Table 119.—Dates of maximum rainfall for 1, 2, 3, 4, 5 consecutive days.

Mahanadi Catchment Section I, 1891—1928, July—September.

Year	1 day	2 days	3 days	4 days	5 days
1891 ..	2·14 J 12	1·22 J 13	1·29 S 12	1·02 J 15	·86 J 15
92 ..	1·79 A 31	1·11 A 31	·92 J 18	·75 J 12	·73 J 21
93 ..	2·39 S 23	1·57 S 24	1·17 S 24	·92 S 24	·79 S 24
94 ..	1·77 J 24	1·22 J 25	·97 J 25	·86 J 12	·85 J 12
1895 ..	2·30 S 19	1·49 S 19	1·37 S 30	1·07 A 8	·89 A 8
96 ..	1·02 A 2	1·44 A 2	1·22 A 3	·98 A 4	·85 A 5
97 ..	1·26 S 6	1·06 S 10	1·00 S 10	·91 S 10	·98 S 10
98 ..	1·80 S 14	1·38 S 14	1·14 S 14	1·00 A 10	·86 A 10
99 ..	1·18 A 4	·78 J 3	·72 J 3	·59 A 23	·57 J 24
1900 ..	2·80 A 18	2·26 A 19	1·68 A 19	1·33 A 19	1·05 A 19
01 ..	1·73 A 18	1·02 A 19	·90 S 23	·77 A 10	·73 A 10
02 ..	2·38 J 15	2·11 J 16	1·68 J 16	1·35 J 17	1·15 J 16
03 ..	2·14 J 14	1·49 J 15	1·23 J 14	1·24 J 15	1·11 J 16
04 ..	2·08 J 1	1·70 J 2	1·23 S 13	1·07 J 4	·89 S 14
1905 ..	2·09 A 1	1·93 A 2	1·58 A 3	1·27 A 4	1·02 A 5
06 ..	3·45 J 22	2·57 J 22	2·15 J 22	1·71 J 22	1·42 J 22
07 ..	3·75 A 20	2·80 A 20	2·06 A 21	1·60 A 21	1·29 A 22
08 ..	1·53 A 8	1·38 A 8	1·10 A 9	1·04 A 10	·95 A 11
09 ..	1·55 J 25	1·14 J 25	·95 J 25	·80 J 26	·70 J 26
1910 ..	5·76 J 4	3·77 J 4	2·74 J 5	2·20 J 5	1·84 J 5
11 ..	1.85 S 24	1·35 S 24	1·15 S 25	·90 S 26	·93 A 18
12 ..	1·66 J 28	1·41 J 29	1·13 J 29	·93 J 29	·91 J 29
13 ..	1·73 A 1	1·33 J 25	1·24 J 25	1·24 J 25	1·13 J 26
14 ..	2·22 J 27	1·55 S 15	1·48 S 15	1·36 S 16	1·28 S 16
1915 ..	2·28 J 29	1·68 A 3	1·46 A 4	1·42 J 29	1·40 J 29
16 ..	1·30 A 15	1·16 A 16	1·07 A 16	·95 A 16	·85 A 17
17 ..	1·71 A 13	1·02 A 13	·77 S 4	·67 S 5	·71 A 17
18 ..	1·33 J 30	1·14 J 30	·85 J 30	·97 J 30	·76 J 15
19 ..	1·91 A 7	1·42 A 25	1·33 J 14	1·30 A 27	1·15 A 27
1920 ..	3·38 J 31	2·86 J 31	1·95 J 24	1·65 J 24	1·57 J 24
21 ..	3·61 S 5	3·12 S 6	2·25 S 5	1·82 S 6	1·50 S 6
22 ..	2·98 J 8	2·02 J 8	1·65 J 9	1·41 J 8	1·31 J 9
23 ..	1·10 J 20	·91 J 20	·73 J 20	·66 S 29	·61 S 29
24 ..	3·09 A 5	2·32 A 6	1·62 A 6	1·29 A 6	1·06 A 6
1925 ..	4·13 S 7	3·01 S 7	2·14 S 8	1·82 J 12	1·52 J 12
26 ..	5·91 A 17	5·57 A 17	4·29 A 17	3·41 A 18	2·77 A 18
27 ..	2·61 S 2	1·58 S 3	1·29 J 13	1·06 J 14	·13 S 6
28 ..	2·53 J 26	2·13 J 26	1·65 J 26	1·33 J 26	1·38 J 26

In Table 119 the periods of maximum rainfall in Mahanadi Section I are shown separately for each year. The amount of average rainfall in inches per day is shown in figures for 1, 2, 3, 4, and 5 consecutive days. In each case the amount of rainfall is followed by the actual date of the last day of the period; dates in July are indicated by "J", in August by "A", and in September by "S". Thus in Table 119 in the column headed 3 days we find that in 1891 the maximum intensity was 1·29 inches per day on the 10th, 11th and 12th September.

Table 120.—Dates of maximum rainfall for 1, 2, 3, 4, 5 consecutive days.

Mahanadi Catchment Section II, 1891—1928, July—September.

Year	1 day	2 days	3 days	4 days	5 days
1891 ..	5·16 A 3	3·57 A 4	2·51 A 4	2·18 A 6	1·82 A 6
92 ..	9·81 J 23	8·74 J 23	6·61 J 24	5·11 J 24	4·18 J 26
93 ..	4·65 S 3	2·98 S 4	2·02 S 5	1·52 S 5	1·60 S 5
94 ..	4·10 J 25	3·13 J 25	2·75 J 25	2·22 J 26	1·88 J 26
95 ..	2·56 A 25	1·57 A 25	1·23 A 25	1·39 A 11	1·21 A 11
96 ..	8·94 J 28	6·17 J 23	4·45 J 24	3·87 J 24	3·05 J 24
97 ..	6·00 J 10	3·08 J 11	2·70 J 10	2·06 J 11	1·67 J 12
98 ..	5·25 A 9	2·80 J 18	2·10 J 18	1·68 J 18	1·42 A 11
99 ..	3·76 J 14	2·41 J 14	1·75 J 14	1·54 J 14	1·31 J 15
1900 ..	4·48 S 1	3·24 S 2	3·04 S 3	2·30 S 4	2·24 S 20
01 ..	6·81 A 17	3·57 A 17	2·40 A 18	2·28 A 21	1·39 A 25
02 ..	3·58 J 26	2·23 J 26	1·63 J 26	1·30 J 26	1·06 J 26
03 ..	2·16 A 2	1·69 J 24	1·29 A 3	1·02 J 24	1·08 J 23
04 ..	3·12 J 2	2·78 J 2	2·10 J 3	1·58 J 4	1·27 J 5
05 ..	3·47 S 8	2·34 S 8	1·63 A 3	1·52 A 4	1·24 A 5
06 ..	2·93 J 22	2·10 J 22	1·58 J 23	1·29 J 23	1·09 J 23
07 ..	2·48 S 6	2·12 S 7	1·80 S 7	1·50 S 8	1·30 S 9
08 ..	2·39 A 12	1·99 A 12	1·81 A 12	1·54 A 13	1·47 A 12
09 ..	2·01 S 22	1·93 J 25	1·58 J 25	1·28 J 25	1·10 J 27
1910 ..	5·04 J 4	4·59 J 5	3·28 J 5	2·78 J 25	2·36 J 5
11 ..	4·68 A 14	4·08 A 15	3·05 A 15	2·50 A 16	2·20 A 18
12 ..	1·92 J 4	1·26 A 3	1·21 J 6	1·06 J 7	·98 J 6
13 ..	3·59 A 1	2·04 A 2	1·52 A 31	1·42 A 31	1·15 A 31
14 ..	1·74 A 4	1·40 J 12	1·19 J 12	·95 J 12	1·00 J 12
15 ..	3·84 A 3	2·78 A 3	2·05 A 3	1·72 A 4	1·25 J 29
16 ..	1·54 A 23	1·20 J 23	1·03 J 24	·97 J 25	·88 J 25
17 ..	1·89 A 6	1·44 J 29	1·12 J 30	1·00 A 13	·86 J 13
18 ..	1·63 A 14	1·54 A 15	1·25 J 29	1·09 S 4	·96 S 5
19 ..	3·58 A 2	2·79 A 2	2·05 A 3	1·55 A 4	1·23 A 5
1920 ..	4·16 A 26	2·89 A 26	2·42 A 26	2·13 J 24	2·62 J 24
21 ..	3·18 S 4	2·78 S 5	2·03 S 5	1·71 S 5	1·48 S 5
22 ..	2·31 S 10	1·58 A 18	1·28 A 18	1·21 A 20	1·10 A 20
23 ..	1·40 A 11	1·16 A 12	·84 A 12	·92 A 14	·82 A 14
24 ..	2·77 A 6	2·24 A 6	1·68 A 6	1·31 A 6	1·08 A 7
25 ..	3·25 J 12	1·97 J 12	2·05 J 12	1·88 J 12	1·65 J 12
26 ..	4·69 A 17	3·93 A 17	3·21 A 18	2·67 A 18	2·21 A 18
27 ..	3·28 J 12	1·87 J 25	1·44 J 25	1·33 S 5	1·20 J 25
28 ..	4·32 J 26	2·69 J 27	2·07 J 27	1·76 J 27	1·51 J 27

Table 121.—Dates of maximum rainfall for 1, 2, 3, 4, 5 consecutive days.

Mahanadi Catchment Section III, 1891—1928, July—September.

Year.	1 day	2 days	3 days	4 days	5 days
1891 ..	5·44 J 26	3·83 J 27	2·73 J 27	2·35 J 27	2·07 J 27
92 ..	6·01 J 23	4·76 J 23	3·74 J 23	3·06 J 23	2·59 J 24
93 ..	2·69 A 7	2·33 A 8	1·82 A 9	1·45 A 9	1·15 A 6
94 ..	3·42 J 25	2·47 J 25	2·02 J 26	1·61 J 26	1·42 J. 9
95 ..	2·36 A 11	1·43 A 8	1·27 A 8	1·11 A 8	1·12 A 11
96 ..	2·51 A 18	2·26 J 23	2·03 J 24	1·88 J 24	1·66 J 24
97 ..	2·85 A 1	2·12 A 2	1·63 A 3	1·30 A 4	1·24 A 5
98 ..	2·30 J 17	1·59 J 18	1·35 J 19	1·15 J 19	·97 J 19
99 ..	1·99 J 2	1·97 J 3	1·35 J 4	1·12 J 5	·99 A 15
1900 ..	3·16 A 27	2·19 A 28	1·69 A 28	1·40 A 28	1·26 A 28

Table 121—*concld.*

Year	1 day	2 days	3 days	4 days	5 days
1901 ..	2·50 S 3	2·14 S 3	1·95 A 25	1·88 A 25	1·50 A 25
02 ..	2·64 A 25	2·03 A 25	1·54 A 26	1·23 A 26	·99 A 27
03 ..	2·14 J 23	1·85 J 23	1·56 J 24	1·30 J 24	1·21 J 24
04 ..	1·83 J 2	1·11 A 14	1·41 A 14	1·29 J 18	1·14 J 18
05 ..	5·11 J 12	3·03 J 12	2·86 J 13	2·35 J 13	2·00 J 14
06 ..	2·71 J 27	2·15 J 27	1·69 J 28	1·38 J 28	1·15 J 28
07 ..	2·25 A 14	2·17 A 15	2·03 A 15	1·62 A 15	1·37 A 15
08 ..	1·80 A 17	1·48 A 15	1·35 J 19	1·29 J 19	1·33 J 19
09 ..	2·35 S 22	1·35 S 22	1·02 J 15	1·07 J 16	1·06 J 17
1910 ..	2·02 A 12	1·75 A 13	1·43 A 9	1·24 A 12	1·28 A 13
11 ..	2·72 A 18	2·37 A 19	1·73 A 20	1·54 A 21	1·41 A 22
12 ..	1·85 A 14	1·55 A 15	1·17 A 17	·99 S 6	·91 S 6
13 ..	3·39 A 1	1·88 A 2	1·49 A 3	1·22 A 4	1·02 A 5
14 ..	3·41 J 15	2·87 A 5	2·42 A 5	2·38 A 5	2·09 A 5
15 ..	2·41 A 3	1·71 A 4	1·44 A 4	1·16 A 4	·93 A 5
16 ..	2·71 A 14	1·65 A 15	1·33 A 16	1·27 A 17	1·08 A 18
17 ..	2·83 A 6	2·17 A 13	1·74 A 13	1·79 A 13	1·53 A 13
18 ..	2·35 A 6	1·76 A 7	1·36 A 21	1·22 A 22	1·05 A 23
19 ..	2·45 S 1	1·47 A 8	1·18 A 8	1·02 A 9	·77 A 10
1920 ..	4·04 J 22	3·48 J 23	3·02 J 22	3·00 J 23	2·69 J 24
21 ..	2·40 J 29	1·62 J 30	1·08 J 31	1·29 J 31	1·25 J 31
22 ..	2·10 J 12	1·51 J 13	1·39 A 18	1·13 A 19	·97 A 18
23 ..	3·00 A 18	2·81 A 18	2·41 A 18	2·11 A 19	1·90 A 19
24 ..	1·50 A 6	1·12 J 27	·95 J 28	·98 J 27	·89 J 28
25 ..	2·31 A 22	1·68 J 7	1·48 J 8	1·43 J 9	1·41 J 10
26 ..	2·44 S 18	1·76 A 17	1·67 A 18	1·43 A 18	1·91 A 18
27 ..	3·40 J 25	2·55 J 25	2·02 A 25	1·64 J 25	1·40 J 25
28 ..	2·80 J 19	2·13 J 27	1·63 A 27	1·27 J 27	1·14 J 27

Table 122.—Dates of maximum rainfall for 1, 2, 3, 4, 5 consecutive days.
Mahanadi Catchment Section IV, 1891—1938, July—September.

Year	1 day	2 days	3 days	4 days	5 days
1891 ..	3·62 27 J	2·34 27 J	1·84 27 J	1·49 27 J	1·38 27 J
92 ..	2·67 11 A	1·88 31 J	1·45 31 J	1·09 1 A	·87 1 A
93 ..	3·65 30 J	2·60 3 A	2·05 3 A	1·66 4 A	2·27 3 A
94 ..	8·98 18 J	5·75 18 J	4·41 18 J	3·66 19 J	3·17 19 J
95 ..	2·45 25 A	2·15 25 A	1·48 25 A	1·45 27 A	1·42 28 A
96 ..	4·05 23 J	2·85 24 J	2·25 25 J	1·76 25 J	1·41 25 J
97 ..	3·11 7 A	1·88 7 A	2·19 7 A	1·64 7 A	1·31 7 A
98 ..	2·56 10 A	2·46 11 A	1·86 12 A	1·49 13 A	1·31 14 A
99 ..	3·50 22 A	2·27 23 A	1·66 24 A	1·29 29 A	1·24 30 A
1900 ..	10·26 12 A	6·27 12 A	4·41 13 A	3·89 13 A	2·77 13 A
01 ..	2·53 10 J	1·64 11 J	1·25 12 J	·99 13 J	·78 13 J
02 ..	2·81 25 A	1·84 26 A	1·32 27 A	1·02 27 A	·82 27 A
03 ..	3·25 14 J	2·46 14 J	1·61 15 J 18 A	1·48 16 J	1·39 18 A
04 ..	1·07 1 A	1·72 2 A	1·30 3 A	1·16 3 A	1·07 4 A
05 ..	3·48 1 J	2·92 2 J	1·95 3 J	1·50 4 J	1·18 5 J
06 ..	3·07 22 J	2·61 22 J	2·06 22 J	1·74 23 J	1·47 23 J
07 ..	3·07 7 S	2·72 7 S	2·32 8 S	2·01 9 S	1·71 10 S
08 ..	2·39 2 A	1·56 25 A	1·15 26 A	·98 27 A	·80 28 A
09 ..	2·64 22 S	1·59 13 J	1·33 13 J	1·17 13 J	1·03 14 J
1910 ..	7·46 4 A	4·44 4 A	3·88 4 A	3·29 4 A	2·78 4 A
11 ..	4·07 14 A	3·49 14 A	3·12 14 A	2·60 15 A	2·18 16 A
12 ..	2·66 3 A	2·53 3 A	2·10 4 A	1·74 4 A	1·21 5 A

Table 122—*concld.*

Year	1 day		2 days		3 days		4 days		5 days	
1913 ..	2·23	1 A	1·77	2 A	1·42	2 A	1·45	12 A	1·16	3 A
14 ..	3·22	29 J	2·17	29 J	1·92	29 J	1·29	30 J	1·36	29 A
15 ..	5·59	29 A	4·90	29 A	3·59	30 A	2·71	31 A	2·36	30 A
16 ..	1·04	14 A	1·28	15 A	1·25	16 A	·99	16 A	·82	16 A
17 ..	2·88	13 J	1·87	8 A	1·56	8 A	1·37	10 A	1·29	10 A
18 ..	4·71	30 J	3·61	30 J	2·88	30 J	2·45	30 J	2·01	31 J
19 ..	2·71	27 A	2·07	27 A	1·56	27 A	1·36	27 A	1·23	2 A
1920 ..	4·96	24 J	3·50	24 J	2·57	24 J	2·15	24 J	1·92	24 J
21 ..	2·73	8 A	2·13	8 A	2·01	9 A	1·76	9 A	1·50	9 A
22 ..	2·54	18 A	1·96	19 A	1·54	19 A	1·32	20 A	1·13	21 A
23 ..	2·25	6 J	1·61	7 A	1·49	7 A	1·50	7 A	1·08	7 A
24 ..	5·23	6 A	4·25	6 A	3·02	6 A	2·33	7 A	1·89	7 A
25 ..	3·00	9 J	2·97	10 J	2·46	11 J	2·57	12 J	2·28	13 J
26 ..	4·39	18 A	3·12	18 A	2·31	18 A	1·83	18 A	1·48	18 A
27 ..	3·24	25 J	2·59	25 J	2·01	25 J	1·62	25 A	1·35	25 J
28 ..	2·73	26 J	2·56	27 J	1·78	27 J	1·55	27 J	1·31	27 A

Table 123.—Dates of maximum rainfall for 1, 2, 3, 4, 5 consecutive days.

Mahanadi Catchment, Section V, 1891—1928, July—September.

Year	1 day		2 days		3 days		4 days		5 days	
1891 ..	4·31	J 27	3·08	J 27	2·19	J 27	1·70	J 28	1·49	J 28
92 ..	4·13	J 13	3·60	J 13	2·67	J 13	2·15	J 13	1·84	J 13
93 ..	2·63	A 3	1·77	A 3	1·66	A 3	1·41	A 4	1·12	A 5
94 ..	2·56	J 26	2·08	J 26	1·72	J 26	1·43	J 26	1·18	J 27
95 ..	1·97	A 7	1·74	A 8	1·23	A 8	1·05	A 9	·97	A 8
96 ..	4·63	J 24	2·98	J 24	2·34	J 24	1·91	J 24	1·63	J 25
97 ..	2·14	A 14	1·46	A 14	1·16	A 16	1·29	A 14	1·21	A 14
98 ..	1·67	A 11	1·47	A 12	1·15	A 12	1·06	J 4	·88	J 5
99 ..	2·26	A 23	1·97	A 24	1·40	A 25	1·22	A 26	1·01	A 26
1900 ..	3·07	S 24	2·31	S 24	1·96	S 25	1·69	S 26	1·53	S 26
01 ..	2·15	S 3	2·01	S 3	1·74	S 3	1·32	S 4	1·06	S 5
02 ..	2·11	J 25	1·12	J 25	·94	A 26	·73	A 27	·60	J 25
03 ..	2·07	J 14	1·75	J 14	1·47	J 15	1·48	J 16	1·23	J 16
04 ..	1·70	A 29	1·49	A 30	1·30	A 30	1·18	A 31	·95	A 31
05 ..	1·75	J 21	1·32	S 9	1·19	S 9	1·03	S 11	1·01	S 11
06 ..	2·31	J 22	1·55	J 23	1·22	J 23	1·03	J 23	·90	J 23
07 ..	1·22	A 15	1·17	A 15	1·04	A 15	1·02	A 15	·93	A 16
08 ..	2·06	A 30	1·81	A 30	1·54	A 30	1·38	A 31	1·12	A 31
09 ..	2·08	S 22	1·20	S 22	1·04	J 14	·93	J 14	·83	J 14
1910 ..	3·58	A 4	2·69	A 4	2·09	A 4	1·79	A 5	1·58	A 5
11 ..	1·49	J 9	1·47	A 6	1·39	A 6	1·29	A 6	1·13	A 7
12 ..	1·75	A 2	1·75	A 3	1·57	A 4	1·42	A 5	1·21	A 5
13 ..	2·02	A 1	2·44	A 2	1·65	A 3	1·28	A 4	1·02	A 5
14 ..	2·09	S 16	1·47	S 16	1·06	S 16	·97	J 12	·88	J 12
15 ..	2·82	A 29	1·84	A 4	1·42	A 30	1·13	A 30	·99	J 29
16 ..	1·91	A 14	1·26	A 15	·97	A 15	·85	A 16	·73	A 17
17 ..	2·20	A 7	1·74	A 8	1·44	A 8	1·20	A 14	1·11	A 11
18 ..	1·69	J 30	1·63	J 30	1·56	J 30	1·38	J 31	1·20	J 31
19 ..	1·79	J 2	1·47	J 2	1·06	J 3	·96	J 9	·82	J 9
1920 ..	2·96	J 25	2·78	J 25	2·47	J 25	2·08	J 25	1·76	J 25
21 ..	2·08	S 5	1·66	S 5	1·37	S 6	1·10	S 7	·91	S 7
22 ..	1·44	J 13	1·12	A 19	·92	A 20	·83	J 16	·73	J 16
23 ..	1·36	J 6	1·34	J 7	1·33	J 7	1·09	J 7	1·06	J 7
24 ..	2·21	A 6	1·79	A 6	1·51	A 6	1·26	A 6	1·06	A 6
25 ..	2·11	J 10	1·57	J 10	1·28	J 11	1·32	J 13	1·26	J 13
26 ..	3·08	A 18	2·13	J 18	1·65	S 21	1·62	S 21	1·37	S 21
27 ..	4·07	J 25	2·46	J 25	1·82	J 26	1·46	J 26	1·29	J 26
28 ..	2·56	J 21	1·74	J 27	1·20	J 27	1·85	J 27	·98	J 27

Table 124.—Maximum rainfall and dates of occurrence.

Whole Mahanadi Catchment, 1891—1928.

Year.	1 day.	2 days.	3 days.	4 days.	5 days.
1891	3·00 July 26	2·91 July 27	2·10 July 27	1·76 July 27	1·52 July 27
92	3·14 „ 23	2·70 „ 23	2·10 „ 24	1·77 „ 24	1·53 „ 24
93	1·29 Aug. 3	1·24 Aug. 3	1·11 Aug. 3	1·03 Aug. 3	1·07 Aug. 3
94	1·91 July 25	1·66 July 25	1·50 July 26	1·26 July 26	1·06 July 26
95	1·72 Aug. 7	1·55 Aug. 8	1·27 Aug. 8	1·05 Aug. 8	·92 Aug. 8
96	2·17 July 28	1·96 July 24	1·75 July 24	1·42 July 25	1·25 July 26
97	1·59 „ 10	1·08 „ 10	1·02 „ 10	·94 Aug. 14	·89 Aug. 14
98	1·41 Aug. 22	1·02 Aug. 23	·94 Aug. 11	·84 „ 12	·74 „ 12
99	1·36 July 3	1·09 July 3	·80 „ 24	·76 „ 26	·68 „ 26
1900	2·05 Sept. 24	1·58 Sept. 24	1·39 Sept. 25	1·20 Sept. 25	1·06 Sept. 26
01	1·48 „ 3	1·33 „ 3	1·08 Sept. 3	·93 „ 3	·81 Aug. 25
02	1·61 Aug. 25	1·40 Aug. 25	1·12 Aug. 26	·90 Aug. 27	·89 „ 25
03	1·77 July 14	1·38 July 15	1·23 July 26	1·15 July 16	1·07 July 16
04	1·51 „ 2	1·38 „ 2	1·12 „ 3	·90 „ 4	·75 „ 5
05	1·67 „ 1	1·35 „ 12	1·25 „ 13	1·06 „ 13	·95 „ 14
06	2·35 „ 22	1·74 „ 22	1·38 „ 22	1·18 „ 23	1·01 „ 23
07	1·47 Sept. 7	1·36 Sept. 7	1·35 Aug. 15	1·21 Aug. 15	1·11 Aug. 15
08	1·28 Aug. 12	1·05 Aug. 12	·95 „ 12	·90 „ 13	·83 „ 14
09	1·76 Sept. 22	1·11 July 25	·98 July 26	·87 July 14	·83 July 14
1910	3·75 Aug. 4	2·76 Aug. 4	2·21 Aug. 4	1·86 Aug. 4	1·60 Aug. 5
11	1·28 „ 12	1·05 „ 12	·95 „ 12	·90 „ 13	·83 „ 13
12	1·41 „ 3	1·40 „ 3	1·17 „ 4	1·06 „ 4	·96 „ 5
13	2·83 „ 1	2·14 „ 1	1·76 „ 2	1·51 „ 2	1·24 „ 2
14	1·36 Sept. 16	1·20 July 12	1·03 July 12	1·01 „ 5	·92 „ 5
15	2·27 Aug. 3	1·85 Aug. 4	1·56 Aug. 4	1·25 „ 4	1·01 „ 4
16	1·81 „ 14	1·30 „ 15	1·11 „ 16	·96 „ 17	·83 „ 17
17	1·48 „ 13	1·37 „ 13	1·20 „ 8	1·09 „ 13	·93 „ 13
18	1·50 „ 6	1·02 „ 7	·90 Sept. 2	·93 „ 1	·96 „ 1
19	1·95 „ 2	1·73 „ 2	1·22 Aug. 3	1·08 „ 27	·97 „ 27
1920	2·76 July 24	2·53 July 24	2·24 July 24	1·94 July 25	1·85 July 24
21	2·08 Sept. 5	1·96 Sept. 5	1·57 Sept. 6	1·29 Sept. 6	1·09 Sept. 6
22	1·65 Aug. 18	1·32 Aug. 19	1·20 Aug. 19	1·06 Aug. 19	·96 Aug. 19
23	1·15 July 6	·99 „ 6	·98 „ 7	·85 „ 7	·82 „ 7
24	2·32 Aug. 6	2·13 „ 6	1·62 „ 6	1·29 „ 6	1·09 „ 6
25	2·07 July 12	1·75 July 10	1·55 July 12	1·57 July 12	1·40 July 12
26	2·73 Aug. 17	2·44 Aug. 17	2·16 Aug. 18	1·83 Aug. 18	1·54 Aug. 19
27	2·87 July 25	2·05 July 25	1·57 July 25	1·34 July 25	1·15 July 25
1928	2·26 „ 26	2·05 „ 27	1·59 „ 27	1·35 „ 27	1·21 „ 27

Table 125.—Accumulated totals of average maximum rainfall per day during July—September (1891—1928).

Mahanadi Catchments, 1891—1928.

Average maximum rainfall in inches per day in excess of	M-I.					M-II.					M-III					M-IV.					M-V.				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0	..	..	38	38	38	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	38	38
·75	38	38	36	34	32	..	38	38	38	38	..	38	38	38	38	..	..	38	38	38	38	38	38	37	35
1·25	30	27	20	16	11	38	36	31	30	29	38	37	33	25	17	..	38	35	30	24	37	34	25	20	9
1·75	27	13	7	4	2	34	29	21	14	9	37	24	12	9	6	34	32	23	16	10	29	16	7	3	2
2·25	16	9	2	1	1	30	20	11	7	4	29	11	6	5	2	34	22	12	9	4	15	7	3		
2·75	10	6	1	1	1	26	17	6	3	2	13	6	3	2	..	23	12	8	3	3	9	4			
3·25	8	2	1	1	..	21	7	3	2	1	8	4	1	..	..	14	8	4	3	..	5	1			
3·75	3	2	1	..	..	16	5	2	2	1	4	2	..	..	..	10	5	3	1	..	4				
4·25	2	1	1	..	..	12	3	2	1	..	3	1	..	..	..	8	4	2	..	..	3				
4·75	2	1	..	..	..	7	2	1	1	..	3	1	..	..	..	6	3								
5·25	2	1	..	..	..	4	2	1	..	..	2	..	..	..	..	4	2								
5·75	2	..	..	..	..	4	2	1	..	..	1	..	..	..	..	3									
6·25	..	..	..	..	..	3	1	1	..	..	..	..	..	..	..	3									
6·75	..	..	..	..	..	3	1	..	..	..	..	..	..	..	..	3									
7·25	..	..	..	..	..	2	1	..	..	..	..	..	..	..	..	3									
7·75	..	..	..	..	..	2	1	..	..	..	..	..	..	..	..	2									
8·25	..	..	..	..	..	2	1	..	..	..	..	..	..	..	..	2									
8·75	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	2									
9·25	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1									
9·75	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1									
10·25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1									

The accumulated total frequencies of the average maximum rainfall per day for 1, 2, 3, 4, 5 consecutive days in the different sections of the Mahanadi Catchment are shown in Table 125. For example, in M-IV we find that the average maximum rainfall per day during the period of 4 consecutive days was in excess of 3·75″ on one occasion during the period 1891—1928; and exceeded 3·25″ on 3 occasions; 2·25″ on 9 occasions; 1·75″ on 16 occasions during the same period. The intensity of average rainfall per day naturally fall off rapidly as the number of consecutive days increases from 1 to 5 days.

CHAPTER 24.—SECULAR CHANGE IN THE LEVEL OF THE MAHANADI AT NARAJ.

The present chapter gives a summary of the statistical analysis of the daily readings of the height of the Mahanadi river at Naraj for the 3 monsoon months July, August and September for the period 1868—1929 inclusive (62 years). Records for July 1891, 1901, 1 0 4, August 1891, 1894 and September 1894 were missing as also certain other records here and there. The number of daily readings available for analysis was 1,876 for July, 1,871 for August and 1,833 for September, giving a total of 5,580 readings in all.

The mean height of the river for each year and for each month was calculated separately as well as the mean height for each year for July, August and September taken together. These figures are given in Tables 126—129. In these Tables column (1 gives the year, column (2) the number of days in the year for which the mean height has been calculated, column (3) the mean height (in feet) with its probable error, and column (4) the standard deviation (in feet) with its probable error for each year. The corresponding graphs are given in chart no. 2.

Table 126.—Mean height (in feet) and standard deviation of the Mahanadi at Naraj for the month of July (1868—1929).

