ANALYSIS OF SOME HEAVY RAINFALLS IN THE RANGITIKEI DISTRICT

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ABSTRACT

Selected 24 hour rainfalls recorded at Koeke (E95761), Marton (E95041), Oxton (E95831), and Otara (E95873), taken from the monthly rainfall charts provided by the New Zealand Meteorological Service, have been analysed by three methods.

Comparisons are made between these methods, and theoretical rainfall intensity - duration - frequency curves are presented. Only the results are given, the main portion of the theory behind the methods being adequately described in the references.

METHOD OF 24 HOUR RAINFALL "EXCEEDANCES".

This method can be recommended for its simplicity rather than its accuracy, and has a tendency to be severely affected by the exceptional rainfalls especially when the period of record is of short duration - in this case 10 - 16 years. It is thus considered that results calculated by this method should be used with caution when the recurrence interval is greater than 2 years, since by this method an exceptional 24 hour rainfall can only have a return period approximately equal to the number of years of record being analysed.

The curves are calculated by plotting the number of occurrences in the complete record, greater or equal to certain selected bases, against these base values; and from these plotted points calculating the mean line (Fig.1).

As a check and further refinement on the calculated mean line drawn through these points, four random 5 year samples were taken from each of the records, a mean line drawn by eye for each 5 year sample, and a calculated mean line drawn for each group. From the original mean lines, and the mean lines of the random 5 year samples, a further series of mean curves was calculated and drawn (Fig.1). These are considered to be reasonably representative of the records, since, by this series of approximations the curves tend towards a straight line plot on logarithmic paper, and the influence of the exceptional 24 hour rainfalls has been somewhat reduced. This relieves the situation of having an extremely large 24 hour rainfall with only a limited return period.

The return period in years (N) for these curves was calculated by considering 1 occurrence in 10 years, giving N = 10; 2 occurrences in 10 years, giving N = 5; 5 occurrences in 10 years giving N = 2 etc.

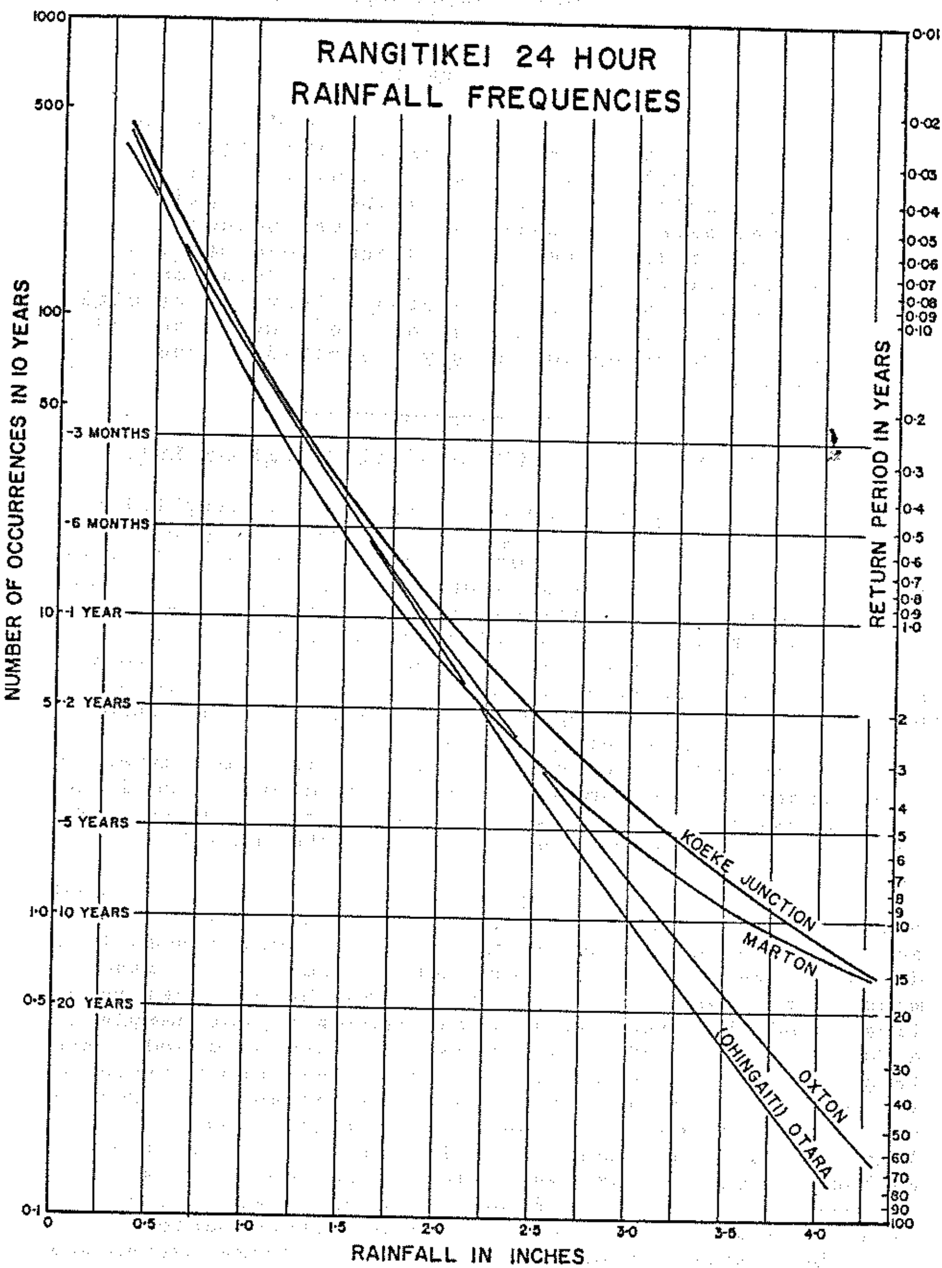
RANGITIKEI 24 HOUR
RAINFALL FREQUENCIES
NUMBER OF OCCURRENCES IN 10 YEARS
RETURN PERIOD IN YEARS
RAINFALL IN INCHES
3 MONTHS
6 MONTHS
1 YEAR
2 YEARS
5 YEARS
10 YEARS
20 YEARS
KOEKE JUNCTION
MARTON
OXTON
(OHINGAITI) OTARA
1000
500
100
50
10
5
1·0
0·5
0·1
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
4·0

