Institute of Hydrology

Natural Environment Research Council

EJS

RUFFORD PARK
RAINFALL STUDY

FURTHER ANALYSIS

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A Report to
Elliot and Brown,
Consulting Engineers

E J Stewart
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1. OBJECTIVE

A previous study has been carried out to assess the rarity of the 5-hour storm which led to flooding near Rufford Park on 1 June 1983. The return period of the storm was estimated to be 5 years. The rainfall data used in the analysis suggested that the effect of the storm had been exacerbated by the wet spring which preceded it. The objective of this further study was to assess the return period of the combination of the storm and the antecedent precipitation conditions.

2. ANALYSIS

2.1 Introduction

The analysis focused on the calculation of the joint probability of the 5-hour storm and the antecedent catchment rainfall conditions. From probability theory, if Q and R are independent events, their joint probability can be expressed as

$$Pr(Q \cap R) = Pr(Q).Pr(R) \quad .$$

Thus, if the probability of the storm was found to be independent of that of the antecedent precipitation, then the joint probability would be equal to their product. The annual probability of the 5-hour storm was already known. The return period of the storm was estimated to be 5 years, and the reciprocal of this (i.e. 0.2) represented the probability of the event being equalled or exceeded in any one year. Therefore, it was required to find the probability of the antecedent rainfall conditions and to determine whether this was independent of the annual exceedence probability.

2.2 Analysis of antecedent precipitation

A preliminary indication of the antecedent rainfall conditions was given by constructing a time series of daily catchment rainfalls for the first five months of 1983. In addition to this, monthly rainfall totals for the only gauge with long-term data situated within the catchment (123017) were extracted from the database. It was apparent that the catchment rainfall totals for April and May 1983 were considerably higher than the mean totals for the long-term gauge (see Table 1).

Table 1. Comparison of catchment monthly rainfall with long-term mean

	Catchment monthly total 1983 (mm)	Mean at gauge 123017 (mm)
April	121.3	48.1
May	112.3	53.7

A series of annual maximum 1-day rainfalls at gauge number 123017 over the period 1910-1983 was constructed. The 1-day rainfall of 31 May 1983 constituted the annual maximum for that year. The antecedent catchment conditions relating to each of the annual maxima were described in terms of an antecedent precipitation index (API). Various definitions of API were considered, that with a daily recession factor (k) of 0.95 ultimately being adopted. APIs for 100 days were calculated for each annual maximum rainfall in the series and are given in Appendix 1. The API value calculated for 31 May 1983 was 44.58 mm and was ranked 51 out of the 67 values. This value is not particularly high, but represents the fact that the API is very sensitive to rainfall totals occurring immediately prior to the annual maximum. In the case of the 31 May 1983, the only appreciable antecedent rainfall occurred thirty days previously.

2.3 Analysis of independence

An analysis of the correlation between the APIs and their corresponding annual maxima was carried out in order to assess the extent of their dependence. The correlation coefficient was calculated to be only 0.184. A significance test was carried out on this value (see Appendix 2) and there was found to be no significant correlation between API and the annual maximum 1-day rainfall at the 5% level. Hence the two were taken to be independent.

2.4 Calculation of the probability of the antecedent rainfall

The API values in Appendix 1 were ranked and plotted on probability paper using the Blom plotting position. From this plot, the probability that the API was less than or equal to 44.58 mm was determined to be 0.74.

2.5 Calculation of joint probability

Since the storm rainfall and antecedent precipitation had been found to be mutually independent, their joint probability was computed by multiplying their individual probabilities together as set out below:

$Pr(x > X) = 0.2$ (Storm rainfall)

$Pr(y > Y) = 1 - 0.74 = 0.26$ (Antecedent rainfall)

$$Pr(x > X \text{ and } y > Y) = 0.2 \times 0.26$$
$$= 0.052$$

The joint probability of 0.052 corresponds to a return period of 19 years.