Year. (1)	Number of days. (2)	Mean height and probable error. (3)	Standard deviation and probable error. (4)
1868 ..	31	72·38± 0·34	2·80± 0·24
1869 ..	31	77·86± 0·43	3·56± 0·30
1870 ..	31	76·53± 0·23	1·93± 0·17
71 ..	31	78·38± 0·31	2·55± 0·22
72 ..	31	83·39± 0·41	3·37± 0·29
73 ..	31	75·04± 0·53	4·36± 0·37
74 ..	31	76·89± 0·32	2·61± 0·22
75 ..	31	79·37± 0·45	3·74± 0·32
76 ..	31	77·47± 0·53	4·41± 0·38
77 ..	31	76·02± 0·41	3·39± 0·29
78 ..	31	72·12± 0·34	2·82± 0·24
79 ..	31	76·09± 0·04	0·36± 0·03
1880 ..	31	81·85± 0·42	3·49± 0·30
81 ..	31	80·04± 0·50	4·14± 0·35
82 ..	31	78·47± 0·54	4·48± 0 38
83 ..	31	80·24± 0·26	2·13± 0·18
84 ..	31	82·20± 0·37	3·07± 0·26
85 ..	31	79·51± 0·31	2·56± 0·22
86 ..	31	76·72± 0·29	2·38± 0·20
87 ..	31	79·01± 0·60	4·92± 0·42
88 ..	31	75·25± 0·48	3·94± 0·34
89 ..	31	75·97± 0·27	2·25± 0·19
1890 ..	31	78·55± 0·27	2·27± 0·19
91 ..	18	77·51± ..	.. ..
92 ..	31	80·18± 0·74	6·10± 0·52
93 ..	31	78·19± 0·32	2·64± 0·23
94 ..	31	81·76± 0·54	4·47± 0·38

* The Naraj readings were copied from the Gauge Register in the Office of the Superintending Engineer, Orissa Circle, Cuttack, by my assistant, Babu Sudhir Kumar Banerjee in July 1930. One single reading taken at 6·0 A.M. local time was available for the period 1868—1895 inclusive, and three readings taken at 6·0 A.M., 12·0 noon, and 6·0 P.M. local time respectively for the remaining period. The average of these three readings were taken in the latter case. It will be noticed that this procedure has introduced a slight heterogeneity in the data used for analysis.

Table 126.—*concld.*

Year. (1)	Number of days. (2)	Mean height and probable error. (3)	Standard deviation and probable error. (4)
1895 ..	31	78·94± 0·47	3·88± 0·33
96 ..	31	80·70± 0·78	6·47± 0·55
97 ..	31	73·13± 0·35	2·86± 0·24
98 ..	31	75·82± 0·39	3·20± 0·27
99 ..	31	74·43± 0·17	1·46± 0·13
1900 ..	31	75·43± 0·24	1·94± 0·17
01 ..	20	75·08± 0·54	4·47± 0·48
02 ..	31	74·74± 0·47	3·88± 0·33
03 ..	31	75·24± 0·78	6·47± 0·55
04 ..	31	79·43± 0·35	2·86± 0·24
05 ..	31	75·71± 0·39	3·20± 0·27
06 ..	31	77·75± 0·17	1·46± 0·13
07 ..	30	74·69± 0·24	1·94± 0·17
08 ..	30	78·92± ..	.. ..
09 ..	31	80·35± 0·46	3·81± 0·33
1910 ..	31	78·12± 0·44	3·67± 0·31
11 ..	31	75·11± 0·41	3·42± 0·29
12 ..	31	75·26± 0·34	2·79± 0·24
13 ..	31	76·02± 0·40	3·34± 0·29
14 ..	31	78·82± 0·29	2·40± 0·21
15 ..	31	73·20± 0·27	2·26± 0·19
16 ..	31	73·47± 0·72	5·91± 0·51
17 ..	30	75·70± 0·80	6·46± 0·56
18 ..	31	75·07± 0·54	4·45± 0·38
19 ..	31	80·48± 0·20	1·65± 0·14
1920 ..	29	78·48± 0·66	5·24± 0·46
21 ..	29	76·58± 0·32	2·54± 0·22
22 ..	31	76·90± 0·26	2·14± 0·18
23 ..	31	73·37± 0·42	3·47± 0·30
24 ..	31	72·81± 0·32	2·64± 0·23
25 ..	30	84·59± 0·43	3·46± 0·30
26 ..	25	73·57± 0·38	2·80± 0·27
27 ..	30	73·34± 0·91	7·37± 0·66
28 ..	31	75·16± 1·01	8·33± 0·71
1929 ..	31	75·75± 1·11	9·13± 0·78

Table 127.—Mean height (in feet) and standard deviation of the Mahanadi at Naraj for August (1868—1929).

Year. (1)	Number of days. (2)	Mean height and probable error. (3)	Standard deviation and probable error. (4)
1868 ..	31	76·05± 0·53	4·40± 0·38
1869 ..	31	77·39± 0·42	3·48± 0·30
1870 ..	31	78·61± 0·29	2·46± 0·21
71 ..	31	79·05± 0·48	4·01± 0·34
72 ..	31	81·48± 0·30	2·49± 0·21

Table 127—*concld.*

Year. (1)	Number of days. (2)	Mean height and probable error. (3)	Standard deviation and probable error. (4)
1873 ..	31	75·84± 0·37	3·09± 0·26
74 ..	31	82·10± 0·35	2·91± 0·25
75 ..	31	79·50± 0·19	1·60± 0·14
76 ..	31	77·34± 0·26	2·14± 0·18
77 ..	31	80·07± 0·51	4·18± 0·36
78 ..	31	79·16± 0·20	1·67± 0·14
79 ..	31	81·59± 0·54	4·50± 0·39
1880 ..	31	79·67± 0·30	2·47± 0·21
81 ..	31	82·22± 0·28	2·32± 0·20
82 ..	31	80·12± 0·26	2·14± 0·18
83 ..	31	76·23± 0·22	1·82± 0·16
84 ..	31	80·48± 0·20	1·61± 0·14
85 ..	31	79·19± 0·25	2·08± 0·18
86 ..	31	76·52± 0·15	1·26± 0·11
87 ..	31	80·03± 0·37	3·06± 0·26
88 ..	31	80·10± 0·33	2·70± 0·23
89 ..	31	81·17± 0·28	2·30± 0·20
1890 ..	31	80·61± 0·20	1·63± 0·14
91 ..	7	79·61	0·75± 0·14
92 ..	31	78·79± 0·29	2·37± 0·20
93 ..	31	79·50± 0·47	3·86± 0·33
94 ..	8	83·24	3·08± 0·52
95 ..	31	82·51± 0·49	4·00± 0·34
96 ..	31	85·62± 0·42	3·47± 0·30
97 ..	31	81·21± 0·35	2·91± 0·25
98 ..	31	80·03± 0·31	2·57± 0·22
99 ..	31	75·75± 0·29	2·43± 0·21
1900 ..	31	80·81± 0·32	2·66± 0·23
01 ..	31	79·92± 0·35	2·88± 0·25
02 ..	31	76·99± 0·29	2·43± 0·21
03 ..	31	78·54± 0·26	2·17± 0·19
04 ..	31	79·31± 0·35	2·92± 0·25
05 ..	31	75·99± 0·22	1·82± 0·16
06 ..	31	77·03± 0·23	1·94± 0·17
07 ..	31	82·05± 0·50	4·14± 0·35
08 ..	31	84·71± 0·34	2·77± 0·24
09 ..	31	78·00± 0·38	3·17± 0·27
1910 ..	30	81·28± 0·59	4·82± 0·42
11 ..	31	82·38± 0·67	5·54± 0·47
12 ..	31	81·31± 0·38	3·12± 0·27
13 ..	30	78·72± 0·51	4·16± 0·36
14 ..	31	81·32± 0·43	3·55± 0·30
15 ..	30	79·11± 0·56	4·59± 0·42
16 ..	31	79·99± 0·30	2·50± 0·21
17 ..	30	82·01± 0·39	3·18± 0·28
18 ..	31	81·13± 0·36	2·94± 0·25
19 ..	31	85·03± 0·29	2·40± 0·21
1920 ..	31	80·97± 0·53	4·41± 0·38
21 ..	30	80·13± 0·39	3·18± 0·28
22 ..	31	77·52± 0·35	2·87± 0·25
23 ..	31	81·39± 0·46	3·79± 0·32
24 ..	31	76·65± 0·47	3·86± 0·33
25 ..	31	83·05± 0·29	2·40± 0·21
26 ..	31	82·46± 0·58	4·75± 0·41
27 ..	31	81·92± 0·48	3·98± 0·34
28 ..	31	76·06± 0·25	2·09± 0·18
1929 ..	31	84·09± 0·52	4·31± 0·37

Table 128.—Mean height (in foot) and standard deviation of the Mahanadi at Naraj for September (1868—1929).

Year. (1)	Number of days. (2)	Mean height and probable error. (3)	Standard deviation and probable error. (4)
1868 ..	30	71·16± 0·15	1·19± 0·10
1869 ..	30	79·13± 0·33	2·65± 0·23
1870 ..	30	77·89± 0·33	2·72± 0·24
71 ..	30	77·03± 0·22	1·76± 0·15
72 ..	30	78·44± 0·25	2·06± 0·18
73 ..	30	76·77± 0·32	2·63± 0·23
74 ..	30	78·66± 0·29	2·34± 0·20
75 ..	30	78·08± 0·26	2·15± 0·19
76 ..	30	80·08± 0·40	3·26± 0·28
77 ..	30	75·83± 0·27	2·22± 0·19
78 ..	30	76·91± 0·19	1·51± 0·13
79 ..	30	78·87± 0·37	3·04± 0·26
1880 ..	30	78·75± 0·22	1·82± 0·16
81 ..	30	77·13± 0·21	1·69± 0·15
82 ..	30	75·50± 0·44	3·56± 0·31
83 ..	30	78·35± 0·30	2·40± 0·21
84 ..	30	81·66± 0·38	3·10± 0·27
85 ..	30	76·68± 0·21	1·70± 0·15
86 ..	30	77·66± 0·12	0·98± 0·09
87 ..	30	78·51± 0·24	1·92± 0·17
88 ..	30	77·58± 0·19	1·53± 0·13
89 ..	30	77·52± 0·17	1·35± 0·12
90 ..	30	77·51± 0·30	2·43± 0·21
91 ..	30	82·11± 0·35	2·84± 0·25
92 ..	30	79·38± 0·43	3·49± 0·30
93 ..	30	82·79± 0·27	2·18± 0·19
94 ..	..	..	.. ..
95 ..	30	76·64± 0·40	3·24± 0·28
96 ..	30	76·63± 0·17	1·38± 0·12
97 ..	30	77·38± 0·41	3·22± 0·28
98 ..	30	76·61± 0·26	2·11± 0·18
99 ..	30	72·66± 0·29	2·33± 0·20
1900 ..	30	81·66± 0·57	4·63± 0·40
01 ..	29	77·16± 0·52	4·20± 0·37
02 ..	30	76·94± 0·16	1·33± 0·12
03 ..	30	76·65± 0·19	1·51± 0·13
04 ..	30	77·41± 0·35	2·83± 0·25
05 ..	30	70·23± 0·34	2·77± 0·24
06 ..	30	77·81± 0·30	2·41± 0·21
07 ..	30	80·17± 0·59	4·80± 0·42
08 ..	30	79·34± 0·38	3·09± 0·27
09 ..	30	76·35± 0·15	1·18± 0·10
1910 ..	30	77·31± 0·18	1·47± 0·13
11 ..	30	80·02± 0·24	1·97± 0·17
12 ..	29	77·67± 0·46	3·71± 0·33
13 ..	30	77·11± 0·36	2·91± 0·25
14 ..	30	78·77± 0·23	1·88± 0·16
15 ..	30	80·48± 0·36	2·96± 0·26
16 ..	30	76·95± 0·15	1·21± 0·11
17 ..	30	80·15± 0·13	1·10± 0·10
18 ..	30	79·07± 0·52	4·24± 0·37
19 ..	30	79·92± 0·57	4·65± 0·40
1920 ..	30	76·43± 0·25	2·07± 0·18
21 ..	30	79·27± 0·43	3·40± 0·30
22 ..	30	80·97± 0·30	2·42± 0·21
23 ..	30	76·35± 0·23	1·86± 0·16
24 ..	30	77·86± 0·23	1·85± 0·16
25 ..	28	80·84± 0·64	5·02± 0·45
26	30	82·60± 0·46	3·74± 0·33
27	30	78·93± 0·66	5·40± 0·47
28 ..	30	76·83± 0·24	1·92± 0·17
1929 ..	29	79·27± 0·44	3·51± 0·31

Table 129.—Mean height (in feet) and standard deviation of the Mahanadi at Naraj for the combined period of July—September.

Year. (1)	Number of days. (2)	Mean height and probable error. (3)	Standard deviation and probable error. (4)	Graduated lines. (5)	Graduated parabola. (6)
1868 ..	92	73·22± 0·21	3·09± 0·15	78·529	79·338
69 ..	92	78·11± 0·23	3·25± 0·16	78·530	79·334
70 ..	92	77·66± 0·17	2·39± 0·12	78·531	79·252
71 ..	92	78·16± 0·21	2·93± 0·15	78·532	79·173
72 ..	92	81·13± 0·19	2·70± 0·13	78·533	79·097
73 ..	92	75·87± 0·24	3·44± 0·17	78·534	79·024
74 ..	92	79·28± 0·18	2·63± 0·13	78·535	78·954
75 ..	92	78·99± 0·19	2·66± 0·13	78·536	78·886
76 ..	92	78·38± 0·24	3·40± 0·17	78·537	78·821
77 ..	92	77·32± 0·24	3·36± 0·17	78·538	78·759
78 ..	92	76·05± 0·15	2·08± 0·10	78·539	78·700
79 ..	92	78·85± 0·22	3·14± 0·16	78·540	78·644
1880 ..	92	80·11± 0·19	2·68± 0·13	78·541	78·590
81 ..	92	79·32± 0·20	2·91± 0·14	78·542	78·539
82 ..	92	78·07± 0·21	3·02± 0·15	78·543	78·491
83 ..	92	78·27± 0·15	2·13± 0·11	78·544	78·446
84 ..	92	81·45± 0·19	2·68± 0·13	78·545	78·404
85 ..	92	78·48± 0·15	2·14± 0·11	78·546	78·364
86 ..	92	76·96± 0·12	1·66± 0·08	78·547	78·327
87 ..	92	79·18± 0·21	3·01± 0·15	78·548	78·293
88 ..	92	77·79± 0·20	2·89± 0·14	78·549	78·262
89 ..	92	78·23± 0·14	2·01± 0·10	78·550	78·234
1890 ..	92	78·95± 0·15	2·13± 0·11	78·551	78·208
91 ..	55	80·29± ..	.. ..	78·552	78·205
92 ..	92	79·45± 0·27	3·83± 0·19	78·553	78·185
93 ..	92	80·13± 0·19	2·73± 0·14	78·554	78·168
94 ..	50	81·27± ..	.. ..	78·555	78·153
95 ..	92	79·39± 0·23	3·27± 0·16	78·556	78·142
96 ..	91	81·14± 0·30	4·22± 0·21	78·557	78·133
97 ..	92	77·24± 0·17	2·43± 0·12	78·558	78·130
98 ..	91	77·53± 0·17	2·45± 0·12	78·559	78·127
99 ..	91	74·34± 0·12	1·69± 0·08	78·560	78·127
1900 ..	92	79·28± 0·15	2·08± 0·10	78·561	78·129
01 ..	80	77·71± ..	.. ..	78·562	78·134
02 ..	92	76·01± 0·19	2·67± 0·13	78·563	78·142
03 ..	92	76·81± 0·28	4·03± 0·20	78·564	78·153
04 ..	92	78·73± 0·19	2·67± 0·13	78·565	78·167
05 ..	92	76·95± 0·14	1·98± 0·10	78·566	78·183
06 ..	92	77·52± 0·16	2·27± 0·11	78·567	78·202
07 ..	90	79·10± 0·21	2·94± 0·15	78·568	78·224
08 ..	91	81·14± 0·15	2·14± 0·11	78·569	78·249
09 ..	92	78·25± 0·19	2·66± 0·13	78·570	78·277
1910 ..	91	78·90± 0·25	3·51± 0·18	78·571	78·307
11 ..	92	79·16± 0·24	3·38± 0·17	78·572	78·340
12 ..	91	78·00± 0·21	2·97± 0·15	78·573	78·376
13 ..	91	77·27± 0·20	2·83± 0·14	78·574	78·415
14 ..	92	79·64± 0·20	2·86± 0·14	78·575	78·457
15 ..	90	77·63± 0·27	3·83± 0·19	78·576	78·501
16 ..	92	76·80± 0·27	3·79± 0·19	78·577	78·548
17 ..	90	79·28± 0·30	4·16± 0·21	78·578	78·598
18 ..	92	78·52± 0·28	3·93± 0·20	78·579	78·651
19 ..	92	81·53± 0·22	3·16± 0·16	78·580	78·707
1920 ..	90	78·65± 0·30	4·21± 0·21	78·581	78·765
21 ..	89	78·57± 0·22	3·06± 0·15	78·582	78·826
22 ..	92	78·44± 0·18	2·49± 0·12	78·583	78·890
23 ..	90	77·14± 0·22	3·15± 0·16	78·584	78·957
24 ..	91	75·75± 0·20	2·89± 0·14	78·585	79·027
25 ..	89	82·87± 0·27	3·78± 0·19	78·586	79·099
26 ..	86	79·02± 0·28	3·84± 0·20	78·587	79·174
27 ..	91	78·44± 0·41	5·75± 0·29	78·588	79·252
28 ..	92	73·69± 0·36	5·08± 0·25	78·589	79·333
1929 ..	90	79·11± 0·44	6·17± 0·31	78·590	79·417

It will be noticed that the probable error is extremely small in every case, and the fluctuations in mean height from year to year appear to be almost entirely sporadic in character. It will be also noticed that the general nature of the fluctuations is very similar in all three months. I have, therefore, restricted my analysis to the data for the combined periods.

In order to investigate whether there is any systematic long period change in the level of the Mahanadi at Naraj we may first analyse the fluctuations into two groups:—

(*a*) fluctuations from year to year, and

(*b*) fluctuations within the same monsoon season.

The analysis of variance is shown in Table 130.

Table 130.—Analysis of variance—Naraj Gauge.

	D. F.	Sum of Squares.	Mean Variance.	S. D.
Between years	61	9945·0237	163·0332	12·77
Within years	5518	83719·9412	15·1722	3·97
Total ...	5579	93664·9649	16·7888	4·10

We notice that the mean variance for fluctuations from year to year (163·0332) is nearly 11 times greater than the mean variance for fluctuations within years (15·1722). The different monsoon seasons are therefore very clearly differentiated from one another. In other words, each individual season can usually be characterized as one of high, moderate or low river levels.

The graph does not, however, appear to indicate that the succession of high, moderate, or low levels follow one another in any systematic order. In fact the graph clearly suggests that the seasonal levels occur in a haphazard manner.

We may test this point by trying to fit a smooth curve to represent the general 'trend' or the systematic change with time. Using least square methods the straight-line and parabola of best fit are given by :—

$$H = 78{\cdot}56 + {\cdot}0010\,(Y - 1899) \quad .. \quad .. \quad .. \quad (1)$$

$$H = 78{\cdot}13 + {\cdot}0010\,(Y - 1899) + {\cdot}0014\,(Y - 1899)^2 \quad .. \quad (2)$$

The straight line is practically indistinguishable from the line of general mean height.

In fact, the average change of level is found to be +·001 feet per year, or just over one inch in a century which is both statistically and physically negligible.

Fitting a parabolic curve also does not lead to any improvement as will be seen from the analysis of variance given in Table 131.

Table 131.—Analysis of variance—Naraj Gauge.

	D. F.	Sum of Squares	Mean variance.	S. D.
Linear Regression	1	6·4333	6·4333	2·54
Second order Regression ...	1	84·7474	84·7474	9·21
Parabolic Regression	2	91·1807	45·5904	6·75
Deviation from Parabolic Regression	59	9853·8430	167·0143	12·93
Total ...	61	9945·0237	163·0332	12·77

In fact, we conclude that during the period 1868—1929, the height of the Mahanadi at Naraj did not show any simple secular (or systematic) change with time. The average river level remained practically steady throughout this period.

CHAPTER 25.—SEASONAL CHANGE IN THE RIVER LEVEL.

I shall now consider the rise in the river level as the monsoon advances. For this purpose, the variation within years is further analysed into two portions:—

(*a*) fluctuations from one day to another as the monsoon season advances from July 1 to September 30.

(*b*) fluctuations within the same day in different years.

The analysis is given in Table 132.

Table 132.—Analysis of variance.

	D. F.	Sum of Squares.	Mean Variance.	S. D.
Days	91	30740·5535	337·8063	18·38
Within days	5488	62924·4114	11·4658	3·39
Total ...	5579	93664·9649	16·7888	4·10

The fluctuations from day to day (mean variance=337·8083) is seen to be nearly 30 times or overwhelmingly greater than the fluctuations for the same day in different years (mean variance=11·4658). We conclude that the seasonal change in the height of the river is statistically significant.

The mean height of the river in feet (with probable errors), for each day from July 1 to September 30 is given in Tables 133—135. The number of years for which data are available, and the standard deviations (with probable errors) are also shown in each case in Tables 133—135, columns (2) and (5) respectively. The corresponding graphs are shown in chart no. 3.

Table 133.—Mean height and standard deviation in feet of the Mahanadi at Naraj during July, 1868—1929.

Date. (1)	Number of years. (2)	Mean height and P. E. (3)	Parabolic graduation. (4)	S. D. and P. E. (5)
July 1	59	75·14± 0·50	74·70	5·69± 0·35
2	59	75·44± 0·48	74·93	5·41± 0·33
3	59	75·78± 0·47	75·15	5·38± 0·33
4	59	75·58± 0·44	75·36	5·06± 0·31
5	59	75·63± 0·42	75·57	4·74± 0·29
6	59	75·60± 0·41	75·78	4·69± 0·29
7	60	75·86± 0·37	75·98	4·31± 0·27
8	60	76·11± 0·33	76·17	3·82± 0·24
9	59	76·13± 0·29	76·36	3·32± 0·21
10	59	76·04± 0·27	76·55	3·11± 0·19
11	60	76·26± 0·26	76·73	3·02± 0·19
12	60	76·36± 0·26	76·91	2·98± 0·18
13	60	77·05± 0·27	77·08	3·13± 0·19
14	61	77·13± 0·28	77·25	3·26± 0·20
15	62	77·43± 0·29	77·41	3·37± 0·20
16	62	77·50± 0·30	77·57	3·48± 0·21
17	62	77·57± 0·23	77·73	2·70± 0·16
18	61	77·33± 0·27	77·88	3·13± 0·19
19	62	77·88± 0·27	78·02	3·22± 0·20
20	62	78·06± 0·28	78·16	3·27± 0·20
21	62	78·09± 0·32	78·30	3·71± 0·22
22	62	78·32± 0·31	78·43	3·65± 0·22
23	62	78·75± 0·33	78·55	3·92± 0·24
24	61	78·86± 0·39	78·67	4·53± 0·28
25	62	79·11± 0·35	78·79	4·05± 0·25
26	62	79·38± 0·41	78·90	4·74± 0·29
27	61	79·38± 0·38	79·01	4·44± 0·27
28	62	79·71± 0·35	79·11	4·08± 0·25
29	62	79·87± 0·29	79·20	3·41± 0·21
30	62	79·90± 0·24	79·30	2·81± 0·17
31	62	79·44± 0·31	79·39	3·65± 0·23

Table 134.—Mean height and standard deviation in feet of the Mahanadi at Naraj during August, 1868—1929.

Date. (1)	Number of years. (2)	Mean height and P. E. (3)	Parabolic graduation. (4)	S. D. and P. E. (5)
August 1	60	79·55± 0·34	79·47	3·97± 0·24
2	60	80·00± 0·33	79·55	3·83± 0·24
3	60	80·25± 0·33	79·63	3·89± 0·24
4	60	80·38± 0·33	79·70	3·83± 0·24
5	60	80·28± 0·35	79·76	4·04± 0·25
6	60	80·32± 0·35	79·82	4·02± 0·25
7	61	80·12± 0·31	79·88	3·54± 0·22
8	60	79·74± 0·30	79·93	3·49± 0·21
9	60	80·38± 0·31	79·97	3·61± 0·22
10	60	80·64± 0·29	80·01	3·34± 0·21
11	59	80·26± 0·38	80·05	3·68± 0·23
12	61	80·42± 0·31	80·08	3·60± 0·22
13	60	80·31± 0·32	80·11	3·68± 0·23
14	60	80·22± 0·34	80·13	3·97± 0·24
15	61	80·35± 0·37	80·15	4·28± 0·26
16	60	80·73± 0·39	80·16	4·48± 0·28
17	60	80·59± 0·38	80·17	4·41± 0·27
18	60	80·17± 0·38	80·17	4·38± 0·27
19	61	79·96± 0·38	80·17	4·42± 0·27
20	61	79·84± 0·38	80·17	4·38± 0·27
21	61	79·77± 0·36	80·16	4·12± 0·25
22	60	79·52± 0·33	80·14	3·84± 0·23
23	60	79·27± 0·31	80·12	3·62± 0·22
24	60	79·42± 0·32	80·10	3·67± 0·23
25	60	79·51± 0·34	80·07	4·00± 0·25
26	61	79·88± 0·35	80·04	4·07± 0·25
27	61	80·17± 0·33	80·00	3·80± 0·23
28	60	80·10± 0·35	79·95	4·07± 0·25
29	61	79·89± 0·30	79·91	3·42± 0·21
30	62	79·72± 0·29	79·85	3·43± 0·21
31	61	79·87± 0·29	79·80	3·31± 0·20

Table 135.—Mean height and standard deviation in feet of the Mahanadi at Naraj during September. 1868—1929.

Date. (1)	Number of years. (2)	Mean height and P. E. (3)	Parabolic graduation. (4)	S. D. and P. E. (5)
September 1	61	79·86± 0·29	79·73	3·40± 0·21
2	61	79·81± 0·30	79·67	3·42± 0·21
3	61	79·70± 0·30	79·60	3·50± 0·22
4	61	79·90± 0·31	79·52	3·63± 0·22
5	61	79·80± 0·31	79·44	3·53± 0·22
6	61	79·69± 0·29	79·35	3·37± 0·21
7	61	79·45± 0·30	79·26	3·41± 0·21
8	61	79·39± 0·28	79·17	3·22± 0·20
9	61	79·33± 0·28	79·07	3·20± 0·20
10	61	79·53± 0·28	78·97	3·26± 0·20
11	61	79·20± 0·29	78·86	3·30± 0·20
12	61	78·89± 0·27	78·74	3·11± 0·19
13	61	78·57± 0·24	78·62	2·72± 0·17

Date. (1)	Number of years. (2)	Mean height and P. E. (3)	Parabolic graduation. (4)	S. D. and P. E. (5)
14	61	78·29± 0·24	78·50	2·78± 0·17
15	61	78·38± 0·26	78·37	2·98± 0·18
16	61	78·25± ·26	78·24	3·05± 0·19
17	61	78·16± 0·26	78·10	2·94± 0·18
18	61	78·01± 0·23	77·96	2·64± 0·16
19	61	77·68± 0·24	77·82	2·76± 0·17
20	61	77·88± 0·26	77·67	2·99± 0·18
21	61	77·66± 0·27	77·51	3·09± 0·19
22	61	77·33± ·25	77·35	2·92± 0·18
23	61	76·84± 0·25	77·18	2·83± 0·17
24	60	76.84± 0·27	77·01	3·06± 0·19
25	61	76·89± 0·28	76·84	3·18± 0·19
26	61	76·88± 0·28	76·66	3·24± 0·20
27	61	76·84± 0·28	76·48	3·18± 0·19
28	61	76·80± 0·28	76·29	3·28± 0·20
29	61	76·74± 0·29	76·09	3·29± 0·20
30	61	76·38± 0·25	75·85	2·83± 0·17

It will be noticed that the change is now quite systematic. The average level of the river gradually rises from about 75 feet in the beginning of July to a little over 80 feet towards the middle of August, and then decreases to 76·5 feet by the end of September. The rise of about 5 ft. in the first six weeks, and the subsequent fall of about 4 feet in the next six weeks represent the seasonal fluctuation due to the progress of the monsoon.

The data have been graduated by a parabolic curve of which the equation is

$$H = 80{\cdot}1487 + 0{\cdot}1054(D) - 0{\cdot}0023\,(D^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where H = Graduated height in ft. and

D = Actual date − August 15

The graduated values are given in column (4) of Tables 133—135, and the graduated parabolic curve is shown in chart 3 ; the graduation appears to be satisfactory, as is clearly seen from the improvement in the residual variance given in the analysis of variance in Table 136.

Table 136.—Analysis of variance : Mahanadi at Naraj.

	D. F.	Sum of squares.	Mean variance.	S. D.
Parabolic Regression ...	2	30034·7629	15017·3815	122·54
Deviation from Parabolic Regression	89	705·7906	7·9302	2·82
Total ...	91	30740·5535	337·8083	18·38

The parabolic graduation (2 degrees of freedom) now absorbs 30034·7629 or practically 98 per cent of the variance. In other words the parabolic graduation is definitely significant. Further the deviations from the parabola (89 degrees of freedom) represent a total variance of only 705·7906, yielding a mean variance of 7·9302 which is actually less than the mean variance for fluctuations within days (11·4658). We do not, therefore, expect to be able to improve the graduation by using a 3rd order parabola. We conclude that the 2nd order parabola given by equation (3) is fully satisfactory and adequate.

Apart from the mean height we may also study the change in fluctuations from year to year. The Standard Deviation, which is a convenient statistic for this purpose, has been given (with probable errors) in Table 126, column (4), and does not exhibit any systematic trend with time, although there exists considerable fluctuations in the Standard Deviation from year to year.

The Standard Deviation for each day is given in column (5) of Table 133—135. It will be noticed that the fluctuations appear to vary in a slightly more systematic manner. There is a gradual decrease in July, showing that the rainfall becomes gradually more steady with the definite establishment of the monsoon by the middle of July. Excepting for a slight rise in the middle of August (probably due to the large increase in the rainfall) the Standard Deviation is practically steady until the end of September.

CHAPTER 26.—THE FREQUENCY DISTBIBUTION OF GAUGE READING AT NARAJ.

The frequency distribution of the height of the river, at intervals of 1 foot, was compiled separately for each month as well as for the whole monsoon period of 3 months taken together and are given in Tables 137—140. The observed frequencies for all the three months rise very steeply and then decrease gradually. This indicates that the modal values in each month are attained very rapidly, lower heights of the river being comparatively rare. Higher levels, on the other hand, occur with decreasing frequency, until very high levels become extremely rare. The curves for July and September are much steeper than those for August, showing the greater steadiness of the height in the middle of the monsoon season. Between July and September the latter shows a steeper gradient.

The frequency distributions were graduated by curves of the Pearson Type. The frequency constants are shown in Table 141. The midpoint was intentionally fixed at 65·25, 66·25 feet, etc., in order to avoid round numbers such as 65, 66, etc., so as to eliminate any bias which might have existed in favour of such round number in noting the original gauge readings. The graduated and observed curves for the frequency distribution for the combined period July—September are shown in chart no. 4.

The skewness is in the same direction (μ_3 positive, with modal value lower than the mean value) in each case. The curves for July, September and the combined period are leptokurtic ($\beta_2<3$) or steeper than the normal curve, while that for August is platykurtic ($\beta_2>3$) or flatter.

The frequency distributions for July can be represented by the following equation (Pearsonian Type IV).

$$y = y_o \left(1+\frac{x^2}{a^2}\right)^{-m} e^{-\gamma \tan^{-1}\frac{x}{a}}$$

Where	yo	=	86·175200
	a	=	12·232736
	m	=	6·057613
	γ	=	—1·365594
Origin at			72·136344

The graduated values (obtained by measuring the area on large-scale curves) are given in column (3) of Table 137.

Table 137.—Mahanadi at Naraj : Frequency distribution of daily river levels for July, 1868—1929 (N=1876).

