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THE FREQUENCY OF HIGH INTENSITY RAINFALLS IN NEW ZEALAND

by

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NOTATION

Letters and symbols are defined where they first appear in the text. Those which are repeated in several places are listed here for convenient reference.

a, b, c are coefficients in equation 15

$D = X_{20} - X_2$ (see equation 14)

k = a statistic defined by Seelye = $2.3026/\alpha$

m = rank from bottom

n = no. of years of observation (sample size)

s = sample standard deviation

t = duration of rainfall (hours)

T, T' = return period (years); see 2.1.

u = mode

V = coefficient of variation = $s/\bar{x}$

x_t or $x(t)$ = maximum rainfall of duration t in a given year.

$X_{T,t}$ or $X(T,t)$ = expected annual maximum rainfall of return period T years and duration t hours (the T-year, t-hour rainfall).

y = reduced variate = $(x-u)\alpha$

y_n = mean of the theoretical reduced extremes

α = scale parameter in the theory of extreme values.

σ = standard error of $X_{T,t}$

σ_n = standard deviation of the theoretical reduced extremes.

SUMMARY

The paper is divided into two parts. Part I deals with the analysis of rainfall intensity data from 44 New Zealand stations where recording raingauges have been in operation for at least nine years. The results are obtained by applying the theory of extreme values, using the well-known Gumbel method. They are presented in Appendix I as 44 rainfall depth-duration-frequency tables containing the expected rainfalls for durations of 10, 20, 30 minutes, 1, 2, 6,12, 24, 48 and 72 hours, each with return-periods of 2, 5, 10, 20 and 50 years. The uncertainties in the results, due mainly to the short records usually available for analysis, are also discussed. It is shown that, for many places, the depth-duration-frequency data can be satisfactorily represented, over a fairly large range of duration, by a formula of the type

$$X(T,t) = a.t\,(t + c)^{-b}F(T,t)$$

where $X(T,t)$ is the rainfall with return-period T years and duration t hours, and $F(T,t)$ is a frequency function. A method is described for using the data tabulated in Appendix I in order to find the parameters a,b, and c, and also $F(T,t)$ for a particular station.

In Part 2 the problem is to estimate the values of $X(T,t)$ - the rainfall of return-period T-years and duration t-hours - at any given point in New Zealand. Using the data in Appendix I, four maps were prepared to represent the variation of $X(2,\frac{1}{2})$, $X(2,2)$, $X(20,\frac{1}{2})$, and $X(20,2)$ throughout the whole country. For durations of 24, 48, and 72 hours the variation from place to place is shown by means of a detailed table (Table 9) containing values of $X(2,24)$, $X(20,24)$, $X(2,48)$, $X(20,48)$. $X(2,72)$, and $X(20,72)$ for over 400 stations. To enable interpolations to be made for other durations and return-periods there are three interpolation diagrams covering (a) durations up to 2 hours, (b) durations greater than 2 hours, and (c) return periods 2 - 100 years. These are used in conjunction with the maps and Table 9 to estimate $X(T,t)$ at any given point.

In order to reduce the estimated point-rainfall to a value appropriate to the average rainfall over a limited area surrounding the given point, use is made of a graph developed in the United States Weather Bureau. Examples are included to illustrate the method of using the various maps, tables and diagrams in the practical estimation of rainfall intensities over small catchment areas.

PART ONE : RAINFALL DEPTH-DURATION-FREQUENCY RELATIONS DERIVED FROM RECORDING RAINGAUGES

Introduction

Since the publication of a set of intensity-duration-frequency curves for Wellington (Seelye, 1947:b) there has been a demand for similar information for other parts of the country, chiefly for hydrological design purposes. Seelye used 18 years of records from a Dines tilting-siphon raingauge at Kelburn which was the longest reliable record available at the time. His analysis followed the now well known "Gumbel" method, based on the theory of extreme values, but extension of this work had to await the accumulation of basic data from additional recording raingauges.

In the 1940's and early 1950's a large number of additional stations were equipped with recording gauges, mostly Dines pattern with daily chart, and a routine summary form was introduced in the Climatological Section. On this form are entered details of the monthly and annual extremes of rainfall of different durations, as extracted from the autographic charts. With these summaries now available for many stations for 10 years or more, a statistical analysis was carried out which led to the results given in the accompanying tables. Also included are results from a number of stations equipped by the Ministry of Works with tipping bucket gauges (weekly charts) mostly in the 1930's. These records were later acquired by the Meteorological Service.