3. CONCLUSION

This study of rainfall frequency indicates that the joint occurrence of the 5-hour storm of 31 May 1983 and the antecedent precipitation has a return period of 19 years. This suggests that the event represented something between a 5 year and a 20 year flood. However, more confidence in this estimate would be gained by carrying out a detailed analysis using a rainfall-runoff method.

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Appendix 1

API VALUES FOR GAUGE [illegible] (K = [illegible])

Date			Annual Maximum (mm)	API (mm)
1	12	1910	58.5	64.17
30	9	1912	54.1	36.15
5	10	1913	47.2	40.12
16	7	1915	51.3	55.49
24	[illegible]	1916	53.5	[illegible]
6	[illegible]	1917	55.9	43.33
4	9	1918	24.1	[illegible]
19	3	1919	34.3	[illegible]
19	2	1920	41.7	[illegible]
3	10	1921	49.5	[illegible]
5	[illegible]	1922	[illegible]	38.13
5	5	1923	25.4	25.29
21	10	1924	[illegible]	[illegible]
19	9	1925	37.5	[illegible]
1	11	1926	21.5	[illegible]
14	9	1927	30.5	45.30
10	10	1928	34.8	26.34
11	11	1929	32.5	47.16
20	7	1930	39.6	29.29
3	9	1931	72.1	51.59
21	5	1932	53.4	41.41
10	10	1933	55.8	44.15
9	11	1934	13.5	24.33
15	11	1935	30.2	78.74
7	7	1936	25.4	41.50
15	7	1937	31.0	14.94
11	8	1938	30.0	35.89
17	7	1939	27.4	43.25
16	10	1940	30.5	22.85
9	10	1941	29.5	19.95
4	3	1942	26.2	16.26
29	5	1943	23.4	23.08
27	2	1944	29.2	33.86
19	3	1946	31.2	55.81
10	5	1947	22.9	33.93
30	12	1948	42.7	26.10
15	7	1949	40.1	24.97
15	7	1950	21.8	20.86
6	8	1951	69.6	16.96
5	6	1952	31.5	23.47
12	10	1953	24.1	14.39
7	6	1954	35.3	60.75
25	3	1955	25.4	30.39
8	6	1956	24.1	27.73
8	5	1957	42.4	31.73
1	7	1958	[illegible]	[illegible]
16	4	1959	[illegible]	[illegible]
3	12	1960	42.4	[illegible]
26	4	1961	[illegible]	[illegible]
6	[illegible]	1962	[illegible]	[illegible]
6	7	1963	[illegible]	[illegible]
14	[illegible]	1964	[illegible]	[illegible]
21	6	1965	[illegible]	[illegible]
21	[illegible]	1966	[illegible]	[illegible]
14	[illegible]	1967	[illegible]	[illegible]
14	7	1968	[illegible]	[illegible]
19	6	1971	[illegible]	[illegible]
20	11	1974	[illegible]	[illegible]
1	12	1975	[illegible]	[illegible]
24	[illegible]	1976	[illegible]	[illegible]
1	11	1977	[illegible]	[illegible]
16	6	1978	[illegible]	[illegible]
25	10	1979	[illegible]	[illegible]
7	5	1980	[illegible]	35.53
24	4	1981	29.7	[illegible]
22	6	1982	45.1	[illegible]
31	5	1983	23.1	[illegible]

Appendix 2

Significance test on the correlation between API and annual maximum 1-day rainfall.

t-test

$r = 0.184 \qquad n = 67$

$H_0 : \rho = 0$ (no significant correlation)

$H_1 : \rho \neq 0$

Two-tailed test at 5% significance level

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

$$= \frac{0.184\sqrt{65}}{\sqrt{1-0.184^2}}$$

$$= 1.509$$

υ (degrees of freedom) $= n-2 = 65$

From tables, $t_{\upsilon=65,\alpha=0.05} = 1.998$

Since $-1.998 < 1.509 < 1.998$, H_0 cannot be rejected. Therefore it must be concluded that there is no significant correlation between API and annual maximum 1-day rainfall.

INSTITUTE of HYDROLOGY

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