Range in feet.	Observed.	Graduated.
—64·75	0	0·8
64·75—65·75	0	2·0
65·75—66·75	5	3·6
66·75—67·75	11	6·8
67·75—68·75	16	12·8
68·75—69·75	36	23·4
69·75—70·75	34	38·8
70·75—71·75	39	61·8
71·75—72·75	52	89·6
72·75—73·75	102	122·6
73·75—74·75	161	153·2
74·75—75·75	246	175·2
75·75—76·75	234	185·4
76·75—77·75	208	183·8
77·75—78·75	146	169·0
78·75—79·75	115	147·8
79·75—80·75	96	123·0
80·75—81·75	77	98·2
81·75—82·75	71	75·6
82·75—83·75	61	57·8
83·75—84·75	37	42·0
84·75—85·75	35	30·4
85·75—86·75	28	22·0
86·75—87·75	21	15·8
87·75—88·75	14	11·4
88·75—89·75	8	8·0
89·75—90·75	12	5·4
90·75—91·75	7	3·8
91·75—92·75	4	2·4
92·75—93·75	0	2·0
93·75—94·75	0	1·6

Table 138.—Mahanadi at Naraj : Frequency distribution of daily river levels for August, 1868—1929 (N=1871).

Range in feet.	Observed.	Graduated.
69·75—70·75	6	
70·75—71·75	3	17·1
71·75—72·75	10	
72·75—73·75	28	44·7
73·75—74·75	63	83·8
74·75—75·75	151	125·1
75·75—76·75	177	153·2
76·75—77·75	177	171·8
77·75—78·75	167	180·4
78·75—79·75	193	181·4
79·75—80·75	156	176·5
80·75—81·75	141	159·2
81·75—82·75	153	136·3
82·75—83·75	107	114·8
83·75—84·75	102	93·1
84·75—85·75	76	74·2
85·75—86·75	53	55·2
86·75—87·75	48	40·1
87·75—88·75	18	26·8
88·75—89·75	17	17·4
89·75—90·75	15	10·7
90·75—91·75	9	
91·75—92·75	0	9·2
92·75—93·75	1	

Table 139.—Mahanadi at Naraj : Frequency distribution of daily river levels for September, 1868—1929 (N=1833).

Range in feet.	Observed.	Graduated.
68·75—69·75	2	
69·75—70·75	23	1·0
70·75—71·75	15	10·6
71·75—72·75	13	37·2
72·75—73·75	32	86·0
73·75—74·75	103	144·0
74·75—75·75	245	189·6
75·75—76·75	248	218·4
76·75—77·75	271	224·0
77·75—78·75	228	209·6
78·75—79·75	177	182·0
79·75—80·75	112	148·4
80·75—81·75	101	115·6
81·75—82·75	60	85·2
82·75—83·75	59	61·6
83·75—84·75	42	42·8
84·75—85·75	30	28·8
85·75—86·75	27	18·8
86·75—87·75	29	12·4
87·76—88·75	7	7·2
88·75—89·75	7	4·6
89·75—90·75	2	2·4
90·75—91·75	..	1·8
91·75—92·75	..	1·0

Table 140.—Mahanadi at Naraj : Frequency distribution of daily river levels for the period July—September, 1838—1929 (N=5580).

Range in feet.	Observed.	Graduated.
Below—68·75	32	12·8
68·75—69·75	38	24·4
69·75—70·75	63	55·2
70·75—71·75	57	99·2
71·75—72·75	75	166·8
72·75—73·75	162	265·2
73·75—74·75	327	367·6
74·75—75·75	642	450·8
75·75—76·75	659	518·4
76·75—77·75	656	556·4
77·75—78·75	541	554·8
78·75—79·75	485	513·6
79·75—80·75	364	456·0
80·75—81·75	319	393·6
81·75—82·75	284	319·2
82·75—83·75	227	241·2
83·75—84·75	181	179·2
84·75—85·75	141	131·6
85·75—86·75	108	94·0
86·75—87·75	98	65·6
87·75—88·75	39	44·4
88·75—89·75	32	29·2
89·75—90·75	29	18·0
90·75—91·75	16	11·6
91·75—92·75	4	6·4
92·75—93·75	1	4·8

Table 141.—Mahanadi at Naraj : Frequency constants: Distribution of daily river levels for July, August and September 1868—1929.

Statistic.	July.	August.	September.	Combined.
Range	65·76—92·75	69·76—93·75	68·76—90·75	65·76—92·75
N.	1876	1871	1833	5580
Grouping Unit ..	1	1	1	1
Mean	77·56	79·9865	78·19	78·53
S. D.	4·383	3·917	3·433	4·097
μ_2	19·192845	15·335647	11·789088	16·785836
μ_3	47·294718	26·076454	28·626216	29·864553
μ_4	1355·238492	649·554880	510·208097	941·367150
β_1	0·32	0·19	0·51	0·19
β_2	3·68	2·76	3·72	3·34
Type	IV	I	III	V
X^2	128·74	36·8402	126·01	312·32
Number of cells ..	31	20	21	26

The frequency distribution for August can be represented by the following equation (Pearsonian Type I).

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

Where y_0 = 182·4338

x = 9·061912

a_1 = 7·248086

m_1 = 1·926832

m_2 = 5·135080

a_2 = 10·316422

Origin at Mean = 79·9865

The graduated values (obtained by measuring the area on large-scale curves) are given in column (3) of Table 138.

The frequency distribution for September can be represented by the following equation (Pearsonian Type III).

$$y = y_0 \, e^{-\gamma x} \left(1+\frac{x}{a}\right)^{\gamma a}$$

Where y_0 = 226·1436

γ = 0·817835

a = 8·350488

Origin at 76·97

The graduated values (obtained by measuring the area on large-scale curves) are given in column (3) of Table 139.

The frequency distributions for the combined period can be represented by the following equation (Pearsonian Type V).

$$y = y_o . (x)^{-p} . e^{-\frac{\gamma}{x}}$$

$$\log y_o = 182{\cdot}980784$$

$$\gamma = 3353{\cdot}256584$$

$$p = 89{\cdot}852400$$

Origin at 40·35 (at start of the curve).

The graduated values (obtained by measuring the area on large-scale curves) are given in column (3) of Table 140.

Considering the nature of the data the graduations are not very unreasonable, although the goodness of fit as judged by the *chi-square* test are not satisfactory.

We may now use this material for constructing tables for the probability of occurrence of river levels of an assigned magnitude. For this purpose we use the accumulated totals given in Tables 142—145. Column (1) in each case shows the height equalled or exceeded, column (2) the observed accumulated total, column (3) the graduated accumulated total (based on the graduation by the Pearsonian curves discussed in preceding paragraphs).

If we divide each figure by the total number of years (62 in this case) we get the number of days in each year on which the river level is likely to equal or exceed the assigned height. The observed and graduated values are given in columns (4) and (5) in Tables 142—145.

The use of Tables 142—145 can be illustrated by the following example. Let us consider a river level of 85·75 feet. From column (2) of Tables 142—145 we find that during the period 1868—1929, the river level actually equalled or exceeded 85·75 feet on 129 occasions in July, 237 in August, 102 in September, or 468 during the whole monsoon period of 3 months. Using column (4) of the same tables, we find that the river level is likely to equal or exceed 84·75 feet on 2·08 days in the year in July, 3·82 in August, 1·65 in September, and 7·55 days in the whole season.

Table 142.—Mahanadi-Naraj, 1868-1929.—Accumulated totals of daily river levels in July.

Height in ft. equalled or exceeded.	Frequency in 62 years.		Frequency per season.	
	Observed.	Graduated.	Observed.	Graduated.
93·75	0	1·6	·0000	0·026
92·75	0	3·6	·0000	0·058
91·75	4	6·0	·0645	0·097
90·75	11	9·8	·1774	0·158
89·75	23	15·2	·3871	0·245
88·75	31	23·2	·5000	0·374
87·75	45	34·6	·7258	0·558
86·75	66	50·4	1·0645	0·813
85·75	94	72·4	1·5161	1·168
84·75	129	102·8	2·0806	1·66
83·75	166	144·8	2·6774	2·34

Height in ft. equalled or exceeded.	Frequency in 62 years.		Frequency per season.	
	Observed.	Graduated.	Observed.	Graduated.
82·75	227	202·6	3·6613	3·27
81·75	298	278·2	4·8064	4·48
80·75	375	376·4	6·0484	6·07
79·75	471	499·4	7·5968	8·05
78·75	586	647·2	9·4516	10·44
77·75	732	816·2	11·8064	13·16
76·75	940	1000·0	15·1613	16·12
75·75	1174	1185·4	18·9355	19·12
74·75	1420	1360·6	22·9032	21·95
73·75	1581	1513·8	26·0000	24·42
72·75	1683	1636·4	27·1452	26·39
71·75	1735	1726·0	27·9839	27·84
70·75	1774	1787·8	28·6128	28·84
69·75	1808	1826·6	29·1613	29·46
68·75	1844	1850·0	29·7419	29·84
67·75	1860	1862·8	30·0000	30·04
66·75	1871	1869·6	30·1774	30·15
65·75	1876	1873·2	30·26	30·21
64·75	1876	1875·2	30·26	30·25
63·75	1876	1876·0	30·26	30·26

Table 143.—Mahanadi-Naraj 1868—1929. Accumulated totals of daily river levels in August.

Height in ft. equalled or exceeded.	Frequency in 62 years.		Frequency per season.	
	Observed.	Graduated.	Observed.	Graduated.
92·75	1	..	0·02	..
91·75	1	..	0·02	..
90·75	10	9·2	0·16	·15
89·75	25	19·9	0·40	·32
88·75	42	37·3	0·68	·60
87·75	60	64·1	0·97	1·03
86·75	108	104·2	1·74	1·68
85·75	161	159·4	2·60	2·57
84·75	237	233·6	3·82	3·77
83·75	439	326·7	7·08	5·27
82·75	546	441·5	8·81	7·12
81·75	699	577·8	11·27	9·32
80·75	840	737·0	13·55	11·89
79·75	896	913·5	14·45	14·73
78·75	1089	1094·9	17·56	17·66
77·75	1256	1275·3	20·26	20·57
76·75	1433	1447·1	23·11	23·34
75·75	1610	1600·3	25·97	25·81
74·75	1761	1725·4	28·40	27·83
73·75	1824	1809·2	29·42	29·18
72·75	1852	1853·9	29·87	29·90
71·75	1862	} 1871·0	30·03	} 30·18
70·75	1865		30·08	
69·75	1871		30·18	

Table 144.—Mahanadi-Naraj 1868—1929. Accumulated totals of daily river levels in September.

Height in ft. equalled or exceeded.	Frequency in 62 years.		Frequency per season.	
	Observed.	Graduated.	Observed.	Graduated.
91·75	0	1·0	0	·02
90·75	0	2·8	0	·05
89·75	2	5·2	·03	·08
88·75	9	9·8	·15	·16
87·75	16	17·0	·27	·27
86·75	45	29·4	·89	·47
85·75	72	48·2	1·16	·78
84·75	102	77·0	1·65	1·24
83·75	144	110·8	2·32	1·93
82·75	203	181·4	3·27	2·93
81·75	263	266·6	4·24	4·30
80·75	364	382·2	5·87	6·16
79·75	476	530·6	7·68	8·56
78·75	653	712·6	10·53	11·49
77·75	881	922·2	14·21	14·87
76·75	1152	1146·2	18·58	18·49
75·75	1400	1364·6	22·58	22·01
74·75	1645	1534·2	26·53	24·75
73·75	1748	1698·2	28·19	27·39
72·75	1780	1784·2	28·71	28·78
71·75	1793	1821·4	28·92	29·38
70·75	1808	1832·0	29·16	29·55
69·75	1831	1833·0	29·53	29·56
68·75	1833	1833·0	29·56	29·56

Table 145.—Mahanadi-Naraj 1868—1929. Accumulated totals of daily river level for the period of 1st July—30th September.

Height in ft. equalled or exceeded.	Frequency in 62 years.		Frequency per season.	
	Observed.	Graduated.	Observed.	Graduated.
92·75	1	4·8	·02	·08
91·75	5	11·2	·08	·18
90·75	21	22·8	·34	·37
89·75	50	40·8	·81	·66
88·75	82	70·0	1·32	1·13
87·75	121	114·4	1·95	1·85
86·75	219	180·0	3·53	2·90
85·75	327	274·0	5·27	4·42
84·75	468	405·6	7·55	6·54
83·75	649	584·8	10·47	9·43
82·75	876	826·0	14·13	13·32
81·75	1160	1145·2	18·71	18·47
80·75	1479	1538·8	23·85	24·82
79·75	1843	1994·8	29·73	32·17
78·75	2328	2508·4	37·55	40·46
77·75	2869	3063·2	46·27	49·41
76·75	3525	3619·6	56·85	58·38
75·75	4184	4138·0	67·48	66·74
74·75	4826	4588·8	77·84	74·01
73·75	5153	4956·4	83·11	79·94
72·75	5315	5221·6	85·73	84·22
71·75	5390	5388·4	86·94	86·91
70·75	5447	5487·6	87·85	88·51
69·75	5510	5542·8	88·87	89·40
68·75	5548	5567·2	89·48	89·79
67·75	5580	5580·0	00·00	90·00

We have so far confined our attention to the single day readings of the river level. For flood studies the continuance of a high average level for a successive number of days is of much greater importance than the occurrence of a very high level only for a short time. I have, therefore, calculated the average height of the river for 2 consecutive days, for 3 consecutive days, for 4 consecutive days, and for 5 consecutive days for the whole period.

The frequency distributions are given in Tables 146—149. The frequency constants are given in Table 151. The graduated values for the combined period are given in Table 150, but graduation of the combined curves by the Pearson family of curves was not satisfactory.

From the nature of the observed frequency distribution it would appear likely that some kind of asymptotic expansion of a frequency function (Edgeworth, Charlier's A and B Series, or Cramer's P Series) would be required to graduate them satisfactorily. I have not had time to examine this point more closely.

The observed accumulated totals of the frequencies for 2 days', 3 days', 4 days' and 5 days' averages are given in Tables 153—156 for July, August, September, and for the combined period respectively.

These accumulated totals correspond to the probability function for the occurrence of assigned heights of the river level. I have, therefore, converted these tables into probability Tables 157—160, which give directly the observed frequency of occurrence per year (monsoon season) of a river level of any assigned height. These tables give the number of days in each year (July—September) on which the river level reached or exceeded any given height.

Table 146.—Mahanadi : Naraj gauge, 1868—1929. Frequency distribution of moving averages of river levels for 2 consecutive days.

Range in feet.	July.	August.	September.	Total.
65·76—66·75	1	..	..	1
—67·75	5	..	..	5
—68·75	12	..	..	12
—69·75	17	..	..	17
—70·75	31	..	2	33
—71·75	28	6	21	55
—72·75	35	4	16	55
—73·75	50	8	17	75
—74·75	100	25	29	154
—75·75	152	68	93	313
—76·75	236	142	237	615
—77·75	240	181	246	667
—78·75	197	154	269	620
—79·75	137	185	228	550
—80·75	107	193	181	481
—81·75	99	149	130	378
—82·75	80	168	94	342
—83·75	75	132	61	268
—84·75	46	118	57	221
—85·75	38	101	50	189
—86·75	34	63	26	123
—87·75	27	58	25	110
—88·75	21	36	21	78
—89·75	8	25	13	46
—90·75	10	12	5	27
—91·75	6	12	1	19
—92·75	12	8	..	20
92·76—93·75	..	2	..	2

Table 147.—Mahanadi : Naraj gauge, 1868—1929. Frequency distribution of moving averages of river levels for 3 consecutive days.

Range in feet.	July.	August.	September.	Total.
65·76—66·75	2	..	..	2
—67·75	12	..	..	12
—68·75	9	..	..	9
—69·75	33	..	..	33
—70·75	31	4	21	56
—71·75	35	4	18	57
—72·75	47	7	12	66
—73·75	80	26	25	131
—74·75	146	76	86	308
—75·75	230	147	221	598
—76·75	238	165	240	643
—77·75	186	153	262	601
—78·75	135	187	241	563
—79·75	112	196	180	488
—80·75	106	163	134	403
—81·75	79	144	95	318
—82·75	55	155	78	288
—83·75	48	119	56	223
—84·75	41	89	47	177
—85·75	25	72	30	127
—86·75	22	55	30	107
—87·75	19	34	17	70
—88·75	7	19	9	35
—89·75	5	15	7	27
—90·75	10	7	..	17
—91·75	7	7	..	14
91·76—92·75	..	1	..	1

Table 148.—Mahanadi : Naraj gauge, 1868—1929. Frequency distribution of moving averages of river levels for 4 consecutive days.

Range in feet.	July.	August.	September.	Total.
65·76—66·75	4	..	..	4
—67·75	12	..	..	12
—68·75	30	..	..	30
—69·75	7	..	1	8
—70·75	26	4	19	49
—71·75	32	3	16	51
—72·75	44	7	13	64
—73·75	77	26	24	127
—74·75	152	63	79	294
—75·75	222	144	211	577
—76·75	222	159	229	610
—77·75	175	160	264	599
—78·75	132	179	243	554
—79·75	102	202	188	492
—80·75	107	173	138	418
—81·75	84	151	112	347
—82·75	59	159	68	286
—83·75	50	128	70	248
—84·75	33	79	39	151
—85·75	27	75	26	128
—86·75	26	54	33	113
—87·75	10	37	16	63
—88·75	8	15	6	29
—89·75	4	11	7	22
—90·75	8	12	..	20
90·76—91·75	5	3	..	8

Table 149. Mahanadi : Naraj gauge, 1868—1929. Frequency distribution of moving averages of river levels for 5 consecutive days.

Range in feet	July.	August.	September.	Total.
66·76—67·75	6	..	..	6
—68·75	12	..	..	12
—69·75	24	..	5	29
—70·75	31	3	14	48
—71·75	25	3	18	46
—72·75	45	7	12	64
—73·75	72	23	19	114
—74·75	134	63	73	270
—75·75	199	133	201	533
—76·75	243	157	237	637
—77·75	173	151	243	567
—78·75	123	201	246	570
—79·75	108	184	200	492
—80·75	95	181	143	419
—81·75	95	160	120	375
—82·75	56	175	74	305
—83·75	50	119	68	237
—84·75	26	90	39	155
—85·75	27	72	28	127
—86·75	15	50	24	89
—87·75	7	32	19	58
—88·75	5	12	8	25
—89·75	4	3	3	10
—90·75	5	18	..	23
90·76—91·75	5	..	..	5

Table 150. Mahanadi : Naraj gauge, 1868—1929. Frequency distribution : Graduated values of the frequency distribution of average river levels for 2, 3, 4 and 5 consecutive days during the period July—September.

Range in feet.	2 days.	3 days.	4 days.	5 days.
65·76—66·75	2	..	5	..
—67·75	6	2	10	4
—68·75	10	8	20	12
—69·75	21	15	36	20
—70·75	48	40	61	40
—71·75	91	78	96	71
—72·75	138	135	144	112
—73·75	190	210	211	179
—74·75	260	309	294	258
—75·75	361	400	386	348
—76·75	459	407	474	443
—77·75	531	509	540	503
—78·75	561	509	567	545
—79·75	539	482	550	557
—80·75	478	428	480	522
—81·75	400	360	396	462
—82·75	321	292	299	373
—83·75	260	223	209	282
—84·75	208	158	138	201
—85·75	152	110	89	126
—86·75	109	73	56	82
—87·75	74	48	30	49
—88·75	49	30	18	24
—89·75	47	18	8	12
—90·75	25	10	2	6
—91·75	13	5	..	3
91·76—92·75	6	..	..	..

Table 151. Mahanadi : Naraj gauge—Frequency constants of the graduated curves based on 2, 3, 4 and 5 days' averages.

Statistic.	2 days.	3 days.	4 days.	5 days.
N	5476	5374	5300	5216
Mean ..	78·5279	78·5561	78·6051	78·6309
S. D.	4· 006	3·9000	3·8264	3·7210
μ_2	16·0480	15·2076	14·6438	13·8458
μ_3	29·9856	23·9728	—·8801	16·6838
μ_4	869·2149	767·7566	732·9884	626·9104
β_1	0·2176	·1634	·0002	0· 105
β_2	3·3751	3·3197	3·4182	3· 273
Type	VI	V	IV	IV

Table 152. Equations of the graduated frequency curves based on 2, 3, 4 and 5 days' averages for the combined period July—September, 1868—1929.

(i) 2 days' averages (Type VI)—

$$y=y_0\,(x-a)^{q_2}\,(x)^{-q_1}$$

Where $\log y_0=294\cdot7875$
$a=82\cdot9843$
$q_1=164\cdot5029$
$q_2=29\cdot9989$
Origin at $-101\cdot2773$

(ii) 3 days' averages (Type V)—

$$y=y_0\,(x)^{-p}\,(e)^{-\frac{r}{x}}$$

Where $\log y_0=210\cdot2357$
$p=102\cdot9083$
$r=3933\cdot4718$
Origin at $38\cdot6739$

(iii) 4 days' average (Type IV)—

$$y=y_0\left(1+\frac{x^2}{a^2}\right)^{-m}\,e^{-r\,\tan^{-1}\frac{x}{a}}$$

Where $\log y_0=2\cdot7568$
$a=15\cdot4759$
$m=9\cdot6791$
$r=0\cdot2331$
Origin at $78\cdot4578$

(iv) 5 days' averages (Type IV)—

$$y=y_0\left(1+\frac{x^2}{a^2}\right)^{-m}\,e^{-r\,\tan^{-1}\frac{x}{a}}$$

Where $y_0=4\cdot8483$
$a=22\cdot3061$
$m=29\cdot1558$
$r=41\cdot3140$

Table 153. Mahanadi : Naraj gauge, 1868—1929. Accumulated totals of average river levels for 2 consecutive days.

Height in feet exceeded.	July.	August.	September.	July—September.
65·75	1804	1850	1822	5476
66·75	1803	1850	1822	5475
67·75	1798	1850	1822	5470
68·75	1786	1850	1822	5458
69·75	1769	1850	1822	5441
70·75	1738	1850	1820	5408
71·75	1710	1844	1799	5353
72·75	1675	1840	1783	5298
73·75	1625	1832	1766	5223
74·75	1525	1807	1737	5069
75·75	1373	1739	1644	4756
76·75	1137	1597	1407	4141
77·75	897	1416	1161	3474
78·75	700	1262	892	2854
79·75	563	1077	664	2304
80·75	456	884	483	1823
81·75	357	735	353	1445
82·75	277	567	259	1103
83·75	202	435	198	835
84·75	156	317	141	614
85·75	118	216	91	425
86·75	84	153	65	302
87·75	57	95	40	192
88·75	36	59	19	114
89·75	28	34	6	68
90·75	18	22	1	41
91·75	12	10	..	22
92·75	..	2	..	2

Table 154. Mahanadi : Naraj gauge, 1868—1929. Accumulated totals of average river levels for 3 consecutive days.

Height in feet exceeded.	July.	August.	September.	July—September.
66·75	1720	1845	1809	5374
67·75	1718	1845	1809	5372
68·75	1706	1845	1809	5360
69·75	1697	1845	1809	5351
70·75	1664	1845	1809	5318
71·75	1633	1841	1788	5262
72·75	1598	1837	1770	5205
73·75	1551	1830	1758	5139
74·75	1471	1804	1733	5008
75·75	1325	1728	1647	4700
76·75	1095	1581	1426	4102
77·75	857	1416	1186	3459
78·75	671	1263	924	2858
79·75	536	1076	683	2295
80·75	424	880	503	1807
81·75	318	717	369	1404
82·75	239	573	274	1086
83·75	184	418	196	798
84·75	136	299	140	575
85·75	95	210	93	398
86·75	70	138	63	271
87·75	48	83	33	164
88·75	29	49	16	94
89·75	22	30	7	59
90·75	17	15	..	32
91·75	7	8	..	15
92·75	..	1	..	1

Table 155. Mahanadi : Naraj gauge, 1868—1929. Accumulated totals of average river levels for 4 consecutive days.

Height in feet exceeded.	July.	August.	September.	July—September.
66·75	1658	1844	1802	5304
67·75	1654	1844	1802	5300
68·75	1642	1844	1802	5288
69·75	1612	1844	1802	5258
70·75	1605	1844	1801	5250
71·75	1579	1840	1782	5201
72·75	1547	1837	1706	5150
73·75	1503	1830	1753	5086
74·75	1426	1804	1729	4959
75·75	1274	1741	1650	4665
76·75	1052	1597	1439	4088
77·75	830	1438	1210	3478
78·75	655	1278	946	2879
79·75	523	1099	703	2325
80·75	421	897	515	1833
81·75	314	724	377	1415
82·75	230	573	265	1068
83·75	171	414	197	782
84·75	121	286	127	534
85·75	88	207	88	383
86·75	61	132	62	255
87·75	35	78	29	142
88·75	25	41	13	79
89·75	17	26	7	50
90·75	13	15	..	28
91·75	5	3	..	8

Table 156. Mahanadi : Naraj gauge, 1868—1929. Accumulated totals of average river levels for 5 consecutive days.

Height in feet exceeded.	July.	August.	September.	July—September.
67·75	1585	1837	1794	5216
68·75	1579	1837	1794	5210
69·75	1567	1837	1794	5198
70·75	1543	1837	1789	5169
71·75	1512	1834	1775	5121
72·75	1487	1831	1757	5075
73·75	1442	1824	1745	5011
74·75	1370	1801	1726	4897
75·75	1236	1738	1653	4627
76·75	1037	1605	1452	4094
77·75	794	1448	1215	3457
78·75	621	1297	972	2890
79·75	498	1096	726	2320
80·75	390	912	526	1828
82·75	295	731	383	1409
82·75	200	571	263	1034
83·75	144	396	189	729
84·75	94	277	121	492
85·75	68	187	82	337
86·75	41	115	54	210
87·75	26	65	30	121
88·75	19	33	11	63
89·75	14	21	3	38
90·75	10	18	..	28
91·75	5	..	..	5

Table 157. Mahanadi at Naraj : Probability of occurrence of assigned heights : Average river levels for 2 consecutive days.

Height in feet exceeding.	July.	August.	September.	July—September.
65·75	29·09	..	..	88·32
66·75	29·08	..	..	88·31
67·75	29·00	..	..	88·23
68·75	28·81	..	..	88·03
69·75	28·53	..	29·39	87·76
70·75	28·03	29·84	29·35	87·23
71·75	27·58	29·74	29·01	86·34
72·75	27·02	29·68	28·76	85·45
73·75	26·21	29·55	28·48	84·24
74·75	24·60	29·15	28·02	81·76
75·75	22·14	28·05	26·52	76·71
76·75	18·34	25·76	22·69	66·79
77·75	14·47	22·84	18·73	56·07
78·75	11·29	20·35	14·39	46·03
79·75	9·08	17·37	10·71	37·16
80·75	7·35	14·26	7·79	29·40
81·75	5·76	11·85	5·69	23·31
82·75	4·47	9·14	4·18	17·79
83·75	3·26	7·02	3·19	13·47
84·75	2·52	5·11	2·27	9·90
85·75	1·90	3·48	1·47	6·85
86·75	1·35	2·47	1·05	4·87
87·75	0·92	1·53	0·65	3·10
88·75	0·58	0·95	0·30	1·84
89·75	0·45	0·55	0·09	1·10
90·75	0·29	0·35	0·02	·66
91·75	0·19	0·16	..	·35
92·75	..	0·03	..	·03

Table 158. Mahanadi at Naraj : Probability of occurrence of assigned heights : Average river level for 3 consecutive days.

Height in feet exceeding.	July.	August.	September.	July—September.
66·75	27·74	..	..	86·68
67·75	27·71	..	..	86·64
68·75	27·52	..	..	86·45
69·75	27·37	..	..	86·31
70·75	26·84	29·76	29·18	85·77
71·75	26·34	29·69	28·84	84·87
72·75	25·77	29·63	28·55	83·95
73·75	25·02	29·52	28·35	82·89
74·75	23·73	29·10	27·95	80·77
75·75	21·37	27·87	26·56	75·81
76·75	17·66	25·50	23·00	66·16
77·75	13·82	22·84	19·13	57·79
78·75	10·82	20·37	14·90	46·10
79·75	8·65	17·35	11·02	37·02
80·75	6·84	14·19	8·11	29·15
81·75	5·13	11·56	5·95	22·65
82·75	3·85	9·24	4·42	16·55
83·75	2·97	6·74	3·16	12·87
84·75	2·19	4·82	2·26	9·27
85·75	1·53	3·39	1·50	6·42
86·75	1·13	2·23	1·02	4·27
87·75	·77	1·34	·53	2·65
88·75	·47	·79	·26	1·52
89·75	·35	·48	·11	0·95
90·75	·27	·24	..	0·52
91·75	·11	·13	..	0·24
92·75	..	·02	..	0·02

Table 159. Mahanadi at Naraj : Probability of occurrence of assigned heights : Average river level for 4 consecutive days.

Height in feet exceeding.	July.	August.	September.	July—September.
66·75	26·74	..	..	85·55
67·75	26·68	..	..	85·48
68·75	26·48	..	..	85·20
69·75	26·00	..	29·06	84·81
70·75	25·89	29·74	29·05	84·68
71·75	25·47	29·68	28·74	83·89
72·75	24·95	29·63	28·48	83·06
73·75	24·24	29·52	28·27	82·03
74·75	23·00	29·10	27·89	79·98
75·75	20·55	28·08	26·61	75·24
76·75	16·97	25·76	23·21	65·94
77·75	13·39	23·19	19·52	56·10
78·75	10·56	20·61	15·26	46·44
79·75	8·44	17·73	11·34	37·51
80·75	6·79	14·47	8·31	29·56
81·75	5·06	11·68	6·08	22·82
82·75	3·71	9·24	4·27	17·23
83·75	2·76	6·68	3·18	12·61
84·75	1·95	4·61	2·05	8·61
85·75	1·42	3·34	1·42	6·18
86·75	·98	2·13	1·00	4·11
87·75	·56	1·26	·47	2·29
88·75	·40	·66	·21	1·27
89·75	·27	·42	·11	0·81
90·75	·21	·24	..	0·45
91·75	·08	·05	..	0·13

Table 160. Mahanadi at Naraj : Probability of occurrence of assigned heights : Average river level for 5 consecutive days.

Height in feet exceeding.	July.	August.	September.	July—September.
67·75	25·56	..	..	84·13
68·75	25·47	..	..	84·03
69·75	25·27	..	28·94	83·84
70·75	24·89	29·63	28·85	83·37
71·75	24·39	29·58	28·63	82·60
72·75	23·98	29·53	28·34	81·85
73·75	23·26	29·42	28·15	80·82
74·75	22·10	29·05	27·84	78·98
75·75	19·94	28·03	26·66	74·63
76·75	16·73	25·89	23·42	66·03
77·75	12·81	23·35	19·60	55·76
78·75	10·02	20·92	15·68	46·61
79·75	8·03	17·68	11·71	37·42
80·75	6·29	14·71	8·48	29·48
81·75	4·76	11·79	6·18	22·73
82·75	3·23	9·21	4·24	16·68
83·75	2·32	6·39	3·05	11·76
84·75	1·52	4·47	1·95	7·94
85·75	1·10	3·02	1·32	5·44
86·75	·66	1·85	·87	3·39
87·75	·42	1·05	·48	1·95
88·75	·31	·53	·18	1·02
89·75	·23	·34	·05	·61
90·75	·16	·29	..	·45
91·75	·08	..	..	·08

Although the above tables are useful for hydrological investigations, for flood studies the higher levels are of much greater importance. I have therefore given a far more detailed analysis of the data for river levels above 85 feet for the monsoon season as a whole (July, August and September combined). Table 161 gives the observed accumulated totals for 2, 3, 4, 5 days' averages.

The accumulated totals were graduated by drawing free-hand curves through the observed points. These graduated totals have been used for the construction of the Probability Table 162, which gives the number of occasions in one season (July—September) on which the river level (average of 2, 3, 4 or 5 consecutive days) is likely to reach or exceed any given height.

Table 161. Mahanadi at Naraj, 1868—1929 : Accumulated totals of average levels (above 85 feet) for 2, 3, 4 and 5 consecutive days.