As the Gumbel method has undergone some modifications since Seelye's results were published, a brief summary of the method will be given to show how these modifications affect the results. For a detailed account reference should be made to Gumbel (1958) or to his published series of lectures (1954) to the U.S. National Bureau of Standards.

2. OUTLINE OF THEORY OF EXTREME VALUES - Gumbel Method

Consider a variate x with density of probability $f(x)$ which we will call the initial distribution. The probability that a particular value of the variate is less than or equal to a certain x is $p(x)$, where $p'(x) = f(x)$. Then the probability that N independent observations all fail to exceed x is $p^N(x) = P_N(x)$. Expressed in another way this means that if a sample of N values is selected at random from the parent population, $P_N(x)$ is the probability that x is the largest value of the sample. Thus if we select n random samples, each of size N, the series of largest values (one from each sample) x_1, x_2, ---- x_n determines a new variate whose probability function is $P_N(x)$. It follows that the distribution of the largest values depends on N the size of the sample, and on the form of the initial distribution.

In developing the mathematical theory of extreme values, Gumbel and others have shown that when N is very large the distribution of the largest values is not very dependent on the exact form of the initial distribution and for a large variety of common initial distributions it tends asymptotically to one of three forms. In the present analysis of rainfall data we are concerned only with what Gumbel (1954) calls the "first asymptote". This applies strictly to initial distributions of the exponential type and the asymptotic probability is given by

$$P(x) = \exp(-e^{-y}) \qquad (1)$$

$$\text{where } y = \alpha(x-u) \qquad (2)$$

y is known as the "reduced variate" and α and u are parameters which may be estimated from the observed largest values, as described below.

2.1 Return Period

In applications of extreme value theory it is usual to express probability in terms of <u>return period</u> $T(x)$, the relationship being defined by the equation

$$T(x) = \frac{1}{1 - P(x)} \qquad (3)$$

When the series $x_1, x_2, \ldots\ldots x_N$ are annual maxima of rainfall of a given duration, say, 6 hours, the return period $T(x)$ of a particular value of x is "the average interval between those years which contain a 6-hour rainfall equal to or greater than x". This is not quite the same as "the average interval between occurrences of 6-hour rainfalls equal to or greater than x" which we shall call $T'(x)$.

Seelye (1947b) showed that T and T' are related by an equation which reduces to

$$\frac{1}{T'} = \ln T - \ln (T - 1)$$

and from which the following table was prepared.

T	2	5	10	20	50
T'	1.44	4.48	9.49	19.5	49.5

NOTES (a) In Seelye's notation $T' \equiv N$.

(b) $T - T'$ is seen to tend rapidly to $\frac{1}{2}$ as T increases.

(c) T' is sometimes called "the recurrence interval of the annual exceedances" - see Chow (1953).

Throughout this paper results are given in terms of $T(x)$ as defined above. In some applications of the result it may be strictly more appropriate to use $T'(x)$ but the difference is usually insignificant except when $T(x)$ is less than about 5 years. If necessary, the results may be adjusted as described above.

2.2. Estimation of Parameters

For estimating the two parameters α and u from the observed largest values several methods have been used.

(a) Moments
(b) Order statistics
(c) Least-squares method based on the use of a special extreme value probability paper.
(d) Maximum likelihood.

In this analysis the least-squares method (c) was adopted. Previous work on New Zealand rainfall and stream flow data has been based on methods (a) and (b). All three methods will be briefly described mainly to show the relationship between them and the effect on the results. For a detailed account reference should be made to Gumbel (1954) or to his more recent book (1958). Method (d) is much more laborious than the others and it is doubtful if the extra effort leads to a significant improvement in the results (see Gumbel (1958) p. 234); no further reference will be made to this method in the present paper.

2.2.1 Method of Moments

In an early application of extreme value theory to meteorological data Gumbel (1942) used this method. Seelye (1947a) adopted it in deriving intensity-duration-frequency relations for Wellington rainfall. Benham (1950) applied it to flood discharges in New Zealand rivers.