FIG. I

GUMBEL'S METHOD

Gumbel's method (Benham, 1950; Raudkivi, 1961) was used for the Marton rainfall record as a study of Fig.1 shows that this curve would be the worst for a comparison of the three methods due to a series of very heavy 24 hour rainfalls in the past 14 years of record (in 1947, 1950, 1958 - all > 3.00") and any degree of correlation between the methods could thus be considered as a minimum for the other three stations.

Two studies were made: one on a long term broken record (1903-20, 1943-44, 1947-50, 1952-61) giving N = 34 (N = total no. of observations); and one on a short term record (as before, though rejecting the period 1903-20) giving N = 16. The record 1903-20 is of doubtful origin for several reasons and is treated with suspicion because of its adverse effect on the present trend of heavy rainfalls when included in the analysis.

The results of the short term and long term record analyses are shown in graphical form in Fig.2, but without the control curves or calculated extensions for the long term theoretical frequency curve. It should be noted that with the exception of two points, the degree of fit between the computed curves and the observed 24 hour rainfalls is quite reasonable.

Even though some of the observed 24 hour rainfalls deviate from the curve implying that the record may not yet be long enough for reliable estimates of future rainfalls, the curves calculated from the short term record are considered more realistic than those calculated from a long term record of doubtful origin. From the short term record there is also a reasonable correlation with the method of 24 hour "exceedances" up to about N = 5, above which the curve from the latter method lies just outside the x_1 control curve.

Both sets of computed curves (Fig.2) are reasonably consistent about the value of the most probable annual 24 hour rainfall, and compare favourably with that derived from the "exceedance" method - the total variation in the most probable annual 24 hour rainfall from all the methods amounts to only 0.35", with an arithmetic mean of annual 24 hour rainfall amounting to 1.96".

SEELYE'S METHOD

This method (Seelye, 1947a) is a modification of Gumbel's theory of extreme values and here involves the calculation of u and k values in the equation $X_N = u + k \log N$ for the four rainfall stations; where X is the 24 hour rainfall, u and k are constants, and N is the recurrence period in years. Such an equation applies to the heavier rains and is suitable when N is at least unity.