Height in feet exceeded.	2 days.	3 days.	4 days.	5 days.
85·2	372	365	345	310
85·4	347	340	315	285
85·6	325	310	290	255
85·8	305	290	265	230
86·0	285	267	242	205
86·2	263	242	220	185
86·4	240	220	195	165
86·6	215	200	175	150
86·8	197	182	155	130
87·0	180	160	148	115
87·2	160	145	122	100
87·4	143	128	110	85
87·6	132	115	98	76
87·8	119	104	88	68
88·0	110	96	80	62
88·2	100	88	73	56
88·4	90	80	65	50
88·6	79	71	61	47
88·8	70	65	56	42
89·0	65	58	50	38
89·2	57	52	42	35
89·4	54	46	40	32
89·6	48	40	36	30
89·8	44	37	33	25

Height in feet exceeded.	2 days.	3 days.	4 days.	5 days.
90·0	40	34	29	22
90·2	35	31	25	18
90·4	32	27	22	15
90·6	28	23	18	10
90·8	25	18	13	8
91·0	20	15	8	5
91·2	15	10	5	
91·4	11	7	2	
91·6	7	3	1	
91·8	4			
92·0	2			

able 162. Mahanadi at Naraj : Probability of occurrence of assigned heights in number of days per season (1st July to 30th September) for 2, 3, 4 and 5 consecutive days.

Height in feet exceeding.	2 days.	3 days.	4 days.	5 days.
85·2	6·00	5·89	5·56	5·00
·4	5·60	5·48	5·08	4·60
·6	5·24	5·00	4·68	4·11
·8	4·92	4·68	4·27	3·71
86·0	4·60	4·31	3·90	3·31
·2	4·24	3·90	3·55	2·98
·4	3·87	3·55	3·15	2·66
·6	3·47	3·23	2·82	2·42
·8	3·18	2·94	2·50	2·10
87·0	2·90	2·58	2·39	1·85
·2	2·58	2·34	1·97	1·61
·4	2·31	2·06	1·77	1·37
·6	2·13	1·85	1·58	1·23
·8	1·92	1·68	1·42	1·10
88·0	1·77	1·55	1·29	1·00
·2	1·61	1·42	1·18	·90
·4	1·45	1·29	1·05	·81
·6	1·27	1·15	·98	·76
·8	1·13	1·05	·90	·68
89·0	1·05	·94	·81	·61
·2	·92	·84	·68	·56
·4	·87	·74	·65	·52
·6	·77	·65	·58	·48
·8	·71	·60	·53	·40
90·0	·65	·55	·47	·35
·2	·56	·50	·40	·29
·4	·52	·44	·35	·24
·6	·45	·37	·29	·16
·8	·40	·29	·21	·13
91·0	·32	·24	·18	·03
·2	·24	·16	·08	
·4	·18	·11	·02	
·6	·11	·05	·02	
·8	·06			
92·0	·03			

In view of the importance of the subject I decided to find out the frequency distribution of gauge-heights for the average of 6, 7, 8, 9, and 10 consecutive days. But as we are more particularly interested in the higher levels, I decided to cut short the lower range of the data. This, of course, required very careful scrutiny of the totals for 2, 3, 4, and 5 days. All individual totals which were likely to lead to an average height of over 83 feet were marked, and the consecutive days' totals worked out in the usual way.

The frequency distributions of the average of 6, 7, 8, 9, and 10 consecutive days gauge-readings (height over 83 feet) are given in Table 163. The accumulated totals are given in Table 164. These observed totals were graduated by free hand curves, and the corresponding graduated totals were divided by 62 to give the probability of occurrence (in number of days per season, July 1—September 30) of different heights of the river for averages taken over periods of 6, 7, 8, 9 and 10 consecutive days. These values are given in Table 165.

Table 163. Mahanadi at Naraj : Frequency distribution of Gauge-heights over 83·0 f', based on 6, 7, 8, 9 and 10 consecutive days' averages for July—September, 1868—1929.

Range in feet.	6 days.	7 days.	8 days.	9 days.	10 days.
83—83·4	51	40	48	46	40
—83·8	44	41	34	36	44
—84·2	38	45	35	35	42
—84·6	31	33	40	33	41
—85·0	36	28	45	43	29
—85·4	33	35	33	24	17
—85·8	36	34	21	17	14
—86·2	31	17	12	18	10
—86·6	14	20	20	16	17
—87·0	28	19	22	18	21
—87·4	18	10	10	11	8
—87·8	6	9	12	9	7
—88·2	8	7	7	5	4
—88·6	7	5	8	3	3
—89·0	4	7	3	5	1
—89·4	4	5	5	2	1
—89·8	6	6	2	1	1
—90·2	5	4	2		2
—90·6	3	2	4	4	6
—91·0	3	1	..	1	
—91·4	1	1	1	..	
—91·8	..	..	..	..	
—92·2	..	..	..	..	
—92·6	1	1	..	..	
—93·0	1	1	1	2	
—93·4	1	1	1	1	
—93·8	1	1	1		

Table 164.—Mahanadi at Naraj : Accumulated totals of frequencies of Gauge-height at Naraj over 83 ft. based on 6—10 consecutive days' averages. Period July—September, 1868—1929.

Height in feet exceeded.	6 days.	7 days.	8 days.	9 days.	10 days.
83·0	411	379	367	330	308
83·4	360	339	319	284	268
83·8	310	298	285	248	224
84·2	278	253	250	213	182
84·6	247	220	210	180	141
85·0	211	192	165	137	112
85·4	178	157	132	113	95
85·8	142	123	111	96	81
86·2	111	100	99	78	71
86·6	97	86	79	62	54
87·0	69	67	57	44	33
87·4	51	51	47	33	25
87·8	45	42	35	24	18
88·2	37	35	28	19	14
88·6	30	30	20	16	11
89·0	26	23	17	11	10
89·4	22	18	12	9	9
89·8	16	12	10	8	8
90·2	11	8	8	8	6
90·6	8	6	4	4	
91·0	5	5	4	3	
91·4	4	4	3	3	
91·8	4	4	3	3	
92·2	4	4	3	3	
92·6	3	3	3	3	
93·0	2	2	2	1	
93·4	1	1	1		

Table 165.—Mahanadi at Naraj: Probability of occurrence of assigned Gauge-height for 6, 7, 8, 9 and 10 consecutive days.

Height in feet exceeded.	6 days.	7 days.	8 days.	9 days.	10 days.
83·0	6·63	6·11	5·93	5·32	4·97
83·4	5·81	5·47	5·14	4·61	4·32
83·8	5·10	4·81	4·58	4·00	3·61
84·2	4·48	4·08	4·00	3·47	2·93
84·6	3·97	3·55	3·37	2·90	2·39
85·0	3·40	3·02	2·66	2·32	1·93
85·4	2·87	2·53	2·24	1·85	1·61
85·8	2·29	2·02	1·79	1·54	1·29
86·2	1·79	1·69	1·50	1·22	1·04
86·6	1·56	1·38	1·19	·98	·80
87·0	1·14	1·11	·92	·71	·60
87·4	·87	·85	·76	·53	·43
87·8	·72	·69	·59	·40	·29
88·2	·58	·56	·58	·31	·22
88·6	·47	·44	·45	·24	·18
89·0	·40	·34	·31	·16	·16
89·4	·35	·27	·27	·14	·14
89·8	·26	·19	·14	·11	·13
90·2	·19	·12	·11	·10	·09
90·6	·13	·09	·08	·06	
91·0	·09	·08	·06	·05	
91·4	·06	·06	·05	·05	
91·8	·06	·05	·05	·05	
92·2	·06	·05	·05	·05	
92·6	·05	·05	·05	·05	
93·0	·03	·03	·03	·02	
93·4	·02	·02	·02		

The free-hand smoothing employed for the construction of Table 162 cannot be considered entirely satisfactory In view of the failure of the Pearsonian system I have not considered it advisable, in the limited time at my disposal, to experiment with more elaborate mathematical functions. I have, however, tried a simple logarithmic formula.

Table 166 gives the values of log f, that is the logarithm (to the base 10) of the frequencies given in Table 161.

It will be noticed that between 85 and 90 feet the logarithmic curves are practically straight lines. Fitting straight lines by least square methods we find the following equations :—

1 day : $\log_{10} f =$ 2·6283—0·17 43 (H—85)
2 days : $\log_{10} f =$ 2·6348—0·20 95 (H—85)
3 days : $\log_{10} f =$ 2·6272—0·22 50 (H—85)
4 days : $\log_{10} f =$ 2·6049—0·22 98 (H—85)
5 days : $\log_{10} f =$ 2·5060—0·23 40 (H—85)

Where H is the height of the river level.

All the logarithmic frequency curves belong to a family of straight lines of the form :—

$$\log_{10} f = a - b\,(H-85)$$

The value of "a" (which gives the logarithm of the frequency of a river level of 85 ft.) naturally decreases as the number of days for which the average is taken is increased. Also the numerical magnitude steadily increases, showing that as the number of days is increased there is an increasingly rapid falling off in the frequency.

Table 166. Mahanadi at Naraj : Logarithm of accumulated totals of river levels.

Height in feet exceeded.	2 days.	3 days.	4 days.	5 days.
85·2	2·57	2·57	2·54	2·48
85·4	2·54	2·54	2·50	2·45
85·6	2·50	2·50	2·46	2·42
85·8	2·48	2·47	2·42	2·36
86·0	2·45	2·43	2·39	2·30
86·2	2·43	2·39	2·34	2·26
86·4	2·39	2·35	2·30	2·22
86·6	2·35	2·31	2·25	2·18
86·8	2·31	2·26	2·19	2·11
87·0	2·26	2·26	2·15	2·06
87·2	2·20	2·17	2·10	1·99
87·4	2·16	2·11	2·03	1·94
87·6	2·12	2·05	1·96	1·89
87·8	2·07	2·01	1·94	1·83
88·0	2·04	1·97	1·89	1·80
88·2	2·01	1·95	1·83	1·75
88·4	1·94	1·90	1·82	1·72
88·6	1·89	1·85	1·78	1·67
88·8	1·84	1·81	1·75	1·61
89·0	1·81	1·76	1·71	1·59
89·2	1·76	1·71	1·61	1·56
89·4	1·72	1·66	1·58	1·51
89·6	1·69	1·60	1·54	1·48
89·8	1·64	1·54	1·52	1·45
90·0	1·61	1·49	1·46	1·40
90·2	1·56	1·48	1·45	1·26
90·4	1·49	1·45	1·38	1·15
90·6	1·45	1·38	1·30	1·00
90·8	1·38	1·23	1·23	0·90
91·0	1·28	1·15	0·90	
91·2	1·23	1·04	0·48	
91·4	1·00	0·60		
91·6	0·85	0·48		
91·8	0·30			
92·0	0·30			
92·2				
92·4				

The graduated values of the accumulated frequencies between 85 and 90 feet as obtained from the above logarithmic curves are shown in Table 167.

Table 167. Mahanadi-Naraj Gauge, 1868—1929. Accumulated totals of river levels from Logarithmic Graduation.

Height in feet exceeded.	1 day.	2 days.	3 days.	4 days.	5 days.
85·2	646	407	398	380	302
·4	602	371	363	347	275
·6	550	339	324	309	246
·8	513	309	295	275	219
86·0	468	282	263	246	200
·2	437	251	240	224	178
·4	398	229	214	204	159
·6	372	209	195	182	145
·8	339	191	174	176	129
87·0	316	174	159	148	115
·2	288	155	141	138	102
·4	269	141	129	118	91
·6	246	129	115	107	83
·8	229	115	105	96	74
88·0	209	107	93	87	68
·2	195	98	85	78	60
·4	178	87	76	71	54
·6	162	79	69	63	49
·8	151	72	62	56	44
89·0	141	66	56	51	39
·2	129	60	50	46	35
·4	118	54	46	42	32
·6	110	49	41	37	28
·8	102	45	37	33	26
90·0	93	41	33	30	23
·2	87	37	30	27	20
·4	81	33	27	25	19
·6	74	30	25	22	17

Absolute maximum river heights.

The absolute maximum river heights for each year cannot be obtained from the above tables, I have therefore given these values separately in Tables 168—171 for July, August, September and the combined period respectively. The figures within brackets give the actual date ending the period for which the average maximum is noted. For example in Table 168, column (5), for the year 1892 we find the figure 90·54 (27). This indicates that in July 1892, the absolute maximum of the average of 4 consecutive days' readings of the river level was 90·54 and that this 4 days' average maximum level referred to the period 24th to 27th July 1892.

The frequency distributions of the maximum readings are given in Table 172, and the accumulated totals in Table 173. These observed totals were graduated by drawing smooth free-hand curves and the graduated values were then converted into a percentage probability by dividing by 62 (and multiplying by 100), and are shown in Table 174. This Table gives the probability of occurrence per 100 years of an assigned maximum height of the Mahanadi at Naraj.

Table 168. Mahanadi at Naraj : Maximum Readings of the Gauge in July with Dates 1868—1929.

(The date given shows the end of each period.)

Year.	1 day.	2 days.	3 days.	4 days.	5 days.
1868	79·30 (31)	80·18 (Aug. 1)	79·88 (Aug. 2)	79·42 (Aug. 3)	79·04 (Aug. 4)
69	85·10 (24)	85·05 (24)	84·50 (24)	84·22 (25)	83·62 (25)
70	81·00 (20)	80·82 (20)	80·42 (21)	79·69 (22)	79·23 (22)
71	82·60 (30)	82·47 (31)	82·04 (31)	81·23 (31)	80·87 (31)
72	92·00 (4)	91·32 (4)	91·15 (6)	91·02 (6)	90·80 (7)
73	81·60 (29)	81·35 (29)	80·90 (29)	80·59 (30)	80·07 (30)
74	83·70 (30)	83·60 (31)	83·51 (31)	83·13 (Aug. 1)	82·60 (Aug. 1)
75	87·40 (25)	86·90 (26)	86·03 (26)	86·24 (26)	85·87 (27)
76	87·50 (21)	84·95 (22)	85·57 (23)	85·00 (24)	84·44 (24)
77	84·80 (1)	84·45 (2)	83·67 (3)	82·37 (4)	81·26 (5)
78	79·70 (29)	79·15 (30)	78·60 (31)	78·28 (Aug. 1)	78·08 (Aug. 2)
79	77·90 (21)	77·75 (21)	77·57 (22)	77·40 (23)	77·34 (24)
80	89·10 (3)	88·95 (4)	88·93 (5)	88·48 (6)	88·14 (6)
81	88·00 (27)	87·45 (27)	87·17 (27)	86·60 (27)	86·16 (28)
82	85·70 (23)	85·60 (24)	85·17 (24)	84·50 (25)	84·38 (26)
83	86·50 (22)	86·05 (3)	85·73 (3)	85·50 (4)	85·32 (5)
84	87·50 (26)	87·30 (26)	87·20 (27)	86·95 (27)	86·64 (28)
85	85·90 (23)	85·25 (23)	84·83 (23)	84·40 (24)	84·04 (24)
86	81·80 (24)	81·40 (25)	80·93 (25)	80·62 (26)	80·32 (26)
87	86·50 (27)	86·35 (20)	86·30 (29)	86·25 (29)	85·98 (29)
88	83·10 (23)	82·75 (23)	82·47 (24)	81·68 (25)	80·96 (26)
89	83·00 (22)	82·90 (23)	81·03 (24)	81·00 (25)	80·26 (26)
90	83·40 (12)	82·95 (13)	82·33 (13)	81·95 (13)	81·64 (14)
91	87·85 (30)	87·75 (30)	87·25 (30)	86·71 (31)	85·62 (31)
92	91·74 (26)	91·60 (26)	91·21 (27)	90·54 (27)	89·96 (28)
93	83·36 (21)	83·23 (22)	82·91 (23)	82·76 (24)	82·61 (24)
94	89·40 (28)	89·08 (29)	88·89 (29)	88·26 (30)	87·85 (30)
95	90·40 (1)	89·76 (2)	88·25 (3)	86·68 (4)	85·11 (5)
96	91·95 (25)	91·64 (26)	91·37 (27)	91·12 (27)	90·80 (28)
97	77·69 (20)	77·40 (20)	77·30 (21)	77·05 (22)	76·79 (23)
98	80·25 (21)	80·16 (21)	80·00 (22)	79·90 (22)	79·60 (23)
99	78·28 (16)	77·45 (17)	76·73 (18)	76·16 (19)	75·86 (19)
1900	77·50 (16)	77·64 (23)	77·30 (23)	77·14 (25)	77·07 (26)
01	77·74 (31)	77·69 (Aug. 1)	78·41 (Aug. 2)	78·84 (Aug. 3)	78·83 (Aug. 4)
02	82·30 (28)	81·50 (29)	80·63 (30)	79·83 (31)	79·71 (Aug. 1)
03	83·28 (25)	82·44 (26)	81·83 (26)	81·23 (27)	80·92 (28)
04	87·80 (4)	87·72 (4)	86·08 (4)	86·55 (5)	86·10 (5)
05	81·40 (15)	81·08 (16)	80·57 (17)	80·18 (17)	79·16 (17)
06	85·98 (30)	85·21 (31)	84·28 (31)	83·51 (31)	83·07 (31)
07	79·57 (5)	79·19 (5)	78·79 (5)	78·54 (5)	78·58 (5)
08	83·10 (22)	82·65 (31)	82·16 (Aug. 1)	82·13 (Aug. 2)	82·30 (Aug. 3)
09	87·23 (27)	86·70 (28)	86·26 (28)	85·82 (29)	85·45 (30)
10	86·88 (7)	86·66 (7)	86·39 (8)	86·50 (8)	85·61 (9)
11	79·05 (16)	78·95 (16)	78·85 (16)	78·76 (16)	78·62 (17)
12	83·44 (30)	83·26 (31)	82·93 (31)	82·95 (1)	82·57 (2)
13	82·93 (28)	82·14 (29)	81·45 (30)	80·77 (31)	80·67 (1)
14	85·55 (31)	84·23 (31)	83·94 (Aug. 1)	83·55 (Aug. 2)	83·19 (Aug. 2)
15	82·45 (31)	82·22 (Aug. 1)	82·72 (Aug. 2)	82·06 (Aug. 3)	81·98 (Aug. 3)
16	78·73 (30)	78·73 (31)	78·39 (Aug. 1)	78·12 (Aug. 1)	77·86 (Aug. 2)
17	82·75 (20)	82·54 (21)	82·29 (21)	81·98 (22)	81·67 (23)
18	80·10 (10)	80·09 (10)	80·07 (11)	79·87 (11)	79·63 (12)
19	83·88 (16)	83·47 (17)	83·00 (18)	82·66 (18)	82·18 (19)
20	91·88 (25)	91·29 (26)	90·96 (26)	90·02 (26)	88·92 (26)
21	82·59 (2)	82·47 (3)	81·42 (4)	80·56 (4)	79·98 (5)
22	81·42 (31)	81·24 (Aug. 1)	81·22 (Aug. 2)	81·26 (Aug. 3)	81·14 (Aug. 3)
23	78·38 (29)	78·33 (29)	78·09 (30)	77·88 (31)	77·65 (Aug. 1)
24	76·64 (31)	76·67 (Aug. 1)	76·56 (Aug. 1)	76·37 (Aug. 2)	76·21 (Aug. 2)
25	91·05 (14)	90·84 (14)	90·64 (15)	90·24 (16)	89·32 (17)
26	76·88 (16)	76·76 (17)	76·54 (18)	76·3) (18)	76·04 (18)
27	85·97 (27)	85·79 (8)	85·50 (29)	85·21 (29)	84·92 (30)
28	87·89 (28)	87·88 (29)	87·81 (30)	87·67 (30)	87·09 (31)
29	89·02 (27)	89·45 (Aug. 1)	89·64 (Aug. 2)	89·16 (Aug. 3)	88·66 (Aug. 3)

Table 169. Mahanadi at Naraj : Maximum Readings of the Gauge in August with Dates, 1868—1929.

(The date given shows the end of each period.)

Year.	1 day.	2 days.	3 days.	4 days.	5 days.
1868	84·70 (10)	84·50 (11)	84·00 (11)	83·60 (11)	83·28 (12)
69	85·70 (28&29)	85·50 (30)	85·43 (30)	85·19 (30)	84·91 (31)
70	84·70 (2)	84·19 (2)	83·65 (3)	83·14 (3)	82·78 (4)
71	88·55 (5)	87·62 (5)	87·35 (5)	87·21 (5)	86·54 (5)
72	86·60 (9)	86·35 (30)	86·13 (30)	85·62 (30)	85·32 (31)
73	82·60 (29)	82·45 (10)	81·80 (10)	81·45 (11)	80·96 (11)
74	90·00 (30)	89·90 (31)	89·57 (31)	88·92 (Sept. 1)	88·27 (Sept. 1)
75	83·68 (11)	83·12 (2)	82·87 (2)	82·32 (3)	81·73 (4)
76	81·50 (21)	80·70 (22)	80·23 (23)	79·85 (24)	79·32 (25)
77	88·10 (16)	87·80 (16)	87·80 (16)	87·45 (16)	87·06 (17)
78	82·30 (17)	82·00 (18)	81·73 (18)	81·50 (19)	81·28 (20)
79	90·90 (14)	90·80 (14)	90·60 (14)	90·50 (15)	89·86 (15)
80	85·10 (6)	84·80 (7)	84·33 (8)	83·98 (8)	83·52 (9)
81	87·10 (15)	87·05 (16)	86·97 (17)	86·70 (17)	86·22 (17)
82	84·90 (8)	84·05 (8)	83·57 (9)	82·25 (9)	82·52 (9)
83	82·20 (1)	82·55 (1)	81·80 (1)	81·12 (1)	80·76 (2)
84	83·40 (2)	83·05 (2)	82·83 (3)	82·02 (5)	82·72 (5)
85	83·70 (2)	83·60 (2)	83·13 (3)	82·65 (3)	82·24 (4)
86	80·00 (25)	79·55 (26)	79·30 (27)	78·98 (28)	88·80 (29)
87	87·60 (26)	86·95 (26)	86·47 (27)	85·40 (27)	84·70 (28)
88	85·20 (11)	85·15 (11)	84·73 (12)	84·50 (12)	84·36 (12)
89	86·50 (20)	86·20 (21)	85·77 (21)	85·20 (22)	84·82 (22)
90	83·50 (24)	83·45 (25)	83·33 (26)	83·10 (27)	82·92 (27)
91	81·05 (29)	80·48 (30)	80·20 (30)	79·91 (30)	79·76 (30)
92	83·93 (4)	83·80 (4)	83·45 (5)	83·01 (6)	82·70 (7)
93	87·52 (6)	86·94 (6)	86·58 (7)	86·28 (7)	86·05 (7)
94					
95	89·22 (3)	88·82 (3)	87·78 (4)	87·04 (12)	86·57 (13)
96	91·48 (5)	91·44 (5)	91·18 (6)	90·65 (6)	90·31 (7)
97	85·85 (14)	85·47 (15)	85·00 (16)	84·89 (17)	84·90 (18)
98	81·97 (31)	84·74 (15)	84·63 (16)	84·25 (15)	84·02 (16)
99	84·82 (14)	81·76 (31)	81·38 (Sept. 1)	81·11 (Sept. 1)	80·71 (Sept. 1)
1900	84·62 (16)	84·32 (16)	84·15 (16)	83·80 (16)	83·55 (17)
01	86·25 (27)	86·20 (28)	86·02 (28)	85·22 (28)	84·64 (29)
02	83·90 (28)	83·15 (28)	82·83 (29)	82·18 (30)	81·42 (31)
03	83·70 (4)	82·96 (5)	82·53 (6)	82·12 (6)	81·84 (7)
04	85·43 (16)	85·19 (17)	84·13 (18)	83·44 (18)	82·64 (19)
05	80·57 (6)	80·08 (7)	79·28 (7)	79·04 (7)	78·71 (8)
06	81·07 (13)	80·28 (31)	81·69 (Sept. 1)	80·45 (Sept. 1)	79·51 (Sept. 1)
07	88·70 (17)	88·45 (18)	88·17 (18)	87·73 (18)	87·39 (19)
08	88·27 (16)	88·02 (17)	87·60 (17)	87·27 (17)	87·06 (17)
09	90·09 (7)	89·96 (7)	89·02 (7)	87·24 (12)	86·53 (13)
10	91·25 (17)	91·08 (18)	90·94 (19)	90·98 (20)	90·69 (20)
11	86·25 (4)	85·75 (4)	85·18 (4)	84·90 (4)	84·71 (4)
12	85·62 (11)	85·53 (11)	85·43 (12)	85·17 (12)	85·01 (12)
13	88·37 (4)	88·22 (4)	87·73 (5)	87·13 (5)	86·55 (6)
14	89·90 (6)	89·43 (7)	88·80 (8)	88·19 (8)	87·59 (9)
15	88·80 (6)	88·48 (7)	88·16 (7)	87·38 (8)	86·90 (8)
16	85·20 (18)	84·94 (19)	84·63 (19)	84·39 (20)	84·05 (21)
17	88·25 (15)	89·04 (16)	88·55 (16)	87·93 (17)	87·55 (17)
18	85·44 (9)	84·80 (10)	84·38 (10)	83·84 (10)	83·52 (10)
19	90·28 (30)	89·63 (31)	89·41 (31)	88·88 (Sept. 1)	88·53 (Sept. 1)
20	89·62 (3)	88·86 (3)	88·24 (4)	87·28 (5)	86·65 (5)
21	86·55 (12)	86·44 (12)	85·99 (12)	85·45 (13)	84·75 (14)
22	83·78 (22)	83·10 (23)	82·56 (23)	82·14 (24)	81·46 (25)
23	87·63 (21)	87·49 (21)	86·92 (22)	86·46 (22)	85·86 (22)
24	86·62 (9)	86·35 (9)	85·58 (10)	84·60 (11)	83·75 (12)
25	87·03 (24)	86·82 (20)	86·36 (25)	85·96 (25)	85·87 (25)
26	91·65 (19)	91·20 (25)	90·84 (20)	90·19 (22)	90·20 (22)
27	87·26 (30)	87·12 (31)	87·11 (30)	87·08 (31)	86·93 (31)
28	79·90 (30)	79·66 (31)	79·57 (Sept. 1)	79·20 (Sept. 1)	78·89 (Sept. 1)
29	91·70 (27)	91·45 (27)	91·04 (28)	90·64 (28)	89·91 (29)

Table 170. Mahanadi at Naraj : Maximum Readings of the Gauge in September with Dates, 1868—1929.

(The date given shows the end of each period.)

Year.	1 day.	2 days.	3 days.	4 days.	5 days.
1868	73·85 (22)	73·60 (23)	73·45 (23)	73·33 (24)	73·10 (25)
69	85·15 (3)	84·98 (3)	84·75 (4)	84·49 (4)	84·35 (4)
70	81·85 (1 & 2)	82·05 (1)	81·98 (2)	81·74 (3)	81·51 (4)
71	80·70 (28)	80·43 (29)	80·12 (29)	79·95 (29)	79·79 (30)
72	81·30 (28)	81·28 (29)	81·00 (30)	80·18 (18)	79·90 (19)
73	82·60 (10)	82·20 (11)	81·90 (12)	81·80 (12)	81·40 (13)
74	87·00 (1)	88·40 (1)	86·30 (2)	84·70 (3)	83·50 (4)
75	81·90 (10)	81·68 (11)	81·03 (11)	80·71 (24)	80·44 (25)
76	84·60 (17)	84·50 (17)	83·80 (18)	83·20 (19)	83·14 (20)
77	80·30 (13)	80·25 (13)	80·00 (13)	79·65 (14)	79·38 (14)
78	80·60 (21)	80·30 (21)	80·27 (21)	79·98 (21)	79·74 (22)
79	84·90 (29)	84·80 (29)	84·37 (29)	83·93 (30)	83·16 (30)
80	82·60 (8)	82·05 (9)	81·80 (9)	81·35 (9)	81·06 (10)
81	81·00 (16)	80·55 (17)	80·33 (17)	79·83 (18)	79·48 (18)
82	82·90 (14)	82·85 (14)	82·13 (15)	81·60 (15)	80·84 (16)
83	84·30 (9 & 10)	84·30 (10)	84·03 (11)	83·58 (12)	83·12 (12)
84	87·20 (9)	87·15 (10)	87·10 (11)	86·83 (11)	86·56 (12)
85	79·70 (3)	79·65 (4)	79·53 (5)	79·50 (6)	79·52 (7)
86	79·40 (20)	79·25 (21)	79·07 (21)	78·95 (22)	78·86 (22)
87	82·40 (17)	82·30 (17)	82·17 (17)	81·98 (18)	81·80 (18)
88	81·10 (18)	80·90 (19)	80·43 (20)	80·35 (21)	80·18 (22)
89	80·10 (1)	79·90 (1)	79·60 (2)	79·43 (3)	79·40 (4)
90	83·30 (29)	83·15 (29)	83·00 (30)	82·58 (30)	82·12 (30)
91	87·02 (16)	86·72 (16)	86·54 (16)	86·38 (17)	85·92 (18)
92	85·10 (5)	84·94 (6)	84·38 (6)	83·90 (7)	83·20 (7)
93	87·60 (26)	87·39 (26)	86·96 (27)	86·41 (27)	86·02 (28)
94					
95	84·96 (1)	85·26 (1)	84·83 (2)	84·25 (3)	83·63 (4)
96	81·66 (1)	81·59 (1)	81·32 (2)	81·13 (3)	81·09 (4)
97	85·32 (10)	85·07 (11)	84·66 (12)	84·05 (13)	83·28 (14)
98	82·87 (18)	81·89 (18)	81·52 (19)	80·82 (20)	80·29 (20)
99	80·62 (1)	81·30 (1)	80·63 (2)	79·97 (3)	79·30 (4)
1900	88·60 (21)	88·56 (22)	88·15 (23)	87·82 (23)	87·77 (24)
01	86·93 (5)	86·92 (6)	85·80 (6)	85·20 (7)	84·28 (7)
02	79·10 (3)	79·00 (4)	78·98 (4)	78·84 (5)	78·82 (6)
03	79·69 (5)	79·65 (5)	79·17 (6)	78·72 (7)	78·38 (8)
04	83·10 (2)	82·72 (3)	82·04 (3)	81·69 (4)	81·16 (5)
05	83·62 (12)	83·46 (13)	83·08 (14)	82·75 (14)	82·61 (14)
06	83·82 (16)	83·15 (16)	82·44 (17)	81·53 (18)	80·75 (19)
07	89·70 (10)	89·40 (11)	89·17 (11)	88·73 (11)	88·36 (12)
08	86·37 (2)	86·35 (3)	86·06 (4)	85·79 (4)	85·40 (5)
09	79·33 (4)	88·90 (4)	78·42 (4)	78·30 (4)	78·39 (4)
10	81·70 (9)	81·54 (9)	81·15 (10)	80·16 (10)	79·34 (10)
11	84·33 (1)	84·15 (2)	83·86 (3)	83·57 (3)	83·17 (4)
12	86·20 (8)	86·06 (8)	85·65 (9)	85·09 (10)	84·35 (10)
13	84·43 (2)	83·82 (3)	83·45 (4)	82·96 (4)	82·50 (5)
14	83·87 (20)	83·59 (20)	83·02 (21)	82·64 (21)	82·07 (21)
15	87·45 (16)	87·31 (16)	86·50 (17)	85·46 (17)	84·60 (18)
16	80·17 (1)	80·15 (1)	80·04 (2)	79·84 (3)	79·42 (4)
17	81·70 (26)	81·50 (12)	81·47 (12)	81·18 (8)	80·94 (9)
18	87·53 (1)	87·14 (5)	86·89 (5)	86·42 (6)	85·97 (7)
19	90·17 (3)	90·00 (4)	89·60 (4)	89·02 (4)	89·01 (4)
20	80·48 (12)	80·35 (13)	80·12 (14)	79·74 (15)	79·48 (15)
21	87·06 (6)	86·92 (7)	86·61 (8)	86·14 (9)	85·57 (9)
22	86·36 (7)	85·32 (7)	84·06 (13)	83·81 (14)	83·50 (14)
23	82·31 (1)	81·60 (2)	80·97 (3)	80·56 (3)	80·21 (4)
24	83·57 (17)	82·98 (18)	82·20 (19)	81·65 (20)	81·28 (20)
25	88·87 (3)	88·39 (4)	88·06 (4)	87·71 (5)	87·41 (5)
26	88·12 (21)	88·05 (21)	87·71 (22)	87·46 (23)	87·26 (24)
27	89·49 (5)	89·32 (6)	89·24 (6)	88·87 (7)	88·60 (7)
28	81·06 (3)	81·05 (3)	80·77 (4)	80·51 (5)	80·29 (5)
29	84·52 (4)	83·78 (5)	83·36 (6)	83·12 (7)	82·86 (8)

Table 171. Mahanadi at Naraj : Maximum Readings of the Gauge in July—September with Dates, 1868—1929.