Let $x_1, x_2, x_3,$ ---- x_n be the observed largest values each year from a record which is n years in length. These could be, for example, the annual maxima of 30-minute or 6-hour rainfalls or the annual maximum flood discharges. The mean $\bar{x}$, and the standard deviation s are given by

$$\bar{x} = \frac{1}{n}\sum x \; ; \qquad s = \sqrt{\frac{\sum x^2 - n\bar{x}^2}{n - 1}}$$

Provided both n and N are large, the parameters may be estimated from these first two moments as follows

$$\frac{1}{\alpha} = \frac{\sqrt{6}.s}{\pi} = 0.7797 \; s \qquad (4)$$

$$u = \bar{x} - \gamma/\alpha = \bar{x} - 0.450 \; s \qquad (5)$$

(γ is Euler's constant 0.5772)

Let X_T be the expected value of x with a return period T, and let y_T be the associated value of y. Eliminating P between (1) and (3) gives

$$y_T = -\ln \; -\ln \left(1 - \frac{1}{T}\right) \qquad (6)$$

Selected values of y_T are given in Table 2; more complete tables are readily available in various publications, if required. In meteorological literature Jenkinson (1955) p. 170 gives a convenient table for y in terms of P.

By substituting for u, α, and γ in (2) we obtain the following expression for estimating X_T

$$X_T = \bar{x} + 0.780 \, (y_T - 0.577) \; s. \qquad (7)$$

As will be seen below, the least-squares method leads to a slightly different expression for X_T, still involving the sample estimates of $\bar{x}$ and s, but introducing n the sample size.

Equation (4) expresses α in terms of the standard deviation s. Gumbel (1942) has shown that a slightly more efficient estimate of α can be obtained from the mean deviation d, $1/\alpha = 1.01731d$. This method of estimating was used by Seelye (1947b) in an analysis of maximum 1-day rainfalls in New Zealand. The statistics of maximum 2-day and 3-day rainfalls were later analysed in the same way and the results are incorporated in Table 9 (see also Part 2 section 10.4).

2.2.2 Order Statistics. In the analysis of 1-day, 2-day and 3-day rainfalls the parameter u was estimated from order statistics.

If the n observed larges values are arranged in ascending order of magnitude and m is the rank of a particular value x_m, it can be shown (see Gumbel, 1958) that the rank corresponding to u is

$$m_u = 0.368n + 0.632 \qquad (9)$$

For example, for the Wellington data given in Table 1, n = 31, so that $m_u = 12.04$ and hence u = 1.61.

Gumbel also gives an expression for the rank of other characteristic values of the distribution, from which α can be derived. However, in the present investigation the least squares method described in the next section was preferred.

2.2.3 **Least-Squares Method.** Use of the first and second moments to estimate u and α, as described above, strictly applies only to very large samples. The least-squares method, applied to extreme value statistics, is a later development and allows better estimates to be made for small samples (n = 20 or less). The two give identical results when n is large.

A brief explanation will be given by reference to a special probability paper developed for practical applications of the theory of extreme values.

2.3 Extreme Value Probability Paper. In the usual form of this paper the horizontal axis is graduated with three related scales :

1. A linear y scale
2. A probability scale on which the graduations are related to the linear y scale by equation (1).
3. A return period scale which is related to the probability scale by equation (3).

The vertical scale is a linear x scale. Basically, the method consists of plotting the series of observed largest values (arranged in ascending order) on extreme value probability paper and then fitting a straight line to the plotted points.

2.4 Plotting Position. Various methods have been proposed for plotting observations on probability paper and for a detailed discussion of the plotting problem reference should be made to Gumbel (1958, 1.2.6-1.2.7). In the present method the cumulative frequency assigned to the mth of the n ranked observed values is $\frac{m}{n+1}$. Alternatively if the observed values are plotted on the return-period scale the mth value is assigned a return-period of $\frac{n+1}{n-m+1}$. This means that the highest observed value ($m = n$) is assigned to a return period of $(n + 1)$ which overcomes the main objection to the earlier, widely used Hazen method in which a cumulative frequency of $\frac{m-\frac{1}{2}}{n}$ assigned the mth value leads to a return-period of 2n for the highest observed value. The present method also replaces an earlier method proposed by Gumbel (1943) and described in Linsley, Kohler and Paulhus (1949). It is interesting to note that, according to Alekseev (1958), the plotting method used extensively in USSR assigns a frequency of $\frac{m - 0.3}{n + 0.4}$ to the mth observation.