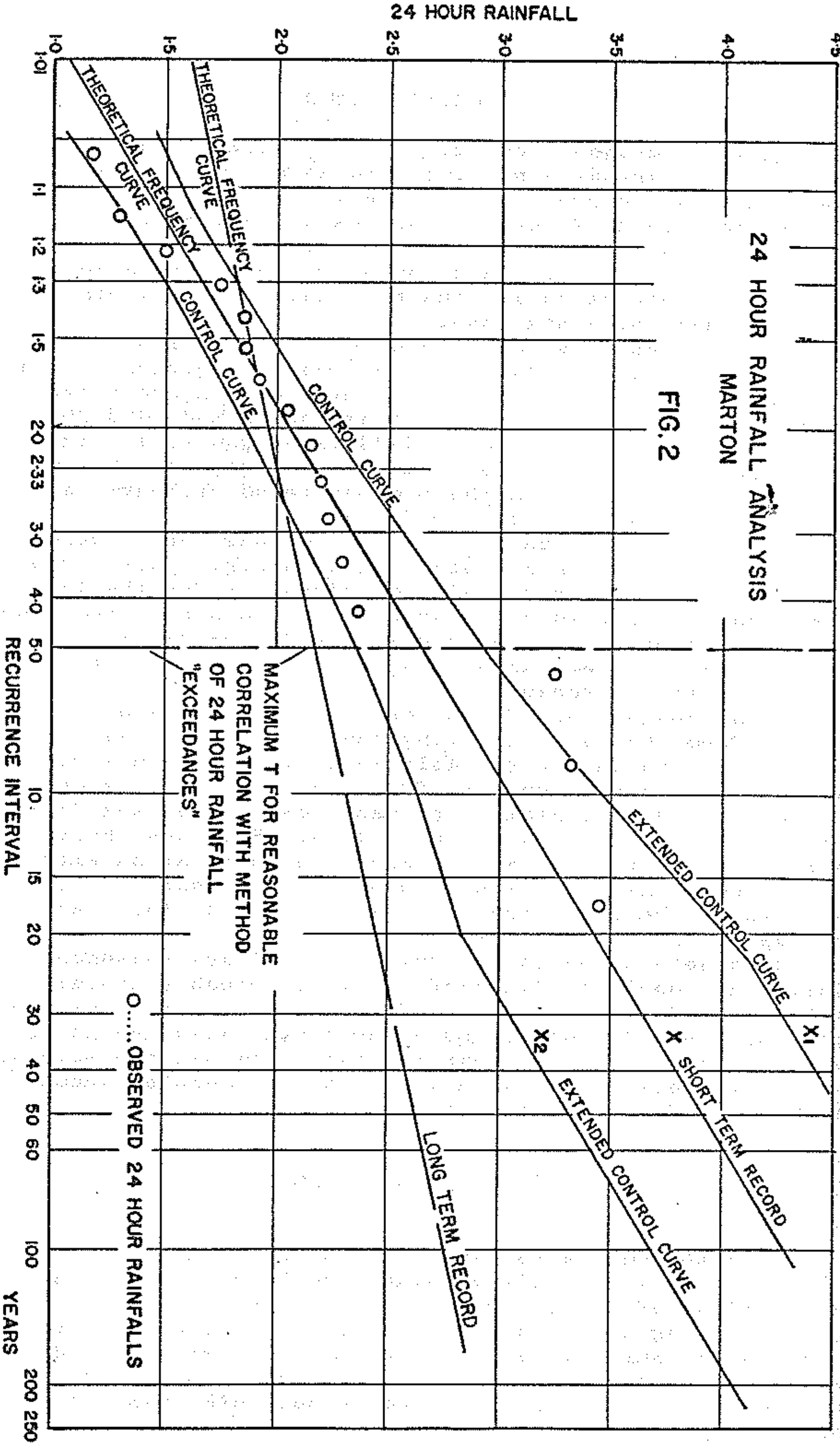
24 HOUR RAINFALL ANALYSIS
MARTON
24 HOUR RAINFALL
1·0
1·5
2·0
2·5
3·0
3·5
4·0
4·5
1·01
1·1
1·2
1·3
1·5
2·0
2·33
3·0
4·0
5·0
10
15
20
30
40
50
60
100
200
250
RECURRENCE INTERVAL
YEARS
THEORETICAL FREQUENCY CURVE
THEORETICAL FREQUENCY CURVE
CONTROL CURVE
CONTROL CURVE
EXTENDED CONTROL CURVE
EXTENDED CONTROL CURVE
SHORT TERM RECORD
LONG TERM RECORD
X1
X2
X
MAXIMUM T FOR REASONABLE CORRELATION WITH METHOD OF 24 HOUR RAINFALL "EXCEEDANCES"
O.....OBSERVED 24 HOUR RAINFALLS

FIG. 2

The results were as follows:

	$u \pm 6u$	$k \pm 6k$
Marton	1.89 ± 0.17	1.20 ± 0.26
Koeke	1.72 ± 0.27	1.52 ± 0.42
Otara	1.95 ± 0.25	1.64 ± 0.38
Oxton	1.85 ± 0.28	1.56 ± 0.43

(6u and 6k represent standard errors in u and k)

From the Marton result, by considering selected values of N and calculating X from the above equation, a very close agreement of X and N was obtained with the Gumbel curves for the short term record (lying well within the control band); and also with the method of 24 hour rainfall "exceedances" except for high values of N. The divergence from the rainfall "exceedances" curve can be explained by its exponential shape on log - log paper (Fig.1) indicating the influence of exceptional 24 hour rainfalls - this is also shown in Fig. 2 by the plotting positions of the observed rainfalls.

Comparing the rainfall "exceedances" curves for Koeke, Otara, and Oxton (Fig.1) with selected values of N in the general equation and using the above u and k values reasonable to good correlation was obtained.

Since only daily manual raingauge records were available for this analysis, intensity - duration data for various values of N were considered best derived by considering the 50 year Kelburn curve as a standard shape for the Rangitikei district. X_{50} (24 hour rainfall once in 50 years) was calculated from the general equation, the average intensity (i) in inches per hour for 24 hours derived, and the points plotted with an ordinate i and abscissa of 24 hours. Curves were then developed through these points parallel to the Kelburn curve thus giving the theoretical local intensity - duration curves for N = 50 years.

Further curves parallel to these for various values of N were drawn by assuming the following mean ratios developed for Kelburn (Seelye, 1947b) and later checking from the general equation:

N = 1 year : Mean ratio 1 year/50 years = 0.49
N = 5 year : Mean ratio 5 year/50 years = 0.70
N = 10 year : Mean ratio 10 year/50 years = 0.79
N = 50 year : Mean ratio 50 year/50 years = 1.00
N =100 year : Mean ratio 100 year/50 years = 1.09

An example of these curves is shown in Fig.3 with cumulative curves plotted on the same sheet for easy reference.

It should be noted, however, that the plotting positions of these curves are still subject to the same standard errors as originally calculated for the u and k values, and are thus no more accurate than these errors allow.

The writer is of the opinion that with the length of continuous records available for analysis in New Zealand at the present time, other than a constant frequency factor with varying duration cannot be justified. Robertson (1959) considers that intensity - duration - frequency curves developed for Christchurch and Tauranga from 25 years and 15 years of record respectively show a variable vertical separation; but some doubt as to the validity of this arises when the method of construction and standard errors in u and k (Seelye, 1947) are considered. The plotting positions for various values of N for each rainfall duration are derived by substitution in the general equation of separately calculated values of u and k; and for the lengths of record from which the Christchurch and Tauranga curves were drawn, standard errors of u and k of at least ± 10% can be expected. It therefore seems unwise to state categorically that these curves do not have a constant frequency factor with varying duration.

THEORETICAL RAINFALL INTENSITY-
-DURATION CURVES
MARTON

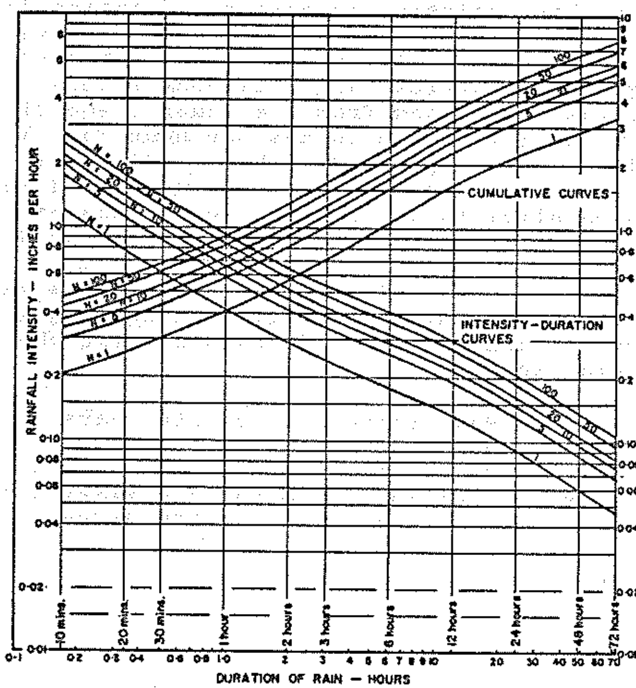

FIG. 3

CONCLUSIONS

In general it has been found that there is good correlation between the three methods used in the analysis: Gumbel's method and Seelye's method being comparable in accuracy, and the method of 24 hour rainfall "exceedances" being suspect in accuracy for N $>$10 years (5 years in the case of the Marton curve). For simplicity, Seelye's method has much to recommend it except for the rather large standard errors in u and k (amounting to as much as a 2" variation in 24 hour rainfall for X_{50}) and more use could be made of it in analyses of this type.

The theoretical rainfall intensity - duration - frequency curves given for Marton (Fig.3) cannot be used with any great degree of certainty for durations other than 24 hours. It is known, for example, that by assuming the shape of the Kelburn curve for durations $<$12 hours, results are substantially under-estimated when considering thunderstorms with local high intensity and short duration rainfalls such as are common at certain times of the year in the Rangitikei district.

The curves presented can be used as a rough guide and can be valuable for initial design estimates in areas where a continuous record is either not applicable or not available. However, more realistic results have been calculated by a parametric analysis of continuous rainfall data.

ACKNOWLEDGMENT

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