49·2
99	26	47·3	99	31	46·7	99	30	47·2
1900	31	46·8	1900	31	49·7	1900	30	50·8
01	31	46·1	01	31	47·6	01	30	48·0
02	31	47·5	02	31	48·2	02	30	47·5
03	15	44·8	03	31	48·2	03	30	48·0
04	31	47·9	04	31	47·4	04	30	47·9
05	31	46·1	05	31	46·7	05	30	47·7
06	31	46·7	06	31	46·4	06	30	49·3
07	31	47·2	07	31	49·9	07	30	48·7
08	31	46·9	08	30	50·4	08	30	48·1
09	29	47·7	09	31	48·8	09	30	48·9
1910	31	47·0	1910	31	49·1	1910	30	48·6
11	31	45·6	11	31	46·3	11	30	49·0
12	31	47·4	12	31	48·9	12	30	48·1
13	30	48·5	13	28	49·7	13	30	48·2
14	..	..	14	26	49·2	14	28	50·3
15	31	45·8	15	31	46·5	15	30	48·6
16	30	47·2	16	31	48·1	16	30	48·0
17	30	48·6	17	31	50·0	17	30	49·0
18	31	46·7	18	31	47·4	18	30	47·9
19	31	47·2	19	31	49·9	19	30	47·8
1920	31	49·6	1920	31	50·2	1920	30	49·1
21	31	47·4	21	31	48·4	21	30	50·6
22	..	..	22	..	..	22	..	..
23	..	..	23	..	..	23	..	..
24	..	..	24	..	..	24	..	..
25	..	..	25	31	49·3	25	30	49·2
26	28	41·1	26	31	48·9	26	30	50·1
27	31	48·3	27	31	51·0	27	30	48·2
28	31	49·6	28	31	50·8	28	30	49·5
1929	10	49·5	1929	31	49·2	1929	30	49·2

Table 306.—Mean height of the Salindi at Randia for the period July—September.

Years.	Mean height.	Years.	Mean height.	Years.	Mean height.	Years.	Mean height.
1876	48·0	1890	47·7	1904	47·8	1918	47·3
77	48·3	91	49·1	05	46·5	19	48·3
78	46·8	92	44·3	06	47·5	20	47·6
79	47·3	93	45·5	07	48·6	21	48·8
80	48·7	94	48·7	08	48·5	22	..
81	49·6	95	48·2	09	48·5	23	..
82	48·1	96	49·7	10	48·2	24	..
83	48·3	97	48·7	11	47·0	25	49·3
84	48·7	98	48·7	12	48·1	26	46·7
85	48·3	99	47·1	13	48·8	27	49·2
86	47·9	1900	49·1	14	49·8	28	50·0
87	48·6	01	47·3	15	47·3	29	49·3
88	47·3	02	47·8	16	47·8		
89	47·9	03	47·7	17	49·2		

Table 307 gives the average height of the Salindi at Randia for each date for the period July 1—September 30, the whole monsoon season. The curve rises rapidly from the beginning of July to about the 1st week of August, more slowly till the middle of August, and is fairly steady between 48·5 and 48·7 until the middle of September, after which the permanent fall sets in very gradually.

Table 307.—Mean height of the Salindi at Randia for each date from July to September (1876—1929).

	July.		August.			September.		
Date.	n.	Mean height.	Date.	n.	Mean height.	Date.	n.	Mean height.
1	42	46·5	1	49	48·5	1	51	48·7
2	42	46·6	2	49	48·7	2	50	48·8
3	42	46·6	3	50	48·6	3	50	48·9
4	43	46·2	4	50	48·2	4	51	48·7
5	45	46·2	5	49	48·0	5	51	49·1
6	45	46·4	6	49	48·1	6	51	49·1
7	44	46·3	7	50	48·5	7	51	48·9
8	44	46·1	8	49	48·4	8	50	48·7
9	44	46·2	9	49	48·6	9	50	48·7
10	45	46·3	10	49	48·6	10	50	48·6
11	44	46·3	11	50	48·3	11	51	48·4
12	46	46·7	12	50	48·2	12	51	49·0
13	46	47·1	13	50	48·3	13	51	48·7
14	45	47·1	14	50	48·5	14	51	48·7
15	45	47·1	15	51	48·3	15	50	48·5
16	45	47·2	16	51	48·1	16	50	48·5
17	46	47·0	17	51	48·6	17	50	48·6
18	46	47·0	18	49	48·4	18	51	48·7
19	45	47·0	19	50	48·7	19	51	48·4
20	46	47·1	20	50	48·8	20	51	48·5
21	45	46·9	21	51	48·7	21	50	48·2
22	47	47·2	22	51	48·6	22	50	48·2
23	47	47·3	23	51	48·7	23	49	48·2
24	48	47·7	24	50	48·8	24	49	48·6
25	48	47·9	25	50	48·8	25	50	48·4
26	47	48·2	26	50	48·7	26	50	48·5
27	48	48·1	27	50	48·5	27	50	48·2
28	48	48·0	28	51	48·7	28	50	48·2
29	47	48·4	29	51	48·7	29	50	48·0
30	47	48·3	30	51	48·4	30	51	47·7
31	47	48·2	31	51	48·6			