In Table 1 the annual maximum 6-hour rainfalls at Kelburn, Wellington for the period 1928-1958 are arranged in ascending order together with the corresponding plotting position, given in terms of return period. These values are plotted in Fig. 1, on S.C.C. Form 15 (from which the probability and "y" graduations have been omitted). The calculation of the theoretical line and the control curves shown on Fig. 1 is described below.

TABLE 1

Plotting Position : Annual Maximum 6-hour Rainfall at Kelburn, Wellington 1928-1958

(rainfall in hundredths of an inch)

m	x_m	T_p	m	x_m	T_p	m	x_m	T_p
1	86	1.03	11	160	1.52	21	178	2.92
2	130	1.07	12	161	1.60	22	183	3.20
3	130	1.10	13	163	1.68	23	184	3.55
4	132	1.14	14	167	1.79	24	199	4.0
5	134	1.18	15	169	1.89	25	200	4.6
6	141	1.23	16	170	2.00	26	206	5.3
7	144	1.28	17	170	2.13	27	208	6.4
8	152	1.33	18	173	2.29	28	223	8.0
9	154	1.39	19	177	2.46	29	234	10.7
10	156	1.46	20	178	2.67	30	251	16
						31	303	32

x_m = mth rainfall in ascending order

$n = 31$

T_p = plotting position on return-period scale $= \frac{n+1}{n-m+1}$

$\bar{x} = 175 \quad s = 41$

$X_2 = 169 \quad X_{50} = 299$

The strict application of the theory of extreme values requires that each of the values x_1, x_2, ---- x_n should be the largest value in a large sample drawn at random from an unlimited initial distribution of the exponential type. If, in addition, the number of samples is large, when all the n observed extremes are plotted on extreme value probability paper the points should lie on a straight line. This follows because of the design of the paper (as described above). The equation of the line is, of course, identical with equation (1), $y = \alpha (x-u)$.

For smaller values of n the scatter of the plotted points increases (see Tauranga data plotted in Fig. 1b) and a modified least-squares technique has been developed for finding the line of best fit. The difference from the classical method is that the squared distances whose sum is to be minimised are not measured parallel to the x (or y) axis, but parallel to a line whose gradient is opposite in sign to that of the line of best fit. As shown by Gumbel (1954, pp. 15-16) this slight modification of the classical least-squares method considerably simplifies the subsequent calculations and leads to the following equations for estimating the parameters α and u.

$$1/\alpha \quad = \quad s/\sigma_n \quad ; \qquad u = \bar{x} - \bar{y}_n/\alpha \qquad (11)$$

where $\bar{y}_n$ and σ_n are respectively the mean and the standard deviation of the series of y's obtained from the plotting positions. For the mth value of the ranked observations the value of y_m is given by

$$m/(n+1) \quad = \quad \exp\left(- e^{-y_m}\right)$$

whence

$$\bar{y}_n \; = \; \frac{1}{n} \sum_{m=1}^{n} y_m \; = \; \frac{1}{n} \sum_{m=1}^{n} -\ln\left(-\ln \frac{m}{n+1}\right)$$

It will be noticed that y_n and $_n$ depend only on n (the number of extremes). A table is given by Gumbel (1958, Table 6.2.3) from which the following have been extracted.

n	$\bar{y}_n$	n
20	0.5236	1.0628
50	0.5485	1.1607
100	0.5600	1.2065
1000	0.5745	1.2685

It can be shown that as $n \rightarrow \infty$ $\bar{y}_n \rightarrow 0.5772$ and $\sigma_n \rightarrow \pi/\sqrt{6} = 1.2826$ so that, in the limit, the expressions for α and u in (11) become identical with equations (5) and (6). Thus the least-squares method and the method of moments lead to the same result when dealing with very large numbers of extreme values. For smaller values of n, say less than 50, the least-squares method is superior.