(The date given shows the end of each period.)

Year.	1 day.	2 days.	3 days.	4 days.	5 days.
1868	84·70 Aug. 10	84·50 Aug. 11	84·00 Aug. 11	83·60 Aug. 11	83·28 Aug. 12
69	85·70 Aug. 28 & 29.	85·50 Aug. 30	85·43 Aug. 30	85·19 Aug. 30	84·91 Aug. 31
70	84·70 Aug. 2	84·10 Aug. 2	83·65 Aug. 3	83·14 Aug. 3	82·78 Aug. 4
71	88·55 Aug. 5	87·62 Aug. 5	87·35 Aug. 5	87·21 Aug. 5	86·54 Aug. 5
72	92·00 July 4	91·32 July 4	91·15 July 6	91·02 July 6	90·80 Aug. 7
73	82·60 Aug. 29 & Sept. 10.	82·45 Aug. 10	81·90 Sept. 12	81·80 Sept. 12	81·40 Sept. 13
74	90·00 Aug. 30	89·90 Aug. 31	89·57 Aug. 31	88·92 Sept. 1	88·27 Sept. 1
75	87·40 July 25	86·90 Aug. 25	86·63 July 26	86·24 July 26	85·87 July 27
76	87·50 July 21	84·95 July 22	85·57 July 23	85·00 July 24	84·44 July 24
77	88·10 Aug. 16	87·80 Aug. 16	87·80 Aug. 16	87·45 Aug. 16	87·06 Aug. 17
78	82·30 Aug. 17	82·00 Aug. 18	81·73 Aug. 18	81·50 Aug. 19	81·28 Aug. 20
79	90·90 Aug. 14	90·80 Aug. 14	90·60 Aug. 14	90·50 Aug. 15	89·86 Aug. 15
80	89·10 July 3	88·95 July 4	88·93 July 5	88·48 July 6	88·14 July 6
81	88·00 July 27	87·45 July 27	87·17 July 27	86·70 Aug. 17	86·22 Aug. 17
82	85·70 July 23	85·60 July 24	85·17 July 24	84·50 July 25	84·38 July 26
83	86·50 July 22	86·05 July 3	85·73 July 3	85·50 July 4	85·32 July 5
84	87·50 July 26	87·30 July 26	87·20 July 27	86·95 July 27	86·64 July 28
85	85·90 July 23	85·25 July 23	84·83 July 23	84·40 July 24	84·04 July 24
86	81·80 July 24	81·40 July 25	80·93 July 25	80·62 July 26	78·80 Aug. 29
87	87·60 Aug. 26	86·25 Aug. 26	86·47 Aug. 27	86·25 July 29	85·98 July 29
88	85·20 Aug. 11	85·15 Aug. 11	84·73 Aug. 12	84·50 Aug. 12	84·36 Aug. 12
89	86·50 Aug. 20	86·20 Aug. 21	85·77 Aug. 21	85·20 Aug. 22	84·82 Aug. 22
90	83·50 Aug. 24	83·45 Aug. 25	83·33 Aug. 26	83·10 Aug. 27	82·92 Aug. 27
91	87·85 July 30	87·75 July 30	87·25 July 30	86·71 July 31	85·92 Sept. 18
92	91·74 July 26	91 60 July 26	91·21 July 27	90·54 July 27	89·96 July 28
93	87·60 Sept. 26	87·39 Sept. 26	86·96 Sept. 27	86·41 Sept. 27	86·05 Aug. 7
94	89·40 July 28				
95	90·40 July 1	89·76 July 2	88·25 July 3	87·04 Aug. 12	86·57 Aug. 13
96	91·95 July 25	91·64 July 26	91·37 July 27	91·12 July 27	90·80 July 28
97	85·85 July 14	85·47 Aug. 15	85·00 Aug. 16	84 89 Aug. 17	84·90 Aug. 18
98	84·85 Aug. 15	84·74 Aug. 15	84·63 Aug. 15	84·25 Aug. 15	84·02 Aug. 16
99	84 82 Aug. 14	81·76 Aug. 31	81·38 Sept. 1	81·11 Sept. 1	80·71 Sept. 1
1900	88·60 Sept. 21	88·56 Sept. 22	88·15 Sept. 23	87·82 Sept. 23	87·79 Sept. 24
01	86·93 Sept. 5	86·92 Sept. 6	86·02 Aug. 28	85·22 Aug. 28	84·64 Aug. 29
02	83·90 Aug. 28	83·15 Aug. 28	82·83 Aug. 29	82·18 Aug. 30	81·42 Aug. 31
03	83·70 Aug. 4	82·96 Aug. 5	82·53 Aug. 6	82·12 Aug. 6	81·84 Aug. 7
04	87·86 July 4	87·72 July 4	86·98 July 4	86·55 July 5	86·10 July 5
05	83·62 Sept. 12	83·46 Sept. 13	83·08 Sept. 14	82·75 Sept 14	82·61 Sept. 14
06	85·98 July 30	85·21 July 31	84·28 July 31	83·51 July 31	83·07 July 31
07	89·70 Sept. 10	89·40 Sept. 11	89·17 Sept. 11	88·73 Sept. 11	88·36 Sept. 12
08	88·27 Aug. 16	88·02 Aug. 17	87·60 Aug. 17	87·27 Aug. 17	87·06 Aug. 17
09	90·09 Aug. 7	89·96 Aug. 7	89·02 Aug. 7	87·24 Aug. 12	86·53 Aug. 13
10	86·25 Aug. 4	85·75 Aug. 4	85·18 Aug. 4	84·90 Aug. 4	84·71 Aug. 4
11	91·25 Aug. 17	91·08 Aug. 18	90·94 Aug. 19	90·98 Aug. 20	90·69 Aug. 20
12	86·20 Sept. 8	85·96 Sept. 8	85·65 Sept. 9	85·17 Aug. 12	85·01 Aug. 12
13	88·37 Aug. 4	88·22 Aug. 4	87·73 Aug. 5	87·13 Aug 5	86·55 Aug. 6
14	89·90 Aug. 6	89·43 Aug. 7	88·80 Aug. 8	88·19 Aug. 8	87·59 Aug. 9
15	88·80 Aug. 6	88·48 Aug. 7	88·16 Aug. 7	87·38 Aug. 8	86·90 Aug. 8
16	85·20 Aug. 18	84·94 Aug. 19	84·63 Aug. 19	84·39 Aug. 20	84·05 Aug. 21
17	89·25 Aug. 15	89·04 Aug. 16	88·55 Aug. 16	87·93 Aug. 17	87·55 Aug. 17
18	87·53 Sept. 1	87·14 Sept 5	86·89 Sept. 5	86·42 Sept. 6	85·97 Sept. 7
19	90·28 Aug. 30	90·28 Aug. 30	89·60 Sept. 4	89·02 Sept. 4	89·01 Sept. 4
20	91·88 July 25	91·29 July 26	90·96 July 26	90·02 July 26	88·92 July 26
21	87·06 Sept. 6	86·92 Sept. 7	86·61 Sept. 8	86·14 Sept. 9	85·57 Sept. 9
22	86·36 Sept. 7	85·32 Sept. 7	84·06 Sept. 13	83·81 Sept. 14	83·50 Sept. 14
23	87·63 Aug. 21	87·49 Aug 21	86 92 Aug. 22	86·46 Aug. 22	85·86 Aug. 22
24	86·62 Aug. 9	86·35 Aug. 9	85 58 Aug. 10	84·60 Aug. 11	83·75 Aug. 12
25	88·12 Sept. 21	88·05 Sept. 21	87·71 Sept. 22	87·46 Sept. 23	87·26 Sept. 24
26	91·65 Aug. 24	91·20 Aug. 20	90·84 Aug. 20	90·19 Aug. 21	90·20 Aug. 22
27	89·49 Sept. 5	89·32 Sept. 6	89·21 Sept. 6	88·87 Sept. 7	88·60 Sept. 7
28	87·89 July 28	87·88 July 29	87·81 July 30	87·67 July 30	87·09 July 31
29	91·70 Aug. 27	91·45 Aug. 27	91·04 Aug. 28	90·64 Aug. 28	89·91 Aug. 29

Table 172. Mahanadi at Naraj 1868—1929 : Frequency distribution of maximum gauge-heights in each year.

Range.	Mid point.	1 day.	2 days.	3 days.	4 days.	5 days.
79·76—80·75	80·25	..	..	..	1	2
80·76—81·75	81·25	..	1	3	2	3
81·76—82·75	82·25	3	3	2	4	2
82·76—83·75	83·25	4	4	4	4	6
83·76—84·75	84·25	3	3	6	7	7
84·76—85·75	85·25	5	9	8	7	7
85·76—86·75	86·25	8	5	6	10	13
86·76—87·75	87·25	10	11	10	9	6
87·76—88·75	88·25	9	7	6	6	6
88·76—89·75	89·25	6	6	8	3	3
89·76—90·75	90·25	4	4	2	5	5
90·76—91·75	91·25	5	8	7	4	2
91·76—92·75	92·25	4	1			
92·76—93·75	93·25	1				

Table 173. Mahanadi at Naraj, 1868—1929 : Accumulated totals of maximum gauge heights in each year.

Height in feet exceeded.	1 day.	2 days.	3 days.	4 days.	5 days.
79·75	..	..	..	62	62
80·75	..	62	62	61	60
81·75	62	61	59	59	57
82·75	59	58	57	55	55
83·75	55	54	53	51	49
84·75	52	51	47	44	42
85·75	47	42	39	37	35
86·75	39	37	33	27	22
87·75	29	26	23	18	16
88·75	20	19	17	12	10
89·75	14	13	9	9	7
90·75	10	9	7	4	2
91·75	5	1			
92·75	1				

Table 174. Mahanadi at Naraj : Probability of occurrence of assigned maximum gauge-heights in number of years per century.

Height in feet exceeding.	1 day.	2 days.	3 days.	4 days.	5 days.
79·75	..	..	..	100·00	100·00
80·75	..	100·00	100·00	98·39	96·77
81·75	100·00	96·77	95·16	94·35	91·94
82·75	95·16	93·55	91·94	88·71	86·29
83·75	89·52	87·90	85·48	81·45	79·03
84·75	83·87	80·65	75·81	70·97	69·35
85·75	75·00	70·16	63·71	58·06	53·23
86·75	62·90	58·06	51·61	44·35	37·10
87·75	46·77	43·55	38·71	29·84	25·81
88·75	33·06	30·65	25·81	20·16	16·13
89·75	22·58	20·97	16·13	12·90	9·68
90·75	14·52	12·10	11·29	8·87	4·84
91·75	8·06	4·84			
92·75	3·23				

The rate of rise (or fall) of the Mahanadi at Naraj is a matter of considerable importance in connexion with flood problems. The frequency distributions of both rise (+) and fall (—) for July, August and September separately as well as for the whole monsoon season are shown in Table 176. (I may note in passing that the three months show practically the same features.) The accumulated totals are given below in Table 175.

Table 175. Change of Level at Naraj in feet per day.

Change of level not exceeding feet per day.	Accumulated frequency of rise.	Accumulated frequency of fall.	Ratio. col. (2)—col. (3).
1	2	3	4
9·25	1	1	
8·75	2	1	
8·25	2	1	2·0
7·75	2	2	1·0
7·25	5	2	2·5
6·75	9	3	3·0
6·25	13	4	3·3
5·75	26	4	6·5
5·25	39	5	7·8
4·75	65	11	6·0
4·25	1 01	11	9·2
3·75	1 39	30	4·6
3·25	2 08	61	3·4
2·75	3 03	1 34	2·3
2·25	4 27	2 68	1·6
1·75	6 38	5 13	1·2
1·25	10 80	9 33	1·1
0·75	15 40	17 44	
0·25	24 02	32 22	

Table 176. Frequency distribution of rise and fall of the river for July, August and September and combined.

Change of Level in feet.	July.	August.	September.	July-September.
—9·25	1	..	..	1
—8·75				
—8·25				
—7·75	..	..	1	1
—7·25				
—6·75	1	..	..	1
—6·25	..	1	..	1
—5·75				
—5·25	1	..	..	1
—4·75	2	1	3	6
—4·25	..	...	..	..
—3·75	4	6	9	19
—3·25	11	15	5	31
—2·75	22	33	18	73
—2·25	32	60	42	134
—1·75	73	115	57	245
—1·25	114	160	146	420
—0·75	224	284	303	811
—0·25	475	411	592	1478
+0·25	321	254	287	862
0·75	176	146	138	460
1·25	133	117	92	342
1·75	69	86	56	211
2·25	40	55	29	124
2·75	35	37	23	95
3·25	24	31	14	69
3·75	14	16	8	38
4·25	14	14	8	36
4·75	10	8	8	26
5·25	8	4	1	13
5·75	7	5	1	13
6·25	..	1	3	4
6·75	3	1	..	4
7·25	2	1	..	3
7·75				
8·25				
8·75	..	1	..	1
9·25	1	..	..	1
	1,817	1863	1844	5,524

It will be noticed that beyond 1·25 ft. the frequency of rise is invariably greater than the frequency of fall, showing that (apart from minor fluctuations within 1·25 ft. of the normal level), the rise is always steeper. The disparity is greatest for readings between 3·25 and 6·25 feet. The above table (Table 175, gives a general picture of the nature of fluctuations in the height of the Mahanadi at the head of the delta. It also gives a scale for judging the suddenness of the flood.

An attempt was made to fit a Pearsonian curve to the whole data but the constants were heterotypic. The standard deviation of change (irrespective of the sign) was found to be 2·8 feet, and β_1 and β_2, 0·81 and 6·88 respectively.

CHAPTER 27.—PRELIMINARY DISCUSSION OF RAINFALL IN RELATION TO FLOODS IN THE MAHANADI.

In this chapter I shall give a preliminary discussion of rainfall as a casual factor in the occurrence of floods in the Mahanadi river. Much of this work was done before the daily gauge readings at Naraj were obtained from Cuttack and before the analytic studies of the rainfall in the Mahanadi catchment had been completed.

Our ultimate aim is to predict the occurrence of floods from a knowledge of the observed rainfall. We want to know, therefore, what is the usual duration of the rainfall which produces floods; what is the average interval between the occurrence of the rainfall and the occurrence of the flood; whether there is any close connexion between the amount of rainfall and the height or the discharge of the river at Naraj, etc. We shall use the more exact methods of correlational analysis in a later chapter; here we shall make a first attempt to obtain a general idea of the part played by the rainfall in producing floods. As a first example, we may consider the monthly excess of rainfall, that is, the precipitation in excess of the normal rainfall in the monsoon season, in the catchment as a whole, and see whether this has any connexion with floods.

MONTHLY EXCESS OF RAINFALL.

In Table 177 are shown the excesses of rainfall in June, July and August of each year since 1898 for all the administrative districts that lie in the catchment areas and the deltas of the various rivers. Excess of rainfall for each month has been expressed as percentage of the normal rainfall for that month for each district. A table showing the actual rainfalls for each district is also given in Table 178.

It will be seen from the above tables that monthly excess of rainfall furnish little or no information regarding the occurrence of floods. In a few cases only the floods are slightly associated with the monthly excess of rainfall. Thus there was a short flood in 1913 in the month of July; monthly excess of rainfall for July was appreciably high only in two districts, namely Cuttack and Balasore. 1915 was a year of long flood which occurred in the middle of June; monthly excess of rainfall for June was appreciably high in the Feudatory States and the districts of Ranchi, Sambalpur, Bilaspur and Raipur. In 1920 a long flood occurred in July; monthly excess of rainfall for that month was fairly high in the Feudatory States, Ranchi, Singhbhum and Sambalpur districts. In 1926 a long flood occurred in the middle of August, but the monthly excess of rainfall was appreciably high only in the districts of Balasore and Angul and the Tributary Mahals.

We conclude that the monthly rainfall covers too large a period of time to give significant correlation with floods.

Table 177. Percentage Excess of rainfall in the Districts for

	Cuttack.			Balasore.			Puri.			Angul.			Tributary Mahals.			Feudatory States.		
Years.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.
1898	−24	−10	+44	−26	−27	+40	−13	−3	−9	−18	−26	−28	−12	−15	−16			
1899	−2	−8	−24	+24	+31	−15	−28	−10	−21	−38	−40	−62	+15	−35	−34			
1900	−26	+4	+68	−11	+15	+80	+11	−25	+43	+8	−53	+11	−9	+000	+46			
1901	−60	−11	−32	−53	−22	−16	−68	−20	−27	−55	−13	−13	−73	−7	−3			
1902	−43	+80	−2	−46	+51	−12	−35	+84	+38	−68	+17	−13	−36	+45	+1			
1903	−17	7	−7	−17	+17	−13	−30	+46	−10	−43	+11	−14	−35	+13	+4			
1904	+40	−34	−2	+46	−14	+2	+6	−39	−8	+122	−12	+6	+53	−002	+10			
1905	−57	−19	−42	−59	−2	−54	−53	−38	−23	−54	+5	−19	−61	−1	−31			
1906	−3	−26	−48	−3	−23	−47	−11	+4	−30	−40	+10	−32	−17	+2	−25	−42	+1	−23
1907	−13	−54	+166	+25	−49	+108	−14	−59	+42	+31	−56	+73	−5	−33	+66	+41	−40	+49
1908	+59	−1	+53	+7	−23	+42	+25	−7	+49	+10	−10	+46	+27	−4	+65	+8	+8	+60
1909	+7	+44	−21	+9	+11	−8	+32	+38	−38	+31	−1	−40	+24	+9	−29	+72	2+1	−31
1910	+8	+3	−5	−7	−7	−26	−24	+50	−12	−4	+34	+14	+18	+10	−2	−22	−6	+6
1911	+42	−61	−33	+28	−51	−30	+29	−30	+5	+13	−58	±15	+62	−51	−4	+115	−49	+27
1912	−46	−4	−10	−37	−4	+14	+8	+32	+28	−68	+18	+10	−51	+5	+19	−49	+11	−5
1913	+1	+105	−19	+63	130	+18	−1	+47	−13	−20	+41	−16	+12	+43	+4	+8	+10	+8
1914	−4	+13	−36	+5	+6	−9	+28	−40	−9	−19	−007	−17	−4	+23	−20	−13	+18	−20
1915	−74	−22	−18	+4	−40	−9	−32	−41	−11	−29	−4	−13	−32	−26	−28	−55	−22	−22
1916	+68	−42	−6	+22	−35	−16	+71	−12	−16	+124	−15	+6	+56	−28	−9	+86	−34	−5
1917	+26	−8	+5	+66	−7	+16	+35	−10	−003	+22	−10	−13	+54	−4	−8	+54	+14	−8
1918	+23	−53	−23	−6	−57	−3	+34	−14	−25	+75	−63	−30	+26	−50	−17	+150	−32	−9
1919	+38	−38	+32	+14	+4	+56	−9	+4	+68	+49	+20	+55	+47	+17	+44	+64	+1	+30
1920	−20	+77	−12	−44	+67	+3	0·00	+43	−25	−38	+81	−31	−24	+77	−14	−36	128	−8
1921	−9	−2	−41	−12	+19	−4	−3	−20	−37	−15	−2	−42	−9	+5	−21	−14	−11	−12
1922	−6	+61	−20	+13	+34	−5	+9	+55	·006	−34	+55	−27	+27	+40	−13	−20	+17	−25
1923	−64	−10	−16	−69	−24	−7	−40	−13	−20	−47	−39	−32	−45	−82	+10	−58	−19	+6
1924	−64	−44	−15	−67	−38	+9	−77	−31	−26	−54	−42	−17	−52	−30	−4	−45	−33	−26
1925	+139	+62	+3	+33	−3	+21	+137	+36	−7	+165	+38	+9	+75	+55	±29	+37	+10	−19
1926	−60	−8	+74	−61	−8	+95	−69	−47	+31	−73	−30	+114	−85	−7	+105	−72	−20	+21

N.B.—The plus (+) sign shows excess over and the minus (−) sign defect from the average value.

the months of June, July and August.

Ranchi.			Singhbhum.			Sambalpur.			Bilaspur			Raipur.			Remarks.
June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	
+20	+18	—10	+27	—9	+21	—25	+18	+4	—12	+3	—31	—8	+35	—2	
+41	+16	—44	+24	—3	—8	+2	—4	—25	—14	—42	—6	—26	—57	+3	
+2	—5	+28	—18	—17	+18	—10	—25	+10	—51	+14	+25	+2	—26	—2	Short Flood late in September.
—58	—16	+25	—57	—23	+40	—82	—22	+50	—62	—5	—3	—58	+3	—3	
—69	+41	—11	—49	+50	—44	—82	+40	—17	—81	+28	—27	—84	—24	—27	
—36	—08	—6	+3	—15	—25	—66	—18	—5	—51	—9	+7	—47	+24	—17	
+90	+33	+15	+49	+39	+8	+104	—16	—4	+47	—30	+4	+98	—40	+3	
—91	+7	—28	—72	+36	—41	—71	+2	—11	—92	—11	—39	—83	+24	—30	
—14	+19	—20	—29	+25	—37	—38	·001	·	—7	+33	—35	—26	+22	—30	
+42	—28	+68	+37	—45	+35	+10	—2.	·55	·32	—48	—12	+32	—37	+18	Long Flood early in September.
—7	+8	+21	+16	—9	+62	—14	+29	+70	—35	+40	+11	+17	—6	+44	Short Flood middle of August.
+51	+16	+2	+8	—17	+12	+77	—13	—35	+28	+19	+39	—11	+22	—60	
+14	—12	—3	+26	—26	—32	—19	—3	+14	+9	—44	—7	+2	—11	—32	Long Flood early in August.
+54	—39	+22	+20	—56	—1	+63	—62	+76	+41	—49	—1	+110	—49	+57	Long Flood middle of August.
—50	+10	+19	—25	+23	+9	—61	—002	—5	—51	+3	—3	—67	+19	+9	Short Flood middle of August.
+65	+2	—10	+74	+23	+8	+31	—32	.12	+53	—28	—38	—22	—11	—9	Short Flood early in July.
—48	—17	+4	—48	+11	—35	—31	+22	+3	—21	+49	—32	—36	+23	—17	Short Flood early in August.
—30	—17	—40	—39	—43	—51	—54	—43	—18	—33	—14	—19	—65	+9	+20	Short Flood early in August.
+27	—60	—8	+28	—51	—003	+87	—33	+35	+88	—4	+2	+55	—35	—20	
+37	+21	—6	+63	—8	—18	+60	—3	+3	+59	—12	+43	+58	—19	—7	Short Flood middle of August.
+93	—60	—2	+21	—54	—14	+190	—49	—6	+108	—47	+8	+210	—17	+22	Long Flood middle of June
+95	+4	+26	+70	—29	+18	+00	+14	—29	+18	—5	+16	+153	+15	+45	Long Flood end of August.
—53	+100	+12	—33	+137	+20	—43	+100	+23	—56	+15	—4	—48	+21	—14	Short Flood early in August also long Flood end of July.
+11	—4	+11	+1	+2	—1	—33	—35	+6	+43	—19	+8	+74	—36	—5	
+6	+38	—14	+21	+11	+23	—17	+14	—29	+2	—7	—42	—21	+9	—32	
—9	+49	+81	—17	—14	+101	—51	—24	+18	—66	—4	+70	—64	+1	+1	
—49	+16	—20	—24	—15	—22	—57	—30	—11	—54	—11	—29	—71	—47	—20	
+13	+98	—33	—12	+18	+7	+97	+44	+6	+91	+49	—13	+20	+65	+18	Long Flood middle of July.
—74	+27	+13	—75	+41	+60	—89	—2	+71	—78	—2	+32	—78	—32	+61	Long Flood middle of August.

Table 178. Actual rainfall in the Districts for

Years.	Feudatory States.			Ranchi.			Singhbhum.			Sambalpur.			Bilaspur.		
	June.	July.	August.	June.	July.	August.	June.	July.	August.	June.	July.	August.	June.	July.	August.
Averages .	9·79	15·03	10·62	8·71	14·44	15·29	9·31	13·49	12·87	8·83	16·31	15·11	7·48	15·00	16·07
1898 . .	..	..	..	10·48	17·05	13·76	11·81	12·22	15·59	6·63	19·28	15·74	6·58	15·04	11·13
1899 . .	..	..	..	12·29	16·08	8·57	11·56	13·15	11·81	9·03	15·64	11·36	6·43	8·64	15·05
1900 . .	..	..	..	8·85	13·67	19·56	7·61	11·23	15·18	7·93	12·22	18·23	3·68	17·12	20·07
1901 . .	..	..	..	3·67	12·14	19·12	3·99	10·35	17·99	1·56	12·78	22·67	2·82	14·20	15·67
1902 . .	..	..	..	2·69	20·38	13·64	4·78	20·24	7·26	1·62	22·82	12·59	1·42	19·18	11·80
1903 . .	..	..	..	5·67	10·68	14·44	9·63	11·50	9·71	3·01	13·32	14·35	3·69	13·65	17·25
1904 . .	..	..	..	17·11	19·27	17·51	13·88	18·74	13·96	18·05	13·71	14·55	11·02	10·55	16·67
1905 . .	..	..	..	1·65	15·52	10·98	2·61	18·35	7·60	2·53	16·64	12·67	0·62	13·32	9·88
1906 . .	5·64	15·72	11·30	7·53	17·25	12·30	6·01	16·82	8·07	5·48	16·37	11·19	6·99	19·02	10·38
1907 . .	13·62	9·30	25·03	12·38	10·43	25·63	12·77	7·43	17·34	9·68	11·14	23·39	9·85	7·83	14·13
1908 . .	10·65	16·89	26·90	8·12	15·54	18·55	10·82	12·28	20·85	7·58	21·12	25·72	4·87	20·97	17·78
1909 . .	16·83	18·89	11·54	13·13	16·72	15·58	10·01	11·25	14·35	15·62	14·14	9·81	9·61	17·78	9·87
1910 . .	7·62	14·75	17·76	9·92	12·63	14·79	11·77	10·04	8·72	7·18	15·83	17·26	8·13	8·47	14·96
1911 . .	21·05	7·96	21·39	13·44	8·36	18·66	11·15	5·99	12·76	14·40	6·20	26·61	10·55	7·68	15·94
1912 . .	4·97	17·31	15·01	4·32	15·87	16·87	7·03	16·63	14·06	3·42	16·27	14·38	3·66	15·40	15·65
1913 . .	10·59	17·13	17·31	14·38	14·80	13·74	10·13	16·54	13·91	11·56	11·11	16·90	11·41	10·75	9·98
1914 . .	5·66	18·47	13·52	4·51	11·99	15·83	4·85	14·93	8·38	6·12	19·90	15·60	5·94	22·42	10·93
1915 . .	4·43	12·16	13·05	6·13	11·98	9·20	5·70	7·69	6·36	4·10	9·35	12·34	5·02	12·53	13·05
1916 . .	18·18	10·36	15·91	11·08	7·29	14·01	11·90	6·50	12·91	16·53	10·93	20·45	14·09	14·11	16·39
1917 . .	15·09	17·84	15·54	11·80	17·52	14·39	15·21	12·45	10·56	14·19	15·82	15·53	11·91	13·19	23·05
1918 . .	24·46	10·61	15·37	16·83	5·77	14·93	11·28	6·22	11·12	25·59	8·25	14·24	15·55	7·90	17·40
1919 . .	16·08	15·77	21·88	16·96	14·96	19·19	15·85	9·56	15·23	8·83	18·61	10·69	8·82	14·24	18·66
1920 . .	6·25	35·60	15·48	4·09	28·84	17·09	6·26	32·03	15·47	5·05	32·63	18·53	3·28	17·29	15·49
1921 . .	8·48	13·90	14·80	9·63	13·84	17·04	9·40	13·79	12·68	5·93	10·58	16·07	10·71	12·19	16·85
1922 . .	7·84	18·25	12·67	9·26	19·99	13·16	11·24	16·01	15·79	7·35	18·61	10·69	7·73	13·90	9·40
1923 . .	4·26	12·63	17·75	7·93	21·49	27·66	7·60	11·54	25·89	4·31	12·33	17·89	2·55	14·46	27·32
1924 . .	5·39	10·54	12·38	4·44	16·79	10·70	7·09	11·41	10·00	3·80	11·36	13·45	2·66	13·41	11·33
1925 . .	13·42	17·12	13·63	9·87	18·13	11·89	8·18	15·91	13·72	17·41	23·49	16·05	14·29	22·36	14·06
1926 . .	2·74	12·51	20·35	2·26	13·30	17·34	2·33	10·07	20·02	1·01	15·93	25·82	1·67	14·66	21·22

the months of June, July and August.

Raipur.			Cuttack.			Balasore.			Puri.			Angul.			Tributary Mahals.		
June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.	June.	July.	Aug.
8·05	14·25	15·14	9·20	12·19	12·68	9·16	11·39	11·23	8·07	10·81	12·62	8·92	13·80	13·54	9·10	13·08	12·09
7·41	19·26	14·91	6·07	10·95	18·23	6·82	8·26	15·70	7·06	11·12	11·49	7·28	10·19	9·77	8·01	11·08	10·17
5·96	6·07	15·64	[illegible]	[illegible]	9·58	11·39	14·93	9·58	5·80	9·76	9·57	5·52	8·29	5·17	10·42	8·52	8·00
8·25	10·52	14·90	6·73	12·71	21·33	8·19	13·13	20·17	8·93	8·11	18·02	9·64	6·44	14·98	8·26	13·08	17·68
3·37	14·72	14·71	[illegible]	[illegible]	8·50	4·26	8·88	9·43	2·62	8·67	9·25	3·00	12·04	11·72	2·50	12·18	12·05
1·29	10·76	11·02	[illegible]	[illegible]	12·39	5·07	17·21	9·89	5·27	19·88	17·46	2·82	16·14	11·74	5·81	18·92	12·22
4·27	17·69	12·67	[illegible]	[illegible]	11·68	7·60	13·36	9·81	5·68	15·73	11·40	5·10	15·37	11·60	5·90	14·76	12·54
15·90	8·51	[illegible]	[illegible]	16	12·47	13·41	9·83	11·43	8·58	6·57	11·62	19·81	12·08	14·31	13·89	13·05	13·29
1·28	17·69	[illegible]	[illegible]	9·85	7·36	3·80	11·21	5·15	3·78	6·74	9·48	4·09	14·44	10·97	3·58	12·96	8·34
5·94	17·38	10·62	6·91	8·96	6·61	8·03	8·79	5·02	7·20	11·19	8·79	5·31	15·21	9·16	7·53	13·36	9·07
10·60	8·94	17·80	8·05	5·63	32·41	11·44	5·77	23·36	6·96	4·41	17·89	11·72	6·09	23·44	8·61	8·70	20·08
9·43	13·38	21·77	14·65	12·03	19·34	9·78	8·76	15·93	10·12	10·01	18·81	9·80	12·38	19·79	11·57	13·03	19·90
8·92	17·36	6·00	9·86	17·52	10·01	10·02	12·59	10·29	10·67	14·88	7·86	11·72	13·62	8·18	11·30	14·30	8·63
8·33	12·62	10·29	9·94	12·52	12·06	8·53	10·59	8·30	6·12	16·25	11·15	8·57	18·55	15·47	10·71	14·34	11·24
16·87	7·31	23·77	13·10	4·77	8·54	11·74	5·59	7·21	10·30	7·57	13·24	20·35	5·78	15·62	14·73	6·43	11·55
2·69	17·00	16·52	4·98	11·75	11·37	5·74	10·97	12·76	8·70	14·28	16·15	3·06	16·26	14·90	4·47	13·80	14·39
6·26	12·73	12·19	9·36	24·97	10·28	14·95	26·16	13·22	8·00	15·93	10·92	7·15	19·50	11·33	10·15	18·73	12·61
5·15	17·48	12·63	8·83	13·82	8·15	9·65	12·07	10·20	10·33	6·45	11·48	7·21	13·70	11·20	8·77	16·04	9·62
2·78	15·58	18·13	2·40	9·54	10·38	0·56	6·78	10·24	5·46	6·43	11·22	6·34	13·30	11·77	6·18	9·72	8·74
12·47	9·21	12·18	15·46	7·07	11·06	11·14	7·45	9·47	13·84	9·49	10·56	19·94	11·79	14·56	14·17	9·42	10·06
12·72	11·54	14·01	11·59	11·25	13·37	15·16	10·55	13·03	10·83	9·08	12·58	10·92	12·37	11·81	13·97	12·62	11·10
24·92	11·83	18·44	11·31	5·77	9·81	8·60	4·85	10·91	10·79	9·25	9·17	15·05	5·13	9·50	11·49	6·51	10·08
20·35	16·36	21·91	12·74	7·56	16·80	10·45	11·81	17·56	7·31	11·23	21·21	13·33	16·51	20·98	13·34	15·24	17·47
4·17	17·31	13·03	7·33	21·60	11·17	5·10	19·00	11·55	8·07	15·45	9·48	5·59	25·02	9·36	6·94	23·09	10·40
14·03	9·15	14·34	8·36	12·00	7·50	8·10	13·67	10·83	7·79	8·70	7·91	7·60	13·57	7·87	8·26	13·71	9·51
6·33	15·56	10·23	8·60	19·98	10·20	9·26	15·31	10·66	8·76	16·80	13·67	5·56	21·39	9·93	11·54	18·31	10·48
2·89	14·33	15·33	3·34	10·92	10·68	2·85	8·67	10·43	4·88	9·44	6·95	3·05	4·43	9·15	4·99	2·32	13·28
2·36	7·51	12·14	3·33	6·78	10·79	2·98	7·24	12·29	1·89	7·44	9·36	4·07	5·91	11·27	4·41	9·16	11·62
9·68	23·49	17·93	21·97	19·69	13·09	12·18	11·02	13·04	19·13	14·69	11·79	23·61	19·06	14·71	15·96	20·29	15·65
1·78	0·63	24·38	3·66	11·26	22·03	3·55	10·52	21·88	2·52	5·77	16·49	2·37	9·61	23·97	1·49	12·16	24·78

Rainfall in the pre-flood period.

By a careful scrutiny of the rainfall records and gauge readings, it is usually possible to locate the patch of rainfall preceding (and presumably causing) particular floods. This was done for 39 floods which occurred during the period 1874—1926. The data are exhibited in Table 180 in the form of the daily average intensity of rainfall in the Mahanadi catchment for each successive day for a period of 10 consecutive days immediately preceding the occurrence of floods at Naraj. In this analysis, the stations above and below Sambalpur were grouped separately.*

The mean values for all 39 floods are shown below in Table 179.**

Table 179.—Average Rainfall preceding Floods.

Mahanadi Catchment.	Days of Rainfall Preceding floods.									
	1	2	3	4	5	6	7	8	9	10
Above Sambalpur	0·69	0·63	0·54	0·48	0·72	1·13	1·33	1·13	0·78	0·45
Below Sambalpur	0·56	0·54	0·52	0·66	1·02	1·41	1·78	1·31	0·69	0·31
Whole Catchment	0·63	0·59	0·54	0·57	0·87	1·27	1·56	1·22	0·74	0·38

It will be noticed from the above table that usually there is a patch of about 3 consecutive days of heavy rainfall of over 1″ (one inch) per day, and 4 or 5 days of fairly heavy rainfall of about 0·75″ or more. The rainfall falls off just before the occurrence of the flood showing that it takes some time, probably about 2 days, for the flood water in the catchment to come down to Naraj.

It will be also noticed that the patch of heavy rainfall occurs about a day earlier in the area below Sambalpur. This is, of course, quite natural, since most of the pre-flood rainfall is given by the rain-storms which move across the catchment roughly from east to west, i.e., from below Sambalpur to above. In order to form an idea of the lag in rainfall we must, therefore, study the average velocity of such rain-storms.

* This analysis was completed before the catchment was divided into 5 sections, and old values of average rainfall were used.

** In Tables 179—180 under column heading " Days of Rainfall preceding floods ", the 1st day refers to the earliest date and the 10th day to the latest.

TABLE 180

Table 180.—Mahanadi catchment : Rainfall during 10 days previous to floods.

Year.	Date.	*Daily average of stations above Sambalpur—River Mahanadi.* Days of rainfall preceding flood.										*Daily average of stations below Sambalpur—River Mahanadi.* Days of rainfall preceding flood.									
		1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.	10th.	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.	10th
1874	21st to 30th August	·82	·89	·15	·14	·56	1·46	1·43	·19	·18	·08	1·55	·10	1·05	·05	·40	·75	5·05	1·25	·30	..
1876	12th to 21st July ..	·42	·29	·62	·30	·96	1·04	1·03	1·11	1·03	·77	·04	·05	·22	·25	·95	·95	·95	·94	·94	·94
1877	7th to 16th August.	·88	·54	·40	·62	·56	·54	·10	·00	·01	·00	·07	..	2·05	·43	3·03	2·60	·33	1·01	2·07	·14
1879	5th to 14th August	·67	·14	·04	·47	1·71	2·21	1·87	·50	·24	·09	·79	·75	·90	1·42	3·89	2·70	2·35	·04	·12	1·14
1880	24th June to 3rd July	·41	·21	·03	1·24	1·00	1·78	1·07	4 03	1·47	1·08	·10	·10	·10	4·09	1·73	1·26	1·83	1·55	1·49	1·23
1881	17th to 26th July ..	1·21	·41	·80	·76	·76	·52	·73	1·66	·08	·01	2·06	·01	·76	·40	·52	·79	1·49	2·25	·10	..
1885	17th to 26th June	1·47	·71	1·44	2·43	2·79	3·24	2·28	·33	·36	·64	·64	·42	1·10	2·35	·07	·54	1·72	·45	·13	·19
1891	18th to 27th July ..	·55	·10	·31	..	·02	·33	·84	·76	3·10	4·23	·14	·42	·42	..	..	1·02	·48	·65	3·71	·90
1892	17th to 26th July ..	·19	2·26	·78	·20	·49	1·28	2·28	1·61	·08	·09	1·13	1·85	·37	·33	1·04	4·30	5·06	·80	·02	·47
1894	19th to 28th July ..	1·35	·27	·17	·25	·23	1·10	2·14	1·49	·15	·29	·08	·68	·28	·17	·94	1·69	2·30	·80	·25	·52
1895 (1)	22nd to 1st July ..	·13	·62	2·29	·64	1·06	·81	1·02	2·05	·32	·00	1·10	1·59	1·81	·14	·50	2·28	3·04	3·68	·62	·14
1895 (2)	25th July to 3rd Aug.	·28	·45	·58	·55	·57	1·35	2·17	·39	·04	·09	·15	·39	·33	·34	·30	·68	1·47	·38	·18	·00
1896 (1)	8th to 17th Aug...	3·78	·91	·95	·70	·27	1·24	1·61	1·13	·08	·35	·39	·04	·36	1·17	·45	·89	2·01	·17	·28	·19
1896 (2)	16th to 25th July ..	·55	·74	·70	·41	·83	·47	·94	1·81	3·28	·63	·05	·13	·63	·90	·53	·97	2·15	3·48	·37	·02
1896 (3)	27th July to 5th Aug.	·94	2·47	1·00	·29	·31	·65	·46	·60	·04	·51	·76	3·12	·08	·27	·53	·71	2·99	1·62	·29	·28
1900	12th to 21st Sept...	·20	·13	·50	·00	·73	2·05	1·18	1·36	·41	·69	·00	·00	·09	·59	1·27	1·01	2·00	·16	·43	·42
1904	25th June to 4th July	·05	·20	·34	·17	·54	·21	·68	1·00	·61	·12	·49	1·03	·55	1·34	1·92	2·19	2·26	1·34	·50	·19
1907 (i)	8th to 17th Aug...	·55	·36	·38	·92	·67	1·31	1·43	1·33	·43	·22	·45	·20	·22	·57	·66	1·64	1·44	2·21	·43	·05

1907 (ii)	1st to 10th Sept...	·01	·04	·09	·08	·53	1·38	1·69	1·14	·53	·37	·07	·11	·40	·78	1·32	·69	·70	·39	·33	·38
1908	7th to 16th Aug...	1·01	·73	·19	·48	·50	1·61	·76	·74	·50	·17	1·32	1·31	·55	1·18	·86	·92	·92	·32	·57	·26
1910	29th, July to 7th Aug.	·23	·14	·07	·60	1·37	1·93	3·62	·60	·20	·48	·03	·15	·43	·47	·66	1·27	2·50	·38	·08	·44
1911	8th to 17th Aug...	·14	·52	·54	·30	·57	1·12	2·44	1·73	·41	·38	·15	1·47	1·09	·19	·38	·56	1·92	·75	·92	·39
1912	9th to 18th Aug...	1·15	·51	·03	·17	·14	·45	1·16	·27	·09	·16	·66	·05	·11	·08	·44	1·51	·35	·36	1·14	·09
1913	26th July to 4th Aug.	1·38	·08	·06	·21	·56	1·50	2·38	1·19	·09	·09	·67	·04	·06	·16	·87	3·11	2·61	·10	·01	·05
1914	29th July to 7th Aug.	1·27	·49	·39	·23	1·51	1·14	1·40	·91	·69	·22	·81	·24	·13	·05	·47	·67	2·16	1·36	·22	·30
1915	28th July to 6th Aug.	·76	1·52	·40	·03	·28	·91	1·89	1·43	·04	·10	·66	1·28	·14	·17	·64	2·04	2·40	·89	·25	·04
1917	6th to 15th Aug. ..	1·13	2·03	1·30	·53	·98	1·07	1·01	1·02	·27	·05	·73	·41	·23	·18	·59	·34	·85	1·94	·13	·01
1918	11th to 20th June..	·40	·77	·92	1·16	1·26	3·39	3·14	1·21	·64	·30	·45	1·15	·94	2·14	3·78	3·15	·53	·29	·32	·03
1919 (i)	26th July to 4th Aug.	·33	·75	·44	·20	·32	·71	1·36	1·64	·13	·05	·41	·53	·37	·41	·30	1·23	·80	1·86	·19	·09
1919 (ii)	25th Aug. to 3rd Sept.	·52	·77	1·32	·58	·19	·28	·59	1·36	·13	·07	·83	·62	1·66	·29	·36	·63	1·61	·96	·14	·20
1920 (i)	16th to 25th July..	·39	·30	·16	·14	1·32	·00	2·06	2·45	3·10	1·21	1·39	·15	·28	1·11	2·31	1·12	1·60	2·50	2·58	·12
1920 (ii)	26th July to 4th Aug	·09	·04	·03	·15	·59	·65	1·74	·18	·25	·04	·08	·07	·01	·13	2·10	3·16	1·09	·21	·20	·32
1921	22nd to 31st July..	·39	·33	·20	·16	·35	·55	·28	·66	·64	·50	·80	·22	·46	·35	·62	1·70	·29	·28	·84	·88
1922	21st to 30th July..	·57	·38	·76	·60	·88	·23	·29	·60	1·26	·49	·51	·77	·61	·68	·69	·22	·14	1·45	·86	·32
1923	12th to 21st Aug...	·53	·83	·61	·63	·72	1·36	·92	·44	·37	·38	·78	·29	·98	·36	1·16	·20	·27	·11	·03	·16
1925 (i)	5th to 14th July..	·58	1·30	·94	·44	1·13	2·08	·93	1·63	1·06	·10	·75	·21	·22	·86	2·12	2·27	1·47	3·03	·34	·34
1925 (ii)	25th Aug. to 3rd Sept.	·03	·04	·70	1·46	·80	·79	·91	1·06	·43	·37	·03	·25	·56	·71	·33	·48	·61	·52	·19	·14
1925(iii)	21st June to 30th June.	·42	·46	·21	·24	·03	·05	·33	2·23	3·76	1·81	·21	·60	·08	·18	·39	·58	2·08	6·32	4·03	·44
1926	16th to 19th Aug...	·86	·68	·35	·24	·12	·31	·84	·41	3·72	·28	·37	·24	·57	·29	·24	2·07	5·25	5·44	1·15	·22
	Total =39	26·94	24·41	21·19	18·68	28·21	44·20	52·00	44·25	30·22	17·51	21·70	21·04	20·20	25·58	39·59	54·89	69·27	51·24	26·75	12·04
	Average ..	·69	·63	·54	·48	·72	1·13	1·33	1·13	·78	·45	·56	·54	·52	·66	1·02	1·41	1·78	1·31	·69	·31
	Above Sambalpur											·69	·63	·54	·48	·72	1·13	1·33	1·13	·78	·45
												1·25	1·17	1·06	1·14	1·74	2·54	3·11	2·44	1·47	·76
	Whole catchment (general average) ..											·63	·59	·54	·57	·87	1·27	1·56	1·22	·74	·38

Lag in Rainfall.

The average velocity of the rain-storms across the catchment area is of considerable importance in connexion with flood studies. As the position of the centre of the rain-storms on each day at 8-0 A.M. is given in the chart book published by the Meteorological Department, it was easy to measure directly the distance moved in 1 day by about 27 storms which crossed Orissa during the months of July, August and September between 1891-1928. It was found that the storms usually moved across the area under consideration in about 2 days; the velocity of movement was found to be about the same on both days and equal to 8·5 miles per hour approximately.

We know that the width of the delta is about 50 miles from the coast; the average time taken by the storm to reach the head of the delta near about Naraj will be about 6 hours from the time of crossing the coast.

We can also find the distance between the approximate positions of the different sections of the Mahanadi catchment. These are given as distances from the coast in col. (2) of Table 181 given below. The next column gives the time taken by the storm to reach the different positions. The lag or time differences between various positions are also given in the other columns.

Table 181.—Movement of Rain-Storms.

Position.	Miles from coast.	Time Difference (in hours).	Lag of heavy rainfall (in hours) on—			
			Delta.	Naraj.	M—I.	M—II and M—III.
1	2	3	4	5	6	7
Centre of Delta	25	3·0	0	...	...	...
Naraj	50	6·0	3·0	0	...	...
Centre of Section I	122	14·5	11·5	8·5	0	...
Centre of Sections II and III ...	234	27·5	24·5	21·5	13·0	0
Ditto IV and V ...	354	41·7	38·7	35·7	27·2	14·2
Extreme end of Section V ...	414	48·7	45·7	42·7	34·2	21·2

We may assume, further, that the locus of heavy rainfall moves with approximately the same velocity as the centre of the storm itself. The sequence of events may be now described. Heavy rain first falls in the delta; about 11 or 12 hours later in Section I; about 24 hours later in Sections II and III, and finally about 39 hours later in Sections IV and V. It will be also noticed that the average duration of the storm within our area is only about 48 hours.

In view of the importance of the above results I tried to check them by an altogether independent method. The average rainfall in the different sections of the Mahanadi have been already given in Chapter 20. By a careful scrutiny of these values it is possible to locate the exact date of maximum rainfall in any two sections, say section I and section V. Hence it is also possible to determine the time interval (in days) between the occurrence of maximum rainfall in these two sections. This was done for 34 different storms, and it was found directly that the interval was 1·15 day or 27·6 hours. From Table (181) we find the lag to be 27·2 hours; the agreement is almost perfect, and is, of course, partly fortuitous. It gives us confidence, however, in accepting these results as fairly reliable.

Table 182.—Interval between date of flood at Naraj and last date of heavy rainfall (average above 1" per day) in the Mahanadi catchment. Period of 3 days.

Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.	Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.
30-6-1872	26-6-1872	4	10-9-1907	8-9-1907	2
30-8-1874	27-8-1874	3	16-8-1908	13-8-1908	3
22-7-1876	19-7-1876	3	7-8-1910	4-8-1910	3
16-8-1877	12-8-1877	4	17-8-1911	15-8-1911	2
14-8-1879	11-8-1879	3	18-8-1912	16-8-1912	2
3-7-1880	3-1-1880	0	4-8-1913	2-8-1913	2
26-7-1881	25-7-1881	1	7-8-1914	4-8-1914	3
26-6-1885	23-6-1885	3	6-8-1915	4-8-1915	2
30-7-1891	27-7-1891	3	15-8-1917	13-8-1917	2
26-7-1892	25-7-1892	1	20-6-1918	17-6-1918	3
28-7-1894	26-7-1894	2	25-7-1920	24-7-1920	1
1-7-1895	29-6-1895	2	21-8-1923	18-8-1923	3
25-7-1896	24-7-1896	1	14-7-1925	12-7-1925	2
17-8-1896	15-8-1896	2	19-8-1926	18-8-1926	1
21-9-1900	18-9-1900	3			
4-7-1904	1-7-1904	3	Interval Average=2·30 days.		

Table 183.—Interval between date of flood at Naraj and last date of heavy rainfall (average above 1" per day) in the Mahanadi catchment. Period of 4 days.

Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.	Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.
30-6-1872	27-6-1872	3	10-9-1907	8-9-1907	2
30-8-1874	28-8-1874	2	16-8-1908	13-8-1908	3
22-7-1876	20-7-1876	2	7-8-1910	4-8-1910	3
16-8-1877	12-8-1877	4	17-8-1911	16-8-1911	1
14-8-1879	11-8-1879	3	18-8-1912	17-8-1912	1
3-7-1880	2-7-1880	1	4-8-1913	2-8-1913	2
26-7-1881	24-7-1881	2	7-8-1914	5-8-1914	2
26-6-1885	23-6-1885	3	6-8-1915	4-8-1915	2
30-7-1891	27-7-1891	3	15-8-1917	13-8-1917	2
26-7-1892	24-7-1892	2	20-6-1918	17-6-1918	3
28-7-1894	26-7-1894	2	25-7-1920	24-7-1920	1
1-7-1895	29-6-1895	2	21-8-1923	18-8-1923	3
25-7-1896	23-7-1896	2	14-7-1925	12-7-1925	2
17-8-1896	15-8-1896	2	19-8-1926	18-8-1926	1
21-9-1900	19-9-1900	2			
4-7-1904	2-7-1904	2	Interval Average=2·16 days.		

Table 184.—Interval between date of flood at Naraj and last date of heavy rainfall (average above 1" per day) in the Mahanadi catchment. Period of 5 days.

Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.	Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.
30-6-1872	28-6-1872	2	10-8-1908	14-8-1908	2
30-8-1874	29-8-1874	1	7-8-1910	5-8-1910	2
22-7-1876	20-7-1876	2	17-8-1911	16-8-1911	1
16-8-1877	12-8-1877	4	18-8-1912	17-8-1912	1
14-8-1879	12-8-1879	2	4-8-1913	2-8-1913	2
3-7-1880	1-7-1880	2	7-8-1914	6-8-1914	1
26-7-1881	24-7-1881	2	6-8-1915	5-8-1915	1
26-6-1885	23-6-1885	3	15-8-1917	13-8-1917	2
30-7-1891	27-7-1891	3	20-6-1918	17-6-1918	3
26-7-1892	24-7-1892	2	4-8-1919	2-8-1919	2
28-7-1894	27-7-1894	1	25-7-1920	24-7-1920	1
1-7-1895	30-6-1895	1	3-8-1920	2-8-1920	1
25-7-1896	24-7-1896	1	14-7-1925	13-7-1925	1
17-8-1896	15-8-1896	2	19-8-1926	19-8-1926	0
21-9-1900	20-9-1900	1			
10-9-1907	9-9-1907	1	Interval Average 1·67 days.		

Table 185.—Interval between date of flood at Naraj and last date of heavy rainfall (average above 1" per day) in the Mahanadi catchment. Period of 6 days.

Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.	Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.
30-6-1872	29-6-1872	1	7-8-1910	7-8-1910	0
30-8-1874	30-8-1874	0	17-8-1911	17-8-1911	0
22-7-1876	21-7-1876	1	18-8-1912	18-8-1912	0
16-8-1877	12-8-1877	4	4-8-1913	4-8-1913	0
14-8-1879	13-8-1879	1	7-8-1914	7-8-1914	0
3-7-1880	2-7-1880	1	6-8-1915	6-8-1915	0
26-6-1885	23-6-1885	3	15-8-1917	15-8-1917	0
26-7-1892	26-7-1892	0	20-6-1918	20-6-1918	0
28-7-1894	28-7-1894	0	4-8-1919	4-8-1919	0
1-7-1895	1-7-1895	0	25-7-1920	25-7-1929	0
25-7-1896	25-7-1896	0	14-7-1925	14-7-1925	0
17-8-1896	15-8-1896	2	19-8-1926	19-8-1926	0
21-9-1900	21-9-1900	0			
10-9-1907	10-9-1907	0	Interval Average 0·48 days.		
16-8-1908	16-8-1908	0			

Table 186.—Interval between date of flood at Naraj and last date of heavy rainfall (average above 1" per day) in the Mahanadi catchment. Period of 10 days.

Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.	Date of maximum flood at Naraj.	Last date of the rainfall period.	Interval between two dates.
30-6-1872	30-6-1872	0	7-8-1910	7-8-1910	0
30-8-1874	30-8-1874	0	17-8-1911	17-8-1911	0
22-7-1876	21-7-1876	1	18-8-1912	18-8-1912	0
16-8-1877	16-8-1877	0	4-8-1913	4-8-1913	0
14-8-1879	14-8-1879	0	7-8-1914	7-8-1914	0
3-7-1880	3-7-1880	0	6-8-1915	6-8-1915	0
26-6-1885	26-6-1885	0	15-8-1917	15-8-1917	0
26-7-1892	26-7-1892	0	20-6-1918	20-6-1918	0
28-7-1894	28-7-1894	0	4-8-1919	4-8-1919	0
1-7-1895	1-7-1895	0	25-7-1920	25-7-1920	0
25-7-1896	25-7-1896	0	14-7-1925	14-7-1925	0
17-8-1896	17-8-1896	0	19-8-1926	19-8-1926	0
21-9-1900	21-9-1900	0			
10-9-1907	10-9-1907	0	Interval Average=.04 days.		
16-8-1908	16-8-1908	0			

The lag between rainfall in the catchment and the occurrence of floods at Naraj.

In the case of a large catchment area like that of the Mahanadi it takes some time for the water to run down to the delta, so that there is a time lag between the period of heavy rainfall in the catchment and the time of occurrence of the maximum flood at Naraj. It is essential to gain some idea regarding this time lag in order to attempt any kind of flood forecast. Tables 182—186 were prepared for this purpose; in these tables the dates refer to the dates of occurrence of maximum floods at Naraj.

The results for the different periods may be exhibited in the following way :—

Table 187.—Lag between Rainfall and Flood.

Period of rainfall in days.	Lag in days in the occurrence of a maximum flood at Naraj.	
	From end of rainfall period.	From centre of rainfall period.
1	2	3
3	2·30	3·30
4	2·16	4·16
5	1·67	4·17
6	0·48	3·48
10	0·04	...

It would appear from the figures for the centre of the rainfall period, that the maximum flood at Naraj occurs about 3 or 4 days later than the day of heaviest precipitation in the catchment. This is encouraging; it leaves time for prediction. Had there been no appreciable lag between rainfall and flood, forecasts of any kind would have been quite impossible.

In view of the importance of the question I decided to analyse the data separately for the different sections. The intervals between the date of occurrence of single day maximum rainfall in each section of the Mahanadi catchment and the date of occurrence of the corresponding maximum level at Naraj were recorded separately for all the sections.

The average values of the intervals for each month separately, and for the monsoon period, are shown in Table 188. The figure within brackets gives the size of the sample in each case.

Table 188.—Lag between Rainfall at different sections and Flood at Naraj.

Section.	Lag in days.			Monsoon period (July—September).	
	July.	August.	September.	Days.	Hours.
1	2	3	4	5	6
M—I ...	1·1 (28)	1·3 (31)	1·0 (16)	1·16 (75)	27·8
M—II ...	1·2 (48)	1·6 (59)	1·3 (30)	1·38 (137)	33·1
M—III ...	2·6 (54)	2·5 (46)	2·3 (21)	2·50 (121)	60·0
M—IV ...	2·8 (34)	2·7 (55)	2·6 (21)	2·70 (110)	64·8
M—V ...	3·4 (27)	3·3 (21)	4·0 (12)	3·50 (60)	84·0
Catchment ...	2·17 (191)	2·20 (212)	2·07 (100)	2·17 (503)	52·1

The rainfall readings refer to the period of 24 hours ending at 8-0 A.M. and may be centred at 8-0 P.M. of the previous day. Most of the gauge readings represent the average of three readings taken at 6-0 A.M., 12-0 noon and 6-0 P.M. and may be centred at 12-0 noon. For readings on the same day, that is, for a nominally zero interval, the real lag is 16 hours. This is the correction which we must add in each case. The corrected values are shown in column (3) of Table 189 given below :—

Table 189.—Average Velocity of Flood Flow.

Section.	Lag in hours.		Equivalent distance from Naraj.	Average velocity of flow.	
	Normal.	Corrected.		Miles per hour.	Feet per second.
1	2	3	4	5	6
M—I	27·8	43·8	96	2·19	3·21
M—II	33·1	49·1	200	4·07	5·97
M—III ...	60·0	76·0	308	4·05	5·94
M—IV ...	64·8	80·8	318	3·95	5·79
M—V	84·0	100·0	408	4·08	5·98
Catchment ...	52·1	68·1	265	3·89	5·71

It will be remembered that in chapter 5 we made an estimate of the average equivalent length of the channels in and from the different sections. Using the above estimates of the average time taken by the rainfall to reach Naraj we can, therefore, calculate the average velocity of flow of the run-off.

The results are shown in Table 189 given above. It will be noticed that, excepting in section I, the mean velocity is, everywhere, of the order of 4 miles per hour or about 6 feet per second. The agreement between the different sections is quite striking, showing that the estimated value of 4 miles per hour is fairly reliable. This is, of course, an average velocity of the run-off. The comparatively low velocity of 2·2 miles per hour in section I is easily explained by the fact that the gradient in this section is very small.

The intensity of rainfall in the period preceding floods.

The daily variation of average rainfall in the Mahanadi catchment for a period of ten days preceding the beginning of each flood is shown in Table 190. Floods which continued to remain above danger level at Naraj for 3 or more days have been called long floods other floods have been called short in this table. Thus all the short floods remained above danger level for 1 or 2 days only. At the end of the table are shown the average rainfalls for each of the ten successive days for all floods since 1872. Averages for short floods and long floods are given separately.

In Chart No. 5 Curve (1) represents data for long floods, Curve (2) represents data for all floods, and Curve (3) represents data for short floods. It is clear from these curves that long floods were preceded by much more rainfall than short floods on an average. The forms of these curves are similar. Curve (1) rises sharply in the 5th day and falls rapidly in the tenth day, the day of maximum flood at Naraj. We find therefore that in the case of long floods there is heavy rainfall for 5 consecutive days on the average up to the day previous to the occurrence of the maximum flood at Naraj. For short floods there is heavy rainfall on the 6th, 7th and 8th day, maximum flood occurring on the 10th day. We may conclude that, on the average, three consecutive days of heavy rainfall (above 1″) cause short floods, and five consecutive days of heavy rainfall cause long floods. In the case of short floods, the maximum flood occurs two days after the cessation of heavy rainfall; in the case of long floods, the maximum flood occurs one day after the cessation of heavy rainfall.

Table 190.—Daily average rainfall in inches in the Mahanadi catchment during 10 days preceding floods at Naraj.

Year.	Period.	Daily averages.										Remarks.
		1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.	10th.	
1872	25th June—4th July ..	1·76	1·55	1·00	0·12	0·47	0·88	1·11	1·56	2·76	0·12	Long flood.
1874	21st—30th August ..	1·03	0·66	0·41	0·11	0·51	1·11	2·40	0·49	0·21	0·06	Ditto.
1876	12th—21st July ..	0·31	0·22	0·51	0·29	0·06	1·02	1·01	1·06	1·01	0·82	
1877	7th—16th August ..	0·65	0·38	0·87	0·66	1·27	1·13	0·16	0·29	0·60	0·04	
1879	5th—14th August ..	0·70	0·32	0·29	0·74	2·33	2·35	2·00	0·37	0·21	0·39	Long flood.
1880	24th June—3rd July ..	0·32	0·18	0·05	2·05	1·21	1·03	1·29	3·32	1·48	1·13	Ditto.
1881	17th—26th July ..	1·49	0·28	0·79	0·64	0·68	0·81	0·98	1·85	0·09	0·01	
1885	17th—26th June ..	1·22	0·02	1·34	2·40	1·07	2·43	2·11	0·37	0·20	0·50	Long flood.
1891	26th—29th July ..	0·34	0·00	0·01	0·56	0·72	0·73	3·30	3·12	0·18	0·00	
1892	17th—26th July ..	0·49	2·00	0·60	0·48	0·66	2·18	3·02	1·40	0·14	0·21	Long flood.
1894	16th—28th July ..	0·80	0·41	0·21	0·20	0·49	1·24	2·01	1·13	0·35	0·37	Ditto.
1895	22nd June—1st July ..	0·50	0·05	1·03	0·41	0·79	1·38	1·80	2·52	0·41	0·10	Ditto.
1895	25th July—3rd August..	0·20	0·41	0·44	0·49	0·52	0·91	1·74	0·48	0·09	0·04	
1896	8th—17th August ..	2·21	0·51	0·68	0·92	0·35	1·08	1·80	0·68	0·17	0·27	
1898	16th—25th July ..	0·34	0·48	0·67	0·62	0·71	0·68	1·45	2·50	2·07	0·37	Long flood.
1900	12th—21st September ..	0·11	0·07	0·31	0·27	0·08	1·57	1·56	0·80	0·42	0·57	
1904	25th June—4th July ..	0·23	0·54	0·43	0·65	1·25	1·02	1·41	1·15	0·60	0·15	
1907	6th—17th August ..	0·51	0·30	0·32	0·79	0·67	1·44	1·43	1·67	0·43	0·16	
1907	1st—10th September ..	0·03	0·07	0·21	0·34	0·83	1·12	1·31	0·86	0·46	0·37	Long flood.
1908	7th—16th August ..	1·13	0·95	0·33	0·75	0·64	1·31	0·83	0·38	0·53	0·20	
1910	29th July—7th August..	0·15	0·15	0·21	0·70	1·14	1·74	3·21	0·53	0·16	0·48	Long flood.
1911	8th—17th August ..	0·14	0·58	0·75	0·25	0·50	0·91	2·24	1·36	0·61	0·38	
1912	9th—16th August ..	0·96	0·33	0·06	0·14	0·20	0·85	0·85	0·30	0·49	0·13	
1913	26th July—4th August..	1·11	0·06	0·00	0·19	0·08	2·11	2·47	0·78	0·06	0·07	
1914	29th July—7th August..	1·11	0·40	0·30	0·17	1·14	0·97	1·67	1·07	0·52	0·25	
1915	23th July—6th August..	0·72	1·43	0·39	0·08	0·41	1·31	2·08	1·23	0·12	0·08	
1917	6th—15th August ..	0·97	1·38	0·87	0·39	0·82	0·78	0·98	1·42	0·21	0·03	
1918	11th—20th June ..	0·42	0·92	0·92	1·55	2·27	3·29	2·09	0·84	0·52	0·20	Long flood.
1919	26th July—4th August..	0·36	0·06	0·41	0·28	0·32	0·91	1·36	1·72	0·15	0·00	
1920	16th—25th July ..	0·78	0·25	0·20	0·53	1·70	0·98	1·88	2·47	2·90	0·79	Long flood.
1920	26th July—4th August..	0·09	0·05	0·02	0·14	1·17	1·74	1·49	0·19	0·29	0·15	
1923	12th—21st August ..	0·81	0·62	0·76	0·53	0·89	0·91	0·67	0·31	0·24	0·29	
1925	5th—14th July ..	0·65	0·58	0·66	0·60	1·52	2·15	1·14	2·17	0·78	0·19	Long flood.
1926	14th—23rd August ..	0·54	0·76	1·58	0·39	0·28	0·49	0·56	0·28	1·16	0·67	
1928	25th Aug.—3rd September	0·03	0·12	0·45	0·93	0·55	0·67	0·80	0·88	0·34	0·23	
1928	10th—19th August ..	0·67	0·51	0·44	0·26	0·17	0·99	2·65	2·35	2·73	0·26	Long flood.
	Total (36) ..	24·57	21·02	20·81	21·00	32·06	47·36	59·72	45·28	23·91	10·30	
	Average ..	*0·66*	*0·57*	*0·56*	*0·57*	*0·87*	*1·28*	*1·61*	*1·22*	*0·65*	*0·23*	
	Short floods (21) Total..	14·71	11·07	11·07	9·89	15·31	23·21	30·16	22·40	8·44	3·76	
	Ditto Average..	·67	·50	·53	·45	·70	*1·05*	*1·37*	*1·02*	·38	·17	
	Long floods (15) Total ..	9·86	9·96	9·14	11·11	16·76	24·15	29·56	22·88	15·47	6·54	
	Ditto Average..	·60	·66	·61	·74	*1·12*	*1·61*	*1·97*	*1·52*	*1·03*	·44	

The Rise of the Mahanadi during floods.

We have just seen that the flood rainfall occurs in heavy patches (over 1" per day) extending over 3 or 4 days, and moderate patches (over 0·5" per day) over 6 or 7 days. How long does the effect of the rainfall persist at Naraj? In order to study this question, a table was prepared showing the actual rise of the river on the 1st day, 2nd day, etc.....up to the 10th day beginning from the day of the sharp rise due to heavy rainfall (of the order of about 3". or over in 3 days) for 104 periods of such heavy precipitation.

The average values are given below.

Table 191.—Rate of change in the level of the Mahanadi at Naraj.

Date of rise.	Rise in the level of the Mahanadi at Naraj.	
	Per day (in feet).	Total accumulated rise (in feet).
1st day	+1·83	1·83
2nd „	+2·30	4·13
3rd „	+1·48	5·61
4th „	+0·42	6·03
5th „	—0·32	5·71
6th „	—0·41	5·30
7th „	—0·33	4·97
8th „	—0·30	4·67
9th „	—0·29	4·38
10th „	—0·19	4·19

It will be seen from the above table that the river rises quite steadily for about 3 days; the rise on the 4th day being usually small.

The level begins to fall slowly from the fifth day and continues to do so at a decreasing rate until on the 10th day the height is about the same as that on the 2nd day. We may say, therefore, that the first and immediate effect of the rainfall persists for about 5 or 6 days, but the river often continues to remain high for a few days more.

General Description of Floods at Naraj.

A typical picture of floods in the Mahanadi can be now constructed. The river floods are caused by the heavy rain given by storms and depressions which have their origin in the Bay of Bengal, and which move across the Orissa delta and the river basins in an approximately west-north-westerly direction with an average velocity of about 8·5 miles per hour. The rainfall in the period immediately preceding floods usually occurs in a well-marked patch of very heavy rain of intensity considerably over one inch per day for about 3 consecutive days, and moderately heavy rain of over three-quarters of an inch per day for about 5 consecutive days. Heavy rain first occurs in the delta, and then gradually moves across the catchment area of the Mahanadi, occurring usually about 12 hours later in section I, about 24 hours later in sections II and III, and finally about 40 hours later in sections IV and V.

It takes some time for the flood water in the basin to reach Naraj. The average velocity of flow is about 4 miles per hour or 6 feet per second, except in section I where owing to the low gradient the velocity is about 2·2 miles per hour or 3·2 feet per second. It usually takes about 44 hours for the flood water from section I to exert its greatest effect at Naraj, and 50 hours, 76 hours, 81 hours, and 100 hours for the water from sections II, III, IV and V respectively. This lag between rainfall and flood makes it possible to attempt flood forecasts.

As regards the level of the Mahanadi at Naraj we found that usually there is a steady rise at first which is maintained for 3 days; the rise on the 4th day, as the river level approaches the maximum, being comparatively small. Ordinarily the river begins to fall slowly from the 5th day, but the river level is maintained quite high for several days longer.

Rainfall and the Rise of the River level at Naraj.

In order to study the relationship between rainfall in the Mahanadi catchment area and the rise of the river at Naraj, a period of six days was selected for the rainfall analysis because a high flood at Naraj is usually caused by heavy rainfall in the catchment area for a period of about six days. The average daily normal rainfall for the months of June, July and August (530,000 cusecs) was subtracted from the actual rainfall in cusecs. This excess of rainfall was then divided by the normal rainfall and multiplied by 100 to obtain the excess of rainfall as a percentage of the normal rainfall. Thus if X denotes the actual average rainfall during the flood period, and A is the normal rainfall (in this case 530,000 cusecs) then—

$$\text{Excess percentage} = \left(\frac{X-A}{A}\right). 100.$$

Table 192 shows the maximum level reached by the Mahanadi above Naraj weir during each flood year since 1872. Percentage excess of rainfall over the normal in the catchment area for six days as well as the rise of the Mahanadi above the weir in six days preceding the occurrence of maximum flood at Naraj are shown against all the flood years. The rise of the river in six days could not be estimated for all the floods because in some case the river had been falling at the time when heavy rains set in in the catchment areas. Sometimes the river rose to its maximum level within three, four or five days of the beginning of heavy rainfall. Such cases are noted in the remarks column.

Chart No. 6 shows the percentage excess of rainfall and the corresponding rise in the river level at Naraj. The year is mentioned against each point.

Table 192.—Percentage excess of rainfall in the Mahanadi catchment and the rise of river level at Naraj.

Years of flood.	Level from which the rise was estimated.	Maximum level reached at Naraj.	Rise of the river in 6 days.	Percentage excess of rainfall in the basin.	Remarks.
1872*	66·48	89·90	23·42	155·6	*1872—Owing to insufficiency of data rainfall analysis is doubtful.
1874	82·85	90·00	7·15	112·4	
1876	75·15	88·60	13·45	142·3	
1877	80·00	88·10	8·10	84·0	
1879*	80·80	90·90	10·10	223·4	*1879—rise in 5 days.
1880	68·70	89·10	20·40	287·2	
1885	68·10	90·50	22·40	313·6	
1892	80·74	91·70	10·96	205·7	
1894*	83·25	89·40	6·15	136·7	*1894—rise in 3 days.
1895	81·36	90·40	9·04	230·4	
(July) 1896	76·45	92·10	15·65	210·6	
(August) 1896	83·75	89·30	5·55	143·0	
1900	76·30	88·75	12·45	138·9	
1907*	78·70	89·70	11·00	110·8	*1907—rise in 5 days.
1908	85·00	88·30	3·30	115·3	
1910*	76·30	90·10	13·80	162·9	*1910—rise in 10 days.
1911	85·20	91·30	6·10	229·3	
1912*	79·80	88·50	8·70	41·07	*1912—rise in 3 days.
1913*	78·70	88·40	9·70	158·1	*1913—rise in 4 days.
1914*	81·40	90·10	8·70	176·9	*1914—rise in 4 days.
1915*	81·80	88·80	7·00	116·2	*1915—rise in 5 days.
1917	84·60	89·20	4·60	102·5	
1918	68·60	89·70	21·10	288·1	
1920*	79·68	91·88	14·48	356·1	*1920—rise in 4 days.
1925	83·00	91·20	8·20	208·6	
1926	83·60	91·70	8·10	321·7	

The floods enumerated in the above Table 192 may be divided into two groups :—

(I) Floods in which the level of the river at Naraj was already 83 feet or above when the period of six days commenced.

(II) Floods in which the level of the river at Naraj was below 83 feet when the period of six days commenced.

Seven floods belonging to group I occurred in the years 1894, 1896 (August), 1908, 1911, 1917, 1925 and 1926.

Nineteen floods belonging to group II occurred in the years 1872, 1874, 1876, 1877, 1879, 1880, 1885, 1892, 1895, 1896 (July), 1900, 1907, 1910, 1912, 1913, 1914, 1915, 1918 and 1920. Figures for 1872 are unreliable owing to insufficiency of data.

It will be seen from the graph in Chart No. 2 that all the floods in group II can be fairly well represented by a straight line passing through the origin. It will also be seen that all the points of group I lie below this straight line. Thus, the most divergent points are those for the floods of 1926, 1925, 1911, 1894, 1896 (August), 1917 and 1908. All of these again can be represented by another straight line passing through the origin but making a smaller angle with the horizontal axis. The explanation is that when the river level approaches 88 feet at Naraj (which is the danger level at that point) the discharge increases more than proportionably owing to the widening of the cross-section and also to spilling in some cases, so that for a given increase in the volume of water carried by the river, the rise of the river level would be less. In this connection it will be relevant to point out that the floods in group I were much higher than the floods in group II as a rule.

In order to maintain the standard period of six days throughout the table an attempt was made to apply suitable adjustments where possible. The procedure followed in applying the adjustment in each case is noted below :

1872. Owing to insufficiency of data rainfall analysis is doubtful.

1879. Available period is five days, and actual rise 10·10 feet. On the 1st day the rise was 2·4; adding this value to 10·10 we get 12·5 feet as the adjusted total rise in six days.

1894. Available period is only three days. Approximation cannot be adopted with any degree of accuracy because the available period is too short.

1907. Available period is five days. Maximum flood occurred on the 10th September. The river stood at minimum level on the 5th, and on the 6th it rose by 0·8 feet. Therefore in this case 0·8 feet can be added to the rise of 11·00 feet in five days, giving an adjusted total rise of 11·80 feet in six days.

1910 Available period is five days. Total rise on the first day was only 0·1 foot. Therefore adding this to the rise of 13·8 feet in five days, we get 13·9 feet as the adjusted total rise in six days.

1912. Available period is only three days. Approximation cannot be adopted because the available period is too short.

1913. Available period is four days. Total rise on the first day was 1·7 feet, and that in the second was 5 feet. It is evident that the flood was just beginning to be fully effective when the available period commenced, so that it would not be justifiable to apply two full days' correction. We shall take 1·6 feet as the total rise in the first two days of the standard period. This makes the total rise 11·4 feet in six days.

1914. Available period is four days. Total rise on the first day was 0·5 feet. Therefore we shall take 0·5 as the total rise in the first two days of the standard period. This brings the adjusted total rise during this flood up to 9·2 feet.

1915. Available period is five days. On the first day the rise was practically nil. Therefore the total rise will not be altered.

1920. Available period is five days. On the first day the river rose 2·3 feet; adding this to 14·48 we get the adjusted rise in six days. The corrected values have been given in Table 193.

It will be noticed that points for floods of 1874, 1915, 1914, 1892, 1879 and 1895 lie between the two straight lines. All of these floods started higher than others in group II and this is exactly what could be expected. Moreover, it will be seen that points for 1879 and 1895 approach the lower straight line. These two floods started from 81·00 feet and 81·30 feet but rose upto the very high levels of 90·90 feet and 90·40 feet respectively.

Equations for the two straight lines are :—

$$y = 0{\cdot}0322x,$$

$$y = 0{\cdot}0721x,$$

where x = Excess percentage of rainfall in six days in the Mahanadi Catchment,

and y = Rise of Mahanadi at Naraj in feet in six days.

Therefore if N_0 is the level in feet from which the flood begins, and R is the actual rainfall in inches in six days, then N_1 and N_2 the maximum heights at Naraj in feet above weir are given in the two cases respectively by the two equations :—

$$N_1 = N_0 + 1{\cdot}36\ (R'') - 3{\cdot}23 \text{ in feet.}$$

$$N_2 = N_0 + 3{\cdot}03\ (R'') - 7{\cdot}21 \text{ in feet.}$$

The predicted and observed values were compared and the average discrepancy for Group I was found to be 19 per cent and for Group II 21 per cent. The present formulæ, therefore, establish a connexion between the precipitation in the catchment for six days and the total rise at Naraj within an average accuracy of about 20 per cent, but are not quite sufficient to enable individual forecasts being made with accuracy.

Table 193.—Corrected rise of the Mahanadi at Naraj and excess percentage rainfall in 6 days in the Mahanadi catchment.

Group I.			Group II.		
Year.	Excess rainfall.	Total rise of level.	Year.	Excess rainfall.	Total rise of level.
1894	Omitted.		1872	Omitted for reasons mentioned before.	
Aug.1896	143·0	5·55	1874	112·4	7·15
1908	115·3	3·30	1876	142·3	13·45
1911	229·3	6·10	1877	84·0	81·00
1917	102·5	4·60	1879	223·4	12·30
1925	208·6	8·20	1880	287·2	20·40
1926	321·7	8·10	1885	313·6	22·40
			1892	205·7	10·97
			1895	230·4	9·04
			1896 July	210·6	15·65
			1900	138·9	12·45
			1907	110·8	11·80
			1910	162·9	13·90
			1912	Omitted.	Omitted.
			1913	158·1	11·30
			1914	176·9	9·45
			1915	116·2	7·00
			1918	288·1	21·10
			1920	356·1	16·80

Rainfall and Discharge.

In order to study the relation between the intensity of rainfall in the Mahanadi catchment and the discharge at Naraj, the average discharge at Naraj for periods of 3, 4, 5, 6 and 10 days were calculated with the help of Rhind's Table. In doing this the discharge corresponding to the height on each day was taken and added and the average obtained from this total. The intensity of rainfall was calculated from isohyet maps, and is given in Tables 194—198 along with the percentage discharge.

The following points may be noted :—

1872. Owing to insufficiency of data rainfall analysis is doubtful. The river came down and subsequently rose to 92·10 feet on the 4th July.

1876. The flood was of very short duration. The Mahanadi rose above the danger level only for a day. Rainfall analysis is applicable to short periods only.

1912. The Mahanadi was above danger level only for a day. The river was coming down at a moderate rate till the 15th August, and on the 17th level was 81·6 feet. On the 18th the river rose above the danger level to 88·5 feet. Rainfall analysis is applicable to short periods only.

1913. The river was coming down till the 31st July; it then suddenly rose to 88·1 feet on the 3rd August. Therefore rainfall analysis will be applicable to short periods only.

Table 194.—Rainfall in the Mahanadi catchment and discharge at Naraj. Period of 3 days.

Year.	Date of flood.	Maximum reading of Gauge at Naraj (above weir).	Average rainfall in inches per day.	Average rainfall in kilocusecs.	Average discharge at Naraj in kilocusecs.	Per-centage discharge.
1872	30th June ..	89·90	1·71	2,284	1,419	62
74	30th August ..	90·00	1·33	1,786	1,180	66
76	22nd July ..	88·60	1·04	1,387	984	71
77	16th August ..	88·10	0·95	1,267	923	73
79	14th ,, ..	90·90	2·27	3,043	1,295	42
80	3rd July ..	89·10	1·77	2,370	1,131	47
81	26th ,, ..	..	0·97	1,294	..	..
85	26th June ..	90·50	1·87	2,509	1,232	49
91	30th July ..	87·90	2·63	3,522	..	..
92	26th ,, ..	91·74	2·04	2,735	1,383	55
94	28th ,, ..	89·40	1·61	2,159	1,101	51
95	1st ,, ..	90·40	1·73	2,318	1,160	50
96-(i)	25th ,, ..	92·10	2·01	2,689	1,419	52
96 (ii)	17th August ..	89·30	1·25	1,668	1,008	64
1900	21st September ..	88·75	1·56	2,093	1,041	50
04	4th July ..	87·80	1·07	1,441	884	61
07	10th September	89·70	1·42	1,899	1,148	60
08	16th August ..	88·30	1·22	1,627	956	58
10	7th ,, ..	90·10	1·86	2,484	1,191	48
11	17th ,, ..	91·30	2·12	2,843	1,341	47
12	18th ,, ..	88·50	0·67	910	661	72
13	4th ,, ..	88·40	1·84	2,457	987	40
14	7th ,, ..	90·10	1·36	1,823	1,096	60
15	6th ,, ..	88·80	1·77	2,366	1,034	44
17	15th ,, ..	89·20	1·18	1,584	1,076	68
18	20th June ..	89·70	2·75	3,676	1,163	32
20	25th July ..	91·88	2·46	3,290	1,351	41
23	21st August ..	86·80	0·97	1,303	898	69
25	14th July ..	91·20	1·87	2,504	1,291	51
26	16th August ..	91·70	2·92	3,907	1,348	34

Table 195.—Rainfall in the Mahanadi catchment and discharge at Naraj. Period of 4 days.

Year.	Date of flood.	Maximum reading of Gauge at Naraj (above weir).	Average rainfall in inches per day.	Average rainfall in kilocusecs	Average discharge at Naraj in kilocusecs.	Per-centage discharge.
1872	30th June ..	89·90	1·66	2,228	1,391	62
74	30th August ..	90·00	1·27	1,707	1,112	65
76	22nd July ..	88·60	1·01	1,352	893	66
77	16th August ..	88·10	0·97	1,300	953	73
79	14th ,, ..	90·90	1·81	2,423	1,281	53
80	3rd July ..	89·10	1·69	2,258	1,099	48
81	26th ,, ..	..	1·07	1,404	..	..
85	26th June ..	90·50	1·81	2,417	1,194	49
91	30th July ..	87·90	1·93	2,587	..	..
92	26th ,, ..	91·74	1·84	2,462	1,308	53
94	28th ,, ..	89·40	1·31	1,753	1,034	59
95	1st ,, ..	90·40	1·84	2,458	1,102	44
96 (1)	25th ,, ..	92·10	1·79	2,397	1,354	57
96 (2)	17th August ..	89·30	0·96	1,290	1,012	78
1900	21st September ..	88·75	1·32	1,764	1,000	57
04	4th July ..	87·80	1·07	1,431	842	58
07	10th September	89·70	1·21	1,624	1,097	67
08	16th August ..	88·30	1·08	1,441	922	64
10	7th ,, ..	90·10	1·37	1,841	1,169	63
11	17th ,, ..	91·30	1·59	2,128	1,347	63
12	18th ,, ..	88·50	0·68	905	583	64
13	4th ,, ..	88·40	1·67	2,233	922	41
14	7th ,, ..	90·10	1·42	1,898	1,030	54
15	6th ,, ..	88·80	1·32	1,767	944	53
17	15th ,, ..	89·20	1·22	1,635	1,004	61
18	20th June ..	89·70	2·70	3,622	1,154	32
20	25th July ..	91·88	2·18	2,917	1,268	44
23	21st August ..	87·80	1·02	1,361	845	62
25	14th July ..	91·20	1·59	2,133	1,208	59
26	19th August ..	91·70	2·76	3,691	1,289	35

Table 196.—Rainfall in the Mahanadi catchment and discharge at Naraj. Period of 5 days.

Year.	Date of flood.	Maximum reading of Gauge at Naraj (above weir).	Average rainfall in inches per day.	Average rainfall in kilocusecs.	Average discharge at Naraj in kilocusecs.	Per-centage discharge.
1872	30th June ..	89·90	1·36	1,824	1,354	74
74	30th August ..	90·00	0·96	1,289	1,040	81
76	22nd July ..	88·60	0·93	1,246	789	63
77	16th August ..	88·10	0·89	1,190	910	76
79	14th ,, ..	90·90	1·47	1,973	1,211	61
80	3rd July ..	89·10	1·71	2,290	1,055	46
81	26th ,, ..	..	0·88	1,175	..	..
85	26th June ..	90·50	1·87	2,499	1,115	44
91	30th July ..	87·90	1·59	2,127	..	..
92	26th ,, ..	91·74	1·48	1,984	1,242	62
94	28th ,, ..	89·40	1·11	1,489	988	66
95	1st ,, ..	90·40	1·58	2,112	1,024	48

Table 196—*concld.*

Year.	Date of flood.	Maximum reading of Gauge at Naraj (above weir).	Average rainfall in inches per day.	Average rainfall in kilocusecs.	Average discharge at Naraj in kilocusecs.	Percentage discharge.
1896 (*i*)	25th July ..	92·10	1·47	1,963	1,367	70
96 (*ii*)	17th August ..	89·30	0·91	1,223	974	79
1900	21st September ..	88·75	1·10	1,468	968	66
07	10th ,, ..	89·70	0·87	1,160	1,055	91
08	16th August ..	88·30	0·94	1,256	895	71
10	7th ,, ..	90·10	1·37	1,839	1,143	62
11	17th ,, ..	91·30	1·41	1,888	1,310	70
12	18th ,, ..	88·50	0·65	870	535	61
13	4th ,, ..	88·40	1·37	1,838	859	47
14	7th ,, ..	90·10	1·27	1,695	965	57
15	6th ,, ..	88·80	1·01	1,349	891	66
17	15th ,, ..	89·20	0·93	1,246	961	77
18	20th June ..	89·70	2·36	3,160	1,124	36
19	4th August ..	89·10	0·90	1,208	831	69
20 (*i*)	25th July ..	91·88	2·11	2,823	1,199	42
20 (*ii*)	3rd August ..	89·70	0·94	1,270	882	69
25	14th July ..	91·20	1·41	1,884	1,194	63
26	19th August ..	91·70	2·02	2,700	1,239	46

Table 197.—Rainfall in Mahanadi catchment and discharge at Naraj. Period of 6 days.

Year.	Date of flood.	Maximum reading of Gauge at Naraj (above weir).	Average rainfall in inches per day.	Average rainfall in kilocusecs.	Average discharge at Naraj in kilocusecs.	Percentage discharge.
1872	30th June ..	89·90	1·01	1,355	1,298	95
74	30th August ..	90·00	0·84	1,126	928	82
76	22nd July ..	88·60	0·96	1,284	685	53
77	16th August ..	88·10	0·72	975	831	85
79	14th ,, ..	90·90	1·28	1,714	1,159	68
80	3rd July ..	89·10	1·53	2,052	977	48
85	26th June ..	90·50	1·64	2,192	1,045	48
92	26th July ..	91·70	1·21	1,620	1,127	70
94	28th ,, ..	89·40	0·94	1,254	912	73
95	1st ,, ..	90·40	1·31	1,750	964	55
96 (*i*)	25th ,, ..	92·10	1·23	1,646	1,038	63
96 (*ii*)	17th August ..	89·30	0·96	1,288	933	72
1900	21st September..	88·75	0·95	1,266	867	68
07	10th ,, ..	89·70	0·83	1,117	936	84
08	16th August ..	88·30	0·85	1,141	878	77
10	7th ,, ..	90·10	1·04	1,393	996	71
11	17th ,, ..	91·30	1·30	1,745	1,283	73
12	18th ,, ..	88·50	0·56	748	498	67
13	4th ,, ..	88·40	1·02	1,368	771	56
14	7th ,, ..	90·10	1·10	1,467	870	59
15	6th ,, ..	88·80	0·86	1,146	807	70
17	15th ,, ..	89·20	0·80	1,073	924	86
18	20th June ..	89·70	1·54	2,057	1,065	52
19	4th August ..	89·10	0·71	949	756	78
20 (*i*)	25th July ..	91·88	1·80	2,416	1,105	45
20 (*ii*)	3rd August ..	89·70	0·85	1,138	814	71
25	14th July ..	91·20	1·22	1,635	1,150	70
26	19th August ..	91·70	1·67	2,235	1,066	48

Table 198.—Rainfall in the Mahanadi catchment and discharge at Naraj Period of 10 days.

Year.	Date of flood.	Maximum reading of Gauge at Naraj (above) weir).	Average rainfall in inches per day.	Average rainfall in kilocusecs.	Average discharge at Naraj in kilocusecs.	Percentage discharge.
1872	20th June ..	89·90	0·91	1,214	1,104	91
74	30th August ..	90·00	0·78	1,051	762	72
76	22nd July ..	88·60	0·71	956	487	51
77	16th August ..	88·10	0·65	864	657	76
79	14th ,, ..	90·90	1·02	1,363	881	65
80	3rd July ..	89·10	1·20	1,612	848	52
85	26th June ..	90·50	1·08	1,440	721	50
92	26th July ..	91·74	0·97	1,287	869	67
94	28th ,, ..	89·40	0·72	960	879	91
95	1st ,, ..	90·40	1·24	1,658	734	44
96 (i)	25th ,, ..	92·10	0·91	1,218	902	75
96 (ii)	17th August ..	89·30	0·86	1,151	836	73
1900	21st September..	88·75	0·59	790	595	75
07	10th ,, ..	89·70	0·60	797	681	85
08	16th August ..	88·30	0·84	1,131	811	71
10	7th ,, ..	90·10	0·75	998	916	91
11	17th ,, ..	91·30	0·94	1,256	992	79
12	18th ,, ..	88·50	0·53	713	534	75
13	4th ,, ..	88·40	0·70	944	607	64
14	7th ,, ..	90·10	0·80	1,070	716	67
15	6th ,, ..	88·80	0·77	1,036	647	62
17	15th ,, ..	89·20	0·78	1,049	791	75
18	20th June ..	89·70	1·40	1,878	781	41
19	4th August ..	89·10	0·65	869	592	68
20	25th July ..	91·88	1·23	1,642	885	54
25	14th ,, ..	91·20	1·07	1,433	908	63
26	19th August ..	91·70	1·32	1,769	912	51

It will be seen from figures that the percentage discharge decreases as the amount of rainfall increases, but for the same rainfall the percentage discharge increases as the period increases. This can be explained in the following way. With increasing rainfall (after, of course, a more or less steady state of seepage has been attained in the monsoon season) there is an increasing lag in the discharge, indicating some kind of retardation in the drainage owing to possible congestion in local drainage channels. On this view the percentage run-off should increase as the time of observation is increased which, of course, is corroborated by experience*.

An attempt has been made to predict the average percentage discharge at Naraj for each period from the average rainfall in the catchment area. This prediction will be applicable only when the Mahanadi is already fairly high, that is, above 80 feet at Naraj at the time when heavy-rain-sets-in the catchment area: that is to say, when the ground in the catchment area is so wet and the atmosphere so moist throughout the area that the loss of rainwater due to seepage and evaporation, etc., is practically constant. All these can be fairly well represented by formulæ of the logarithmic type given below:

$$y = 74 \cdot (x)^{-0.72} \quad \ldots \quad \ldots \quad \text{(3 days)}$$
$$y = 73 \cdot 2(x)^{-0.76} \quad \ldots \quad \ldots \quad \text{(4 days)}$$
$$y = 73 \cdot 6(x)^{-0.77} \quad \ldots \quad \ldots \quad \text{(5 days)}$$
$$y = 70 \cdot 0(x)^{-0.80} \quad \ldots \quad \ldots \quad \text{(6 days)}$$
$$\text{and } y = 61 \cdot 0(x)^{-0.86} \quad \ldots \quad \ldots \quad \text{(10 days)}$$

*Mr. Shaw in his type written note dated 20-12-38 remarks "A point of interest in these run-off tables is that the percentage run-off has not increased from 1872—1926, so there is no indication of increasing run-off due to deforestation, extension of cultivation, etc., which is feared, and justly so in other river catchments."

The curves evidently belong to a family of curves of the form:— $y=(a).(x)^{-(b)}$. It will be noticed that (a) decreases and the numerical value of (b) increases as the period is increased.

In these formulæ "y" represents percentage discharge at Naraj and "x" represents average rainfall in inches per day in the Mahanadi catchment area. The data for the period of 10 days, have been shown in a graphical form in Chart no. 7; the graduated logarithmic curve is also shown in the same chart.

Prediction formulæ for 3, 4, 5, 6 and 10 days were reduced, and 5 tables, given in columns (2)—(6) of Table 199, were prepared, one for each period, showing the average predicted discharge at Naraj in cusecs for successive values of average rainfall per day in the catchment area for the corresponding period. By referring to these tables it is possible to predict the average maximum discharge at Naraj for any of the periods if the average rainfall in the catchment area for the past few days is available.

Predicted values of the discharge for the period of three days have been compared with the actual discharge for each flood since 1874 in Table 200. It will be seen that the average percentage deviation is only 6·8 per cent. With the exception of the years 1892, 1896, 1913, 1915 and 1918 the average deviation is only 4·5 per cent. So that the prediction formula for three days is not quite unsatisfactory.

Table 199.—Graduated discharge at Naraj for periods of 3, 4, 5, 6 and 10 days for different intensities of rainfall (average per day) in the Mahanadi catchment.

Average rainfall in inches per day.	Average discharge in kilocusecs.				
	3 days.	4 days.	5 days.	6 days.	10 days.
0.5-0·6					760
-0·7	896	903	900	873	776
-0·8	931	932	928	895	791
-0·9	962	959	953	917	804
-1·0	989	983	976	937	815
-1·1	1,016	1,004	999	954	826
-1·2	1,042	1,027	1,019	972	837
-1·3	1,066	1,048	1,037	987	846
-1·4	1,087	1,067	1,055	1,001	855
-1·5	1,109	1,085	1,073	1,016	864
-1·6	1,129	1,101	1,088	1,028	872
-1·7	1,147	1,118	1,104	1,043	892
-1·8	1,166	1,133	1,118	1,053	885
-1·9	1,182	1,147	1,132	1,063	893
-2·0	1,200	1,162	1,146	1,077	900
-2·1	1,217	1,175	1,158	1,085	905
-2·2	1,230	1,187	1,169	1,096	910
-2·3	1,247	1,201	1,183	1,106	918
-2·4	1,263	1,215	1,192	1,189	922
-2·5	1,276	1,225	1,205	1,125	927
-2·6	1,291	1,236	1,215	1,159	933
-2·7	1,304	1,247	1,226	1,142	936
-2·8	1,318	1,260	1,237	1,151	941
-2·9	1,330	1,270	1,246	1,157	947
-3·0	1,345	1,277	1,257	1,165	952
-3·1	1,356	1,291	1,266	1,175	955
-3·2	1,366	1,298	1,277	1,183	960
-3·3	1,378	1,308	1,286	1,189	963
-3·4	1,393	1,320	1,293	1,193	965
-3·5	1,401	1,326	1,303	1,200	970

Table 200.—Comparison of observed and predicted discharge at Naraj from average rain fall for 3 consecutive days in the Mahanadi catchment.

Year.	Discharge at Naraj in Cusecs.		Percentage difference.
	Predicted.	Actual.	
1874 ..	1,072,233	1,179,665	9·1
1876 ..	1,000,197	984,280	1·8
1877 ..	975,561	992,845	1·7
1879 ..	1,241,744	1,294,545	4·1
1880 ..	1,160,604	1,130,868	2·6
1885 ..	1,177,474	1,232,241	4·4
1892 ..	1,206,664	1,382,603	12·7
1894 ..	1,130,611	1,100,590	2·7
1895 ..	1,153,105	1,160,265	0·6
1896 ..	1,201,442	1,475,405	17·6
1896 ..	1,053,755	1,068,293	1·3
1900 ..	1,120,703	1,040,713	7·8
1904 ..	1,008,231	883,829	14·1
1907 ..	1,091,514	1,147,533	4·8
1908 ..	1,046,525	955,855	9·3
1910 ..	1,175,868	1,190,772	1·2
1911 ..	1,219,786	1,341,420	9·1
1913 ..	1,172,654	980,716	18·8
1914 ..	1,078,660	1,095,649	1·6
1915 ..	1,160,604	1,033,979	12·3
1917 ..	1,036,617	1,076,202	3·6
1918 ..	1,311,504	1,163,000	12·7
1920 ..	1,270,666	1,351,766	6·0
1923 ..	981,131	898,051	9·2
1925 ..	1,177,474	1,290,807	8·3
1926 ..	1,333,884	1,347,638	1·2
			Average deviation = 6·9.

Rainfall in the Delta.

Harris had stated in 1858 that the Mahanadi system can carry about 900,000 cusecs in the delta. Accepting this figure, the discharge at Naraj in excess of 900,000 cusecs would give the excess or flood volume. It would be interesting to compare this excess with the actual rainfall in the delta itself.

A period of 6 consecutive days was selected for this purpose. The average excess discharge in cusecs (i.e. actual average discharge in 6 days minus 900,000 cusecs) is given in column (2) of Table (201). The rate of precipitation in the delta (average of 6 consecutive days) is given in column (3). In column (4), the rainfall in the delta is expressed as a percentage of the total flood volume obtained by adding column (2) and column (3). Column (4), therefore, represents the maximum contribution to the flood volume.

The average maximum contribution is about 35 per cent and is quite high. We conclude that although local rainfall by itself cannot cause a flood of importance in the Mahanadi delta, it is of sufficient importance in prolonging the duration of floods.

Table 201.—Comparison of rainfall in the Delta and excess rainfall in the catchment.
(Based on six consecutive days' readings.)

Year.	Excess flood water at Naraj in cusecs.*	Rain water in the delta in cusecs.	Quantity supplied by the delta expressed as percentage of the total.
1872 ..	454,700	280,240	38·1
1874 ..	141,559	61,380	30·1
1876 ..	42,139	32,240	43·3
1877 ..	47,589	27,280	36·4
1879 ..	259,876	91,760	26·1
1880 ..	132,826	51,460	27·9
1885 ..	179,210	15,190	7·8
1892 ..	284,606	46,810	14·1
1894 ..	100,295	57,350	36·4
1895 ..	134,989	167,400	55·4
1896(1) ..	403,991	66,960	14·2
1900 ..	87,023	74,710	46·2
1907 ..	131,366	35,650	21·3
1908 ..	40,970	67,270	62·1
1910 ..	208,458	87,110	29·4
1911 ..	383,165	23,250	5·7
1912 ..	29,756	48,670	62·1
1913 ..	49,107	89,280	64·5
1914 ..	97,823	46,560	32·2
1915 ..	66,989	91,450	57·7
1917 ..	88,101	58,280	39·8
1918 ..	186,971	44,640	19·3
1919 ..	55,948	72,540	56·5
1920(1) ..	248,999	106,330	29·9
1925 ..	250,729	84,010	25·1
1926 ..	299,397	102,610	25·5
Average ..	..	....	34·9

*Excess over 900,000 cusecs.

It should be noted here that a big proportion of the rain-water in the delta* must pass away before the floods arrive from above.

* The same six consecutive days have been used in calculating "excess flood water at Naraj" and "rain water in the delta". The rainfall stations used for this purpose were Cuttack, Hukitolah, Kendrapara, Khurdah, Jagatsingpur, Kanas, Kakatpur, Bhubaneswar, and Pipli.

CHAPTER 28—CORRELATION BETWEEN RAINFALL AND DISCHARGE.

So far as floods are concerned the purpose of correlational studies is two-fold :—

(1) To investigate the connexion between the height of the river at different points, and hence, where possible, to construct suitable prediction formulae for forecasting river heights at lower stations based on data for upper reaches.

(2) To investigate the connexion between rainfall in the catchment and the discharge of the river, and hence to construct prediction formulae for forecasting the height and time of maximum floods in the river.

Owing to the immense labour of computation, it is not possible to attempt directly an exhaustive correlational analysis, for even with the available data there is no end to the number of correlations which may conceivably subsist between the different factors. For example, let us consider the height of the Mahanadi at Naraj on a particular date say the 15th of August, 1927. Consider available data. We have daily records of the height of the river at Sambalpur. It is not impossible that the height at Sambalpur in previous years or during the winter and summer seasons is an appreciable factor. It is not, however, very probable, and we neglect these factors and begin, say, from the 1st of June of the current year. Previous to 15th August we then have 75 daily readings at Sambalpur (let us call these $x_1, x_2, x_3 \ldots\ldots x_{75}$) each of which is likely to show some correlation with the height at Naraj on the 15th August (let us call this Y). For a complete discussion of the correlational problem (limiting ourselves, however, to linear regressions), we require 75 direct correlations of each of $x_1, x_2, x_3 \ldots\ldots \ldots\ldots x_{75}$ with Y, and further $(75 \times 76)/2 = 2{,}850$ inter-correlations between the 75 different x's. We shall then have a system of linear equations involving 2,925 parameters, solving which we can write down the complete relationship.

Besides the gauge at Sambalpur, we also have the daily rainfall records at more than 50 stations in the catchment area and other daily records (such as atmospheric pressure, wind velocity, temperature and humidity) at a smaller number of stations. But I think it is scarcely necessary to elaborate the subject any further. It is clear that we must make exploratory surveys and proceed cautiously along the most promising tracks. In this part I shall give a brief resume of the work carried out so far.

I may say a few words here regarding the interpretation of correlational analysis. Let us consider the rainfall in the Mahanadi catchment and the level of the river at Naraj. We know that the level depends ultimately on the rainfall, but we also know that it is not possible to establish an exact, algebraic connexion between, say, the number of inches of rainfall on a particular day or a particular period and the level on a succeeding day or period. This for many reasons. Our estimate of the rainfall is only approximate, as it is based on a small number of stations scattered in a rather irregular manner over the catchment. Further, as I have already pointed out, there are a large number of other factors such as the previous rainfall, temperature, humidity, condition of the soil, state of the drainage channels in the delta, tidal action, etc We are, therefore, obliged to seek a statistical connexion, which will allow us to make average predictions. Correlational studies enable us to formulate such statistical connexions, and also give some idea regarding the reliability and the closeness of the connexion.

We usually assume in the first instance, for convenience of calculations, a linear relation between the variates ; this, of course, is justified in any case as a first approximation. For such linear relations the most convenient statistic is the coefficient of correlation, and this has been used throughout the present study. The coefficient of correlation is defined in such a way that its numerical magnitude can never exceed unity. It, therefore, varies between -1 and $+1$, the plus or the minus sign being merely conventional marks to indicate whether both the variates increase or decrease together (plus), or one

increases as the other decreases (minus). Thus the numerical magnitude of the coefficient (irrespective of the sign) measures the degree of association between the variates. The higher the numerical value the closer is the connexion. A value of −1 or +1 indicates that one variate is an exact algebraic linear function of the other ; such values, of course, can never occur in practice. The value zero on the other hand indicates that the variates are independent, and nothing can be known about one variate from even a complete knowledge of the other. I ought to mention here that the scale of "r", the coefficient of correlation, is very congested at the upper end. Even a little increase in the value near about 0·6 or 0·9 indicates a great increase in the closeness of connexion and hence in the accuracy of prediction. Thus the difference in significance (or usefulness for purposes of forecasting) between 0·85 and 0·80 is far greater than the difference between say 0·65 and 0·60, while for purposes of prediction the difference between 0·45 and 0·40 is very small*.

The Pearsonian product-moment formula has been used in calculating the coefficients of correlation. With samples of size less than 40, the product moments were usually computed by direct multiplication, while with larger samples the data were first grouped, but the grouping unit was kept small so as to yield at least 10 or 12 groups for each variate.

As a first example I shall consider the rainfall in the nearest section of the catchment (M—I) and the level of the river at Naraj on the same day. The rainfall readings refer to the 24 hours ending at 8-0 A.M. on a particular day ; we may therefore centre the rainfall data at 8-0 P.M. of the previous evening. The Naraj gauge readings (average of 6-0 A.M., 12-0 noon and 6-0 P.M.) may be centered at 12-0 noon, so that there is an interval (or lag) of 16 hours between the rainfall and gauge readings on the same day.

With such a small size of sample as n = 31, coefficients lower than 0·35 are not significant. It will be noticed from Table 202 that most of the coefficients are negligible. The fact that both plus and minus correlations are occurring shows that there is practically no connexion between the rainfall in section I and the level of the Mahanadi 16 hours later. This merely indicates, of course, that 16 hours is too small an interval for the water to become effective at Naraj.

Table 202.—Correlation between rainfall in Mahanadi catchment section I and River-level at Naraj on the same day in August.

Year.	n.	r.	Year.	n.	r.
1892	31	+·1192	1911	31	+·1104
93	31	—·2164	12	31	+·0939
94	No gauge reading		13	30	—·1171
95	31	—·1526	14	31	—·1104
96	31	+·000045	15	30	—·0734
97	31	—·0175	16	31	+·0265
98	31	—·1620	17	30	+·1211
99	31	—·1833	18	31	—·2719
1900	31	+·0045	19	31	—·2123
01	31	—·4509	20	31	—·2807
02	31	—·1040	21	30	+·1019
03	..	—·1679	22	31	—·2035
04	31	—·4636	23	31	—·2398
05	31	—·3147	24	31	—·3653
06	31	—·1190	25	31	+·0079
07	31	+·1040	26	31	—·0068
08	..	—·4929	27	31	+·4951
09	31	+·2427	28	31	—·1425
10	30	—·2018			

A better method of judging the value of "r" is to use Fisher's z-transformation which is given by— $z = \frac{1}{2}[\log(1+r) - \log(1-r)]$.

Thus r ...	0·20	0·40	0·60	0·70	0·80	0·85	0·90	0·95	0·96	0·93
z ...	0·21	0·43	0·70	0·87	1·10	1·36	1·48	1·84	1·95	2·30

Seasonal Correlation.

The following table shows the correlations between the total (or average) rainfall during the period of July 1 to September 30 in the different sections of the Mahanadi catchment and the average height of the river at Naraj in the same year. The sectional values (with the exception of Section I) are of the order of 0·50, and indicate a moderate degree of connexion between the rainfall in each individual section and the river level. It is not surprising that the correlations are not higher, since the level at Naraj is determined by the joint effect of the rainfall in the different sections. I may note here that the low value for Section I may probably be partly explained by the small number of rainfall stations in this section, which probably rendered the estimate of the rainfall a little uncertain.

In order to investigate this point further, I combined Sections I and II (the area below Sambalpur) and Sections III. IV and V (the area above Sambalpur). The coefficients are now + 0·41 ± ·092 and + 0·59 ± ·071. The low value of the former is evidently due to Section I (which has an individual correlation of only + 0·26), while the value + 0·59 shows that the joint effect of Sections III, IV and V is fairly high.

Table 203.—Seasonal Correlation between Rainfall and River-level at Naraj.

Section of the Catchment.	Number of years.	Coefficient of correlation.
M—I	38	+ 0·265 ± 0·13.
M—II	38	+ 0·506 ± 0·08.
M—III	38	+ 0·463 ± 0·09.
M—IV	38	+ 0·458 ± 0·09.
M—V	38	+ 0·474 ± 0·09.
M-I and M-II ...	38	+ 0·408 ± 0·09.
M-III, M-IV, M-V ...	38	+ 0·590 ± 0·07.
Whole Catchment ...	38	+ 0·720 ± 0·053

Finally for the whole catchment we have a much higher correlation of + 0·72 ± ·05 for 38 years. Using this value, I have constructed the seasonal prediction formula given below :

$$N = 20{\cdot}26\,(X) \pm 70{\cdot}12.$$

when N = Average Level at Naraj (in feet).

and X = Average rainfall in the whole catchment in any particular year (in inches).

With the help of this formula it is possible to reconstruct the average level of the Mahanadi at Naraj for each year from the known value of the average rainfall. Such reconstructed values have been given in Table 204, together with observed levels of the rivers for comparison. It will be noticed that the agreement is quite satisfactory.

Although a correlation coefficient of magnitude + 0·72 ± ·05 is not high enough to yield useful results for individual years, it is sufficiently high to give a reliable control for averages taken over a number of years. If the bed of the river at Naraj changes suddenly in future, this would be revealed by significant discrepancies between observed and predicted values (calculated by the above formula) which would persist from year to year. The seasonal correlation can, therefore, function as a reliable test for sudden changes in river conditions.

Table 204.—Calculated and observed values of the Mean level of the Mahanadi at Naraj.

Year.	Rainfall.	Calculated.	Observed.	Obs.—Cal.
1891 ..	0·51	80·45	80·29	—0·16
92 ..	·45	79·24	79·45	+0·21
93 ..	·46	80·44	80·13	—0·31
94 ..	·47	79·64	81·27	+1·63
95 ..	·37	77·62	79·39	+1·77
96 ..	·49	80·05	81·14	+1·09
97 ..	·42	78·63	77·24	—1·39
98 ..	·40	78·22	77·58	—0·64
99 ..	·29	75·99	74·34	—1·65
1900 ..	·54	81·06	79·28	—1·78
01 ..	·39	78·02	77·71	—0·31
02 ..	·37	77·62	76·01	—1·61
03 ..	·42	78·63	76·81	—1·82
04 ..	·34	77·01	78·73	+1·72
05 ..	·45	79·24	76·95	—2·29
06 ..	·40	78·22	77·52	—0·70
07 ..	·37	77·62	79·10	+1·48
08 ..	·45	79·24	81·14	+1·90
09 ..	·36	77·41	78·25	+0·84
1910 ..	·43	78·83	78·90	+0·07
11 ..	·38	77·82	79·16	+1·34
12 ..	·41	78·43	78·00	—0·43
13 ..	·34	77·01	77·27	+0·26
14 ..	·45	79·24	79·64	+0·40
15 ..	·43	78·83	77·63	—1·20
16 ..	·35	77·21	76·80	—0·41
17 ..	·42	78·63	79·28	+0·65
18 ..	·33	76·80	78·52	+1·72
19 ..	·45	79·24	81·53	+2·29
20 ..	·43	78·83	78·63	—0·20
21 ..	·37	77·62	78·57	+0·95
22 ..	·47	79·64	78·44	—1·20
23 ..	·41	78·43	77·14	—1·29
24 ..	·35	77·21	75·75	—1·46
25 ..	·57	81·67	82·87	+1·20
26 ..	·51	80·45	79·92	—0·53
27 ..	·45	79·24	78·44	—0·80
1928 ..	·37	77·62	76·69	—0·93

Rainfall and Excess Discharge.

We may now consider the relation between the rainfall and discharge at Naraj for short periods. It will be remembered that floods are caused by continued rainfall for at least 3 or more consecutive days. We must, therefore, concentrate our attention on periods of the order of 3, 4, 5 or 6 days. One way of doing this is to mark off sustained periods of rainfall of over say 1" (one inch) per day in the catchment as a whole. Carefully examining the gauge-readings, we next try to locate the date on which the level begins to rise. Usually the river rises quite sharply at first and continues to do so for about 3 or 4 days ; sometimes it begins to fall almost immediately ; sometimes it continues to rise at a slow rate for 2 or 3 days more, remains steady for a day or two and then begins to fall fairly rapidly ; in very prolonged floods the level may remain high for a large number of days.

In most cases a kind of a hump in the gauge-height curve can be distinguished. At the end of this hump the river falls down approximately to the level from which the rise had started. The period covered by the hump (that is, the number of days beginning from the date of the first sharp rise to the day previous to that on which the normal level is reached) may be called the period of excess discharge due to the preceding period of heavy

rainfall. The amount of the excess discharge was then calculated in the following way. The average discharge for 3 consecutive days previous to the date from which the rise started was determined; this was taken to be the normal (or basic) rate of discharge at that time. Multiplying this normal (or basic) rate by the number of days of excess discharge we would get the total discharge which would have occurred had there been no rise of the height of the river; this may be called the total basic discharge. We can also calculate directly the actual total discharge during the period covered by the hump. Subtracting the total basic discharge from the actual total discharge, we get the excess discharge. The total precipitation during the preceding period of heavy rainfall was also calculated in each case. The data collected in this way are given in Tables (205) and (206).

Table 205.—Total rainfall in the Mahanadi catchment and the corresponding total excess discharge at Naraj.

Serial no.	Date of beginning of rainfall period.	Total rainfall in inches.	No. of days of heavy rainfall.	Date of beginning of sharp rise in gauge-height.	Total excess of gauge height in feet over 70 feet.	Period of rise of gauge.	Initial gauge height (over 70).
1	1891—July 26	5·82	2	1891—July 27	78·2	5	5·4
2	92— „ 10	6·04	4	92— „ 12	71·3	6	3·6
3	92— „ 20	7·08	5	92— „ 22	125·0	7	10·8
4	93— „ 17	3·31	3	93— „ 19	66·7	4	8·0
5	93— „ 23	5·02	4	93— „ 26	89·2	5	14·4
6	96— „ 22	5·25	3	96— „ 23	109·0	6	7·3
7	1905— „ 11	3·76	3	1905— „ 14	40·7	4	5·9
8	06— „ 20	4·74	4	06— „ 23	48·0	4	6·0
9	09— „ 23	3·47	4	09— „ 25	59·3	4	9·4
10	1910— „ 3	5·16	3	1910— „ 4	73·6	5	6·8
11	13— „ 22	4·49	5	13— „ 23	61·9	7	6·4
12	14— „ 8	4·41	5	14— „ 11	48·9	5	6·5
13	14— „ 27	3·19	4	14— „ 28	52·5	4	10·5
14	15— „ 24	6·55	6	15— „ 27	44·7	5	1·6
15	18— „ 26	5·23	4	18— „ 29	53·0	6	2·2
16	18— „ 1	2·55	2	19— „ 3	60·9	6	6·8
17	19— „ 12	3·37	3	19— „ 15	50·7	4	10·4
18	1920— „ 20	10·32	6	1920— „ 21	138·5	7	7·5
19	25— „ 4	11·34	10	25— „ 7	177·8	10	9·0
20	27— „ 22	5·34	4	27— „ 23	97·3	8	5·8
21	28— „ 25	4·78	3	28— „ 26	83·1	5	10·5
22	1896— „ 27	3·11	2	1896— „ 29	63·6	2	19·5
23	1893— „ 30	5·37	5	93—August 2	75·1	5	6·0
24	95—August 6	3·80	3	95— „ 9	68·2	4	12·0
25	96— „ 1	3·61	3	96— „ 3	101·7	5	18·5
26	97— „ 10	4·46	5	97— „ 13	103·6	7	11·2
27	1900— „ 27	2·63	2	1900— „ 29	37·9	3	6·9
28	01— „ 22	3·51	4	01— „ 25	61·0	4	7·2

Table 205—*concld.*

Serial no.	Date of beginning of rainfall period.	Total rainfall in inches.	No. of days of heavy rainfall.	Date of beginning of sharp rise in gauge-height.	Total excess of gauge height in feet over 70 feet.	Period of rise of gauge.	Initial gauge height (over 70.)
29	1902—August 24	2·81	2	1902—August 26	46·8	4	4·5
30	03—July 31	4·00	4	03— ,, 3	48·5	4	6·3
31	06—August 26	3·92	4	06— ,, 30	46·3	4	6·1
32	07— ,, 11	5·57	5	07— ,, 14	83·5	5	9·1
33	08— ,, 7	7·19	9	08— ,, 9	146·5	9	11·5
34	10— ,, 2	6·64	7	10— ,, 4	130·6	7	8·0
35	1911— ,, 4	3·71	3	1911— ,, 7	63·5	5	4·5
36	11— ,, 13	4·83	3	11— ,, 15	154·8	7	11·5
37	12— ,, 1	4·24	4	12— ,, 4	55·7	4	10·7
38	13—July 30	6·03	4	13— ,, 2	83·8	5	10·5
39	14—August 2	4·03	4	14— ,, 5	88·1	5	11·9
40	15— ,, 2	4·69	3	15— ,, 4	69·5	4	11·9
41	15— ,, 28	3·49	2	15— ,, 31	43·9	3	6·5
42	16— ,, 14	3·34	3	16— ,, 16	54·1	4	7·9
43	17— ,, 6	2·70	2	17— ,, 8	41·0	3	9·0
44	17— ,, 12	2·74	2	17— ,, 14	71·8	4	15·2
45	19—July 31	4·44	3	19— ,, 3	53·6	3	12·2
46	19—August 7	2·46	2	19— ,, 9	42·3	3	11·6
47	1920—July 30	4·19	3	1920— ,, 1	68·9	4	12·7
48	21—August 7	2·95	3	21— ,, 9	59·1	4	9·4
49	24— ,, 5	4·25	2	24 ,, 7	57·1	4	6·3
50	26— ,, 7	5·80	5	26— ,, 10	65·4	5	6·1
51	26— ,, 15	7·33	4	26— ,, 17	133·9	7	10·8
52	27— ,, 11	2·81	2	27— ,, 13	54·2	4	8·0
53	27— ,, 24	2·47	2	27— ,, 25	47·0	3	12·6
54	1891 September 11	4·25	3	1891 September 13	78·1	5	9·3
55	97— ,, 8	1·89	2	97— ,, 10	43·0	3	9·2
56	1900— ,, 16	9·35	10	1900— ,, 10	183·8	11	6·7
57	01— ,, 2	2·66	2	01— ,, 4	47·4	3	10·5
58	05— ,, 3	1·74	2	05— ,, 5	21·0	2	7·6
59	05— ,, 7	7·17	9	05— ,, 10	91·9	8	10·0
60	07— ,, 5	4·30	4	07— ,, 7	86·0	5	9·2
61	12— ,, 3	3·14	5	12— ,, 5	67·4	5	8·9
62	15— ,, 11	3·34	3	15— ,, 14	50·6	4	7·4
63	18— ,, 1	1·86	2	18— ,, 2	61·0	4	9·2
64	21— ,, 4	4·70	3	21— ,, 5	63·2	4	8·0
65	22— ,, 4	1·93	2	22— ,, 6	30·7	2	7·7
66	25—August 30	7·07	10	25— ,, 1	182·8	11	12·5
67	26—September 17	5·35	5	26— ,, 18	128·1	8	7·4
68	27— ,, 2	3·50	4	27— ,, 3	92·9	5	15·3

Table 206.—Total precipitation and total excess discharge at Naraj.

Serial no.	Total rainfall in inches.	Total excess discharge in kilocusecs.	Serial no.	Total rainfall in inches.	Total excess discharge in kilocusecs.
1	5·82	3087	35	3·71	1860
2	6·04	1928	36	4·83	7948
3	7·08	4830	37	4·24	927
4	3·31	2503	38	6·03	2733
5	5·02	1819	39	4·03	2881
6	5·25	4908	40	4·69	2163
7	3·76	850	41	3·49	1416
8	4·74	978	42	3·34	1246
9	3·47	1516	43	2·70	829
10	5·16	2336	44	2·74	952
11	4·49	702	45	4·44	1683
12	4·41	693	46	2·46	679
13	3·19	726	47	4·19	1801
14	6·55	1201	48	2·95	1478
15	5·23	1373	49	4·25	1826
16	2·55	816	50	5·80	1764
17	3·37	572	51	7·33	5697
18	10·32	6859	52	2·51	1264
19	11·34	4129	53	2·47	888
20	5·34	2188	54	4·25	2272
21	4·78	2622	55	1·87	993
22	3·11	876	56	9·35	7496
23	5·37	2653	57	2·66	1313
24	3·80	1998	58	1·74	214
25	3·61	925	59	7·17	362
26	4·46	2218	60	4·30	3169
27	2·63	807	61	3·14	1357
28	3·51	1985	62	3·34	989
29	2·81	1123	63	1·86	1053
30	4·00	969	64	4·70	2111
31	3·92	862	65	1·93	978
32	5·57	2908	66	7·07	4438
33	7·19	4079	67	5·35	4595
34	6·64	6046	68	3·59	1771

The coefficient of correlation between the total rainfall and the total excess discharge was then worked separately for July, August and September, and also for the monsoon period as a whole and are given below.

Table 207.—Coefficient of Correlation between Total Rainfall and Total Excess Discharge of the Mahanadi at Naraj.

	Number.	Correlation Coefficient.	Mean of total Rainfall.	Mean of total Discharge.	Standard Deviation.	
					Rainfall.	Discharge.
July	22	0·7341 ± ·064	5″·20	2164 × 10^3 cusecs	2″·16	1650 × 10^3 cusecs
August	31	0·7049 ± ·062	4″·18	2150 × 10^3	1″·35	1666 × 10^3
September	15	0·6241 ± ·097	4″·15	2247 × 10^3	2″·10	1858 × 10^3
July-Sept. ,,	68	0·6995 ± ·042	4″·50	2175 × 10^3	1″·89	1713 × 10^3

The value of the correlation is quite high, being of the order of + 0·70. We may, therefore, construct a fairly reliable equation connecting the rainfall and the excess discharge. The equation for the whole monsoon period is given below :—

$$D = 634(R) + 1731.$$

where D = Total Excess discharge in Kilocusecs.

R = Total Rainfall in inches.

The excess discharge corresponding to a given rainfall can be calculated from the above equation, but unfortunately owing to the very high variability of the discharge for different floods the accuracy of prediction is comparatively small.

Rainfall and Total Discharge.

Instead of working with the Excess Discharge, we may also work with the Total Discharge for different periods.

Table 208.—Average rainfall in inches per day (x) in the Mahanadi catchment and discharge (d) at Naraj (in kilocusecs) for periods immediately preceding floods in the Mahanadi.

3 days.		4 days.		5 days.		6 days.		10 days.	
x.	d.	x.	d.	x.	d.	x.	d.	x.	d.
1·71	1419	1·66	1391	1·36	1354	1·01	1298	91	1104
1·33	1180	1·27	1112	·96	1040	·84	928	78	762
1·04	984	1·01	893	·93	789	·96	685	71	487
·95	993	·97	952	·89	909	·72	831	65	657
2·27	1295	1·81	1281	1·47	1211	1·28	1159	102	881
1·77	1131	1·69	1099	1·71	1054	1·53	977	120	848
..	..	..	..	..	..	..	..	..	..
1·87	1232	1·81	1194	1·87	1115	1·64	1045	108	721
..	..	..	..	..	..	..	..	..	..
2·04	1383	1·84	1308	1·48	1241	1·21	1126	97	369
1·61	1101	1·31	1033	1·11	989	·94	912	72	879
1·73	1160	1·84	1102	1·58	1023	1·31	964	124	734
2·01	1419	1·79	1354	1·47	1367	1·23	1038	91	902
1·25	1068	·96	1012	·91	974	·96	933	86	836
1·56	1041	1·32	1000	1·10	968	·95	867	59	595
1·07	884	1·07	842	·87	1055	·83	937	60	681
1·42	1148	1·21	1097	·94	895	·85	878	84	810
1·22	956	1·08	922	1·37	1143	1·04	996	75	915
1·86	1191	1·57	1169	1·41	1310	1·30	1283	94	992
2·12	1341	1·59	1347	·65	535	·56	498	53	534
·67	661	·68	583	1·37	859	1·02	771	70	606
1·84	987	1·67	922	1·27	965	1·10	870	80	715
1·36	1096	1·42	1036	1·01	890	·86	807	77	647
1·77	1034	1·32	944	·93	961	·80	924	78	790
1·18	1076	1·22	1004	2·36	1124	1·54	1065	140	781
2·75	1163	2·70	1154	·90	831	·71	756	65	592
2·46	1352	2·18	1268	2·11	1199	1·80	1105	123	885
0·97	898	1·02	845	·94	882	·85	814	107	908
1·87	1291	1·59	1268	1·41	1194	1·22	1150	132	912
2·92	1348	2·76	1289	2.02	1239	1·67	1066	..	..

Table 209.—Correlation between rainfall in the Mahanadi catchment and the discharge at Naraj.

Period.	Number of years.	Co-efficient of correlation with probable error.	Average values of—		Standard deviation.	
			Rainfall in inches per day.	Discharge in kilocusecs.	Inches.	Kilocusecs.
10 days ..	27	0·5038±·0968	0·8896±·0296	779·37±18·50	0·2326±·0210	145·1±13·08
6 days ..	28	·6309±·0767	1·0975±·0400	952·06±22·03	0·3135±·0283	172·8±15·57
5 days ..	28	·6313±·0767	1·3000±·0533	1039·86±23·66	0·4181±·0377	185·6±16·73
4 days ..	28	·6913±·0666	1·5057±·0615	1086·25±23·81	0·4825±·0435	186·8±16·84
3 days ..	28	·7350±·0586	1·6650±·0682	1136·86±22·78	0·5349±·0482	178·7±16·10

The average rainfall in inches (determined by Isohyet method) in the Mahanadi catchment per day for periods of 3, 4, 5, 6 and 10 days immediately preceding heavy floods and the corresponding discharge at Naraj are shown in Table 208. We can use this material for calculating directly the co-efficient of correlation between the two variates. The results are given in Table 209.

We correlate these with the actual height (in feet) of the river on the pth day (which we may call N). The actual correlation coefficients are given below (Table 210).

All the correlations are definitely significant. It is interesting to note that the closeness of association between rainfall and discharge decreases as the period is increased. The coefficient for a period of 3 days is + 0·7350±·0586 which is high enough to construct a prediction formula.

The equation is given by—

$$D = 243{\cdot}7334\,X + 731{\cdot}04$$

where D=discharge at Naraj in kilocusecs

and X=average rainfall in inches per day in the Mahanadi catchment for a period of 3 days.

With an average rainfall of 1·665 inches per day the rate of precipitation will be about 2,281 kilocusecs. Of this quantity the discharge at Naraj (average of 3 days) amounts to only about 1136·86 kilocusecs or just about half the precipitation.

The probable error of the forecast by the above formula is about 78·3 kilocusecs which is just under 7 per cent of the average discharge.

A Prediction Formula for the Level of the Mahanadi at Naraj.

Our chief object in making correlational studies is to forecast the height at Naraj as accurately as possible. Suppose we want to forecast one day in advance. To fix our ideas, let us say that we want to predict the height of the river on the pth day. We know that it usually requires at least 3 consecutive days of heavy rainfall to produce a flood, and that it takes about 2·3 days for the rainfall to make itself felt at Naraj. We may, therefore, take the total rainfall in 3 consecutive days ended two days previously that is, on the (p—2)th day. So far, we have neglected to take into consideration the previous state of the river. It is clear, however, that this is a relevent factor. If the river level is already high, the probability of occurrence of a flood is, of course, much higher with the same rainfall than when the river level is low. So we now include the height of the river at Naraj for 3 consecutive days ending on the day of the forecast, that is on the (p—1)th day as a relevant factor. We now have two factors :—

R=total rainfall in inches for a period of 3 consecutive days ended on the (p—2)th day.

G=average height in feet of the river for 3 consecutive days ending on the (p—1)th day.