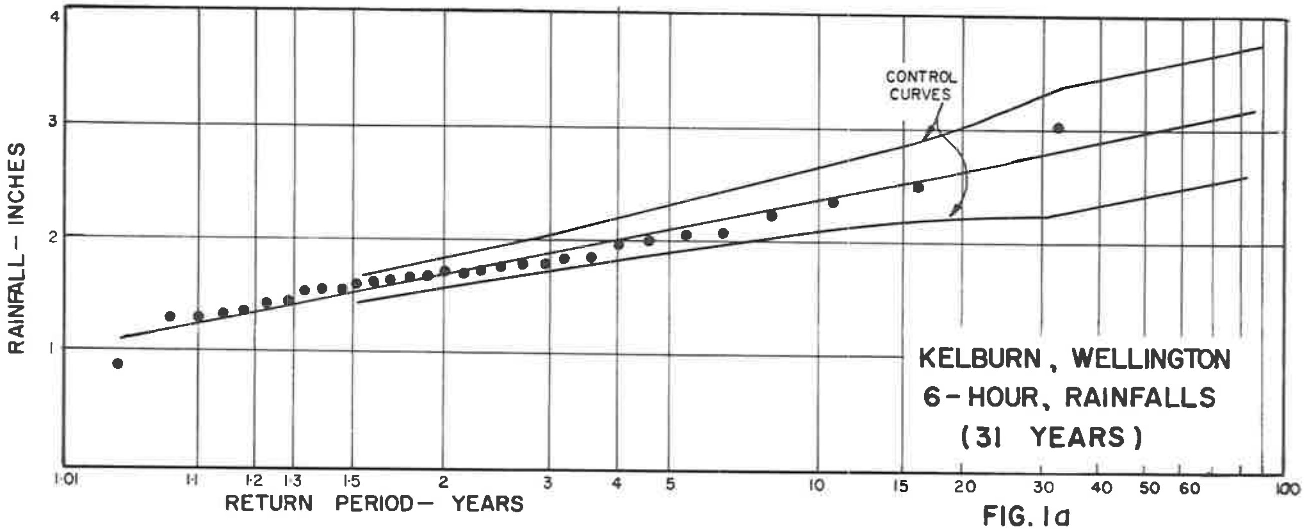

RAINFALL - INCHES
CONTROL CURVES
KELBURN, WELLINGTON
6-HOUR, RAINFALLS
(31 YEARS)
RETURN PERIOD - YEARS

FIG. 1a

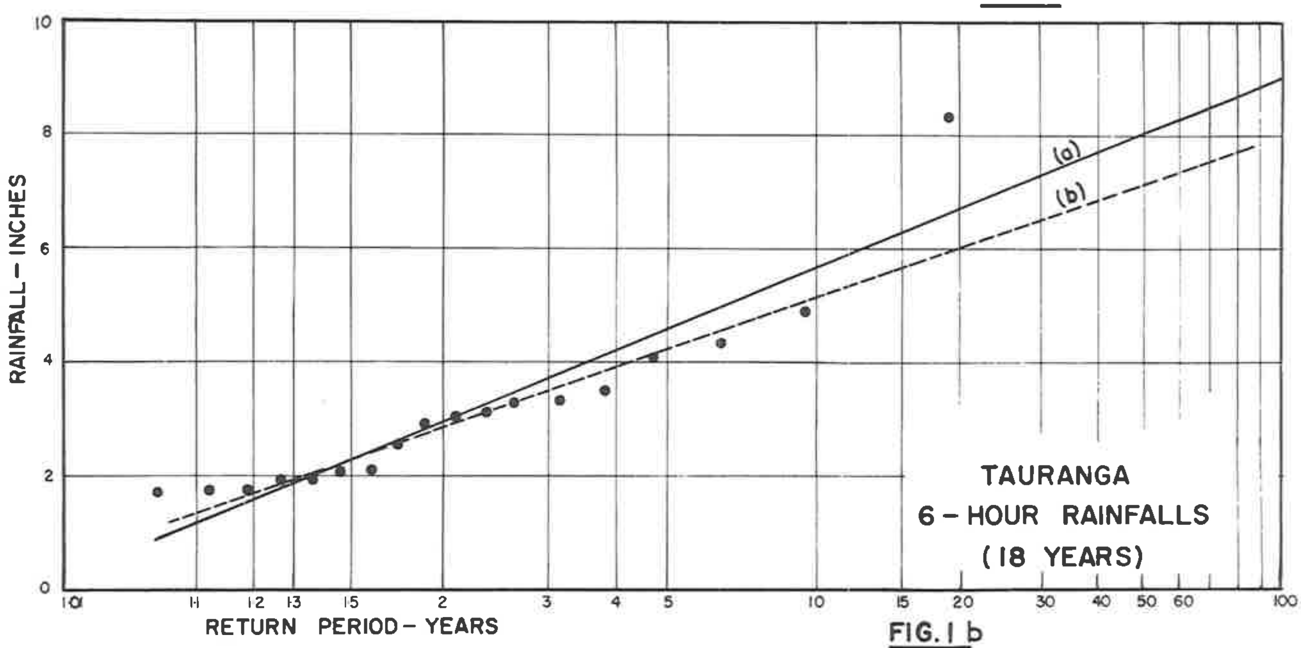

RAINFALL - INCHES
(a)
(b)
TAURANGA
6-HOUR RAINFALLS
(18 YEARS)
RETURN PERIOD - YEARS

FIG. 1 b

3. GUMBEL METHOD APPLIED

3.1 Limitations

It is known that not all types of extreme-value data follow the theoretical distribution given by equation (1), but there is no theoretical basis for deciding whether this form of distribution or some alternative form is the one which should be used for the analysis of rainfall records. The annual maxima of rainfall certainly do not comply exactly with all the conditions upon which the distribution given by equation (1) is based. The exact form of the frequency distribution of rainfalls of duration t, from which the annual maxima are selected, is not known.

A rough test which can be carried out without much trouble is to plot the annual extremes on extreme-value probability paper. If the points plot close to a straight line one may be reasonably confident that the records from that particular station fit the theoretical distribution. Sometimes the plotted points show some curvature, either upwards or downwards, or there may be so much scatter among the plotted points that they reveal nothing about the probable nature of the theoretical distribution - this is particularly noticeable with short records, say, under 20 years. Thus, when the plotted points do show a definite curvature there is a problem to decide whether the departure from linearity is due to the available records not being a representative sample of the long-period rainfall at the station or whether there is some local climatic factor which influences the frequency distribution of the rainfall.

3.2 Comparison with other methods

Various other theoretical distributions which have been used in the analysis of rainfall records include the log-normal (McIllwraith, Chow, 1954, - though Chow, 1953 has also used the Gumbel method), and the incomplete gamma-function (Thom, 1958 Maher, 1960). Jenkinson (1955) derived an ingenious procedure for choosing a theoretical distribution which will improve the fit for any particular sample; equation (1) is included as a special case in Jenkinson's generalised equation.

The Gumbel method appeals because of its relative simplicity especially when dealing with large volumes of data, as in this investigation. Furthermore, when many of the records are barely long enough to justify the use of the Gumbel method there is little point in attempting to utilize the additional refinements suggested by Jenkinson. Gumbel's method has been used extensively in the Hydrologic Services Division of the U.S. Weather Bureau, and its value for predicting extremes of rainfall has been subjected to detailed and critical examination by Hershfield and Kohler (1960). After applying a number of statistical tests they expressed the conclusion that the method was an acceptable procedure. To sum up, the main justification for the use of the Gumbel method is that it is well-tried, and experience shows that it gives satisfactory results in practice.

Plotting the annual extremes, as we have seen provides a rough check that the data do fit the theoretical distribution. A graphical indication of the goodness of fit may be obtained by drawing two "control curves" on either side of the theoretical line, the interval between the curves being such that there is a two-thirds probability that each plotted value should lie between the two curves. The method of drawing the control curves is described by Gumbel (1958, p 215), and a summary is given below in 5.2 when discussing possible errors in the calculated results.

Once the data are arranged in order and plotted on Gumbel paper it is usually quite satisfactory to fit a straight line by eye to the plotted points; in fact this method has some advantages over the least-squares method, particularly when dealing with short series of data. It is for instance the method recommended by the U.S. Geological Survey (see Dalrymple, 1960) for the analysis of flood-flow data. A few of the results presented in Appendix I to the present paper are derived in this way.

4. PROCESSING THE DATA FROM RECORDING RAINGAUGES

4.1 Notes on the observations

Most of the data used in this investigation were extracted from the daily charts used on Dines tilting-siphon recording raingauges. The scale of these charts is sufficiently open for reasonably accurate scalings of intense rainfalls down to durations of 10 minutes. For the routine analysis of these charts the following standard durations were selected:-

10, 20, 30 minutes 1, 2, 6, 12, 24, 48 and 72 hours.

Tabulations were prepared for each station containing the maximum rainfall each year for each of the standard durations. Occasionally some adjustment had to be made for interruption to the records during a storm, mainly caused by leaves or twigs blocking the collecting funnel, but, generally speaking, the Dines gauge provides a clear and continuous record during the heaviest rainfalls encountered in this country.

Also used were data from a number of weekly-chart tipping bucket gauges. From these charts no attempt was made to tabulate maximum annual rainfalls for durations less than 30 minutes. Many of these records were obtained in the period 1920 - 1940, before it became standard practice to install a manual raingauge alongside the recording gauge as a check on its accuracy. As the tipping-bucket type of gauge has proved to be neither as accurate nor as reliable as the Dines pattern, this has detracted considerably from the value of some of the early records.

4.2 Computation of Rainfall Depth-Duration-Frequency Tables

Let X_T be the expected value of x with a return period of T years. Then from equation (2) we have

$$X_T = u + y_T/\alpha \qquad (12)$$

The value of y_T depends only on T, the relationship being given by equation (6).

Corresponding values of T, y_T and the cumulative probability P are given in Table 2 for selected values of T.

Table 2

T	2	5	10	20	50
P	0.50	0.80	0.90	0.95	0.98
y_T	0.3665	1.4999	2.2504	2.9702	3.9019

Adopting the least squares method, we replace α and u by their sample estimates given by (11), whence

$$X_T = \bar{x} + \frac{y_T - \bar{y}_n}{\sigma_n} . s$$

$$= \bar{x} + K(T,n).s \qquad (13)$$

where $$K(T,n) = \frac{y_T - \bar{y}_n}{\sigma_n}$$

Values of K(T,n) were calculated for the selected return periods given in Table 2 and for n = 10(2)88. These values are given in Table 3.

Using the tabulations of observed annual maximum rainfalls we calculate, for each of the selected durations t, the mean $\bar{x}_t$ and the standard deviation s_t. From Table 3 we select the row for which n is equal to the number of years of observations and thus obtain the required values of K(T,n). The complete table is found by repeated substitution in (13).

In order to facilitate the calculations, the basic tabulations of annual maximum rainfalls each year for the selected durations were punched on IBM cards, as was Table 3, and processed by machine. The results for 44 stations are reproduced as Appendix I.

5. Discussion of Results

Each of the tables in Appendix I consists of ten lines, one for each of the selected durations - 10, 20, 30 minutes, 1, 2, 6, 12, 24, 48, and 72 hours. Reading across the lines the columns contain:

1.	n	= number of years of data.
2.	t	= duration
3 to 7	X_T	for T = 2, 5, 10, 20, and 50 years
8.	$\bar{x}$	= mean of the annual maxima.
9.	s	= standard deviation
10.	$s/\bar{x}$	= coefficient of variation = V

Only stations with at least 9 years of data are included in the tables. At some stations n is less than 9 only for durations of 10 and 20 minutes, and so the first two lines of such tables are blank; the replacement of an earlier weekly-chart gauge by a daily-chart gauge less than 9 years ago usually accounts for this.

TABLE 3

Values of $K(T,n) = \frac{y_T - \bar{y}_n}{\sigma_n}$ (Equation 13)

n \ T	2	5	10	20	50
10	-0.14	1.06	1.85	2.61	3.59
12	-0.14	1.01	1.78	2.51	3.46
14	-0.14	0.98	1.72	2.44	3.36
16	-0.14	0.95	1.68	2.38	3.28
18	-0.15	0.93	1.65	2.33	3.22
20	-0.15	0.92	1.62	2.30	3.18
22	-0.15	0.90	1.60	2.27	3.14
24	-0.15	0.89	1.58	2.25	3.10
26	-0.15	0.88	1.57	2.22	3.07
28	-0.15	0.87	1.55	2.20	3.05
30	-0.15	0.86	1.54	2.19	3.03
32	-0.15	0.86	1.53	2.17	3.00
34	-0.15	0.85	1.52	2.16	2.99
36	-0.15	0.84	1.50	2.14	2.96
38	-0.15	0.84	1.50	2.14	2.96
40	-0.16	0.84	1.50	2.13	2.94
42	-0.16	0.83	1.49	2.12	2.93
44	-0.16	0.83	1.48	2.11	2.92
46	-0.16	0.83	1.48	2.10	2.91
48	-0.16	0.82	1.47	2.09	2.90
50	-0.16	0.82	1.47	2.09	2.89
52	- .16	.82	1.46	2.08	2.88
54	-0.16	.81	1.46	2.07	2.87
56	-0.16	.81	1.45	2.07	2.86
58	-0.16	.81	1.45	2.06	2.86
60	-0.16	.81	1.45	2.06	2.85
62	-0.16	.80	1.44	2.05	2.85
64	-0.16	.80	1.44	2.05	2.84
66	-0.16	.80	1.44	2.05	2.83
68	-0.16	.80	1.43	2.04	2.83
70	-0.16	.80	1.43	2.04	2.82
72	-0.16	.80	1.43	2.03	2.82
74	-0.16	.79	1.42	2.03	2.81
76	-0.16	.79	1.42	2.03	2.81
78	-0.16	.79	1.42	2.02	2.81
80	-0.16	.79	1.42	2.02	2.80
82	-0.16	.79	1.42	2.02	2.80
84	-0.16	.79	1.41	2.02	2.79
86	-0.16	.79	1.41	2.01	2.79
88	-0.16	.78	1.41	2.01	2.79

n = No of years of record

T = return period (years)

The annual maximum 6-hour rainfalls at Tauranga plotted in Fig. 1b illustrate the problem of interpreting data from relatively short records. It is rather an extreme case as this 18 year record contains one 6-hour rainfall of 8.35 in. which is considerably higher than any of the others. Following our plotting convention this value is assigned a return period of n + 1 = 19 years. There are good reasons for suspecting that such a high value has a return period considerably longer than 19 years. It is , for instance, the highest 6-hour fall recorded by a recording raingauge anywhere in New Zealand. In Fig. 1b the Gumbel least squares line is labelled (a) and this obviously does not give a good fit to the majority of the plotted points. The line labelled (b) has been drawn (by eye) to fit all the points except the single exceptional value. By extending the line (b) we find that the return period to be assigned to a 6-hour rainfall of 8.35 in. at Tauranga is about 150 years, which, in the circumstances, appears to be quite reasonable.

The same procedure was adopted for some of the other short records. After fitting the line (by eye) to the majority of the plotted points the values of X_T for T = 2, 5, 10, 20 were read off. These values appear as the appropriate rows in Appendix I and are distinguished from the least-squares values by the absence of entries for $\bar{x}$, s and V in the right hand columns of these rows.

5.1 Interpolation for other Return Periods

The return periods for which the results have been calculated are those most commonly used for hydrologic design purposes. As most of the records used were only 10-20 years in length, the inclusion of extrapolated values for T = 50 is scarcely justified. If these results are to be used it should be done only with due recognition of the possible errors involved; this is discussed in the next section. Should X_T be required for values of T other than those given in Appendix I, this can be easily calculated from the known values of X_2 and X_{20} as follows:

In equation (12) we substitute for T = 2 and T = 20 in turn. Then, after subtracting and re-arranging we obtain:

$$\frac{X_T - X_2}{X_{20} - X_2} = \frac{y_T - y_2}{y_{20} - y_2}$$

whence

$$X_T = X_2 + C_T . D \qquad (14)$$

where $C_T = 0.384 (y_T - 0.367)$

and $D = X_{20} - X_2$

Substituting appropriate values of y_T the following values of C_T are derived:

TABLE 4

T	2	5	10	15	20	25	30	40	50	75	100
C_T	0	0.44	0.72	0.89	1.00	1.09	1.16	1.28	1.36	1.52	1.63

Example

From the table for Christchurch given in Appendix I,
we read $X_{20} = 1.66$ and $X_2 = 1.06$ for a duration of 6 hours
Hence, $D = 0.60$ and $X_{30} = 1.06 + 0.60 \times 1.16 = 1.76$

The same result can be obtained graphically with the aid of Fig. 5 or any other Gumbel probability paper, such as SCC Form 15. Let us select from Appendix I the values of X_T for T = 2, 5, 10, 20, and 50, for a given station and duration, that is, we select the values across a row of the table. When plotted on Fig. 5 these will all lie on a straight line, from which the value of X_T for any other value of T can be read off. The line is fixed, of course, by any two known values of X_T, and in Part 2 the use of Fig. 5, in conjunction with X_T for T = 2 and T = 20, will be described as part of a general method of estimating X_T for any place where a long series of observations is not available for detailed analysis.

5.2 Sources of Error

Reference has already been made to errors which may exist in the basic tabulations of annual maximum rainfalls due to the gauge failing to record or perhaps giving a spurious record because of a blockage in the collecting funnel during the most intense storm of the year. Although it is not possible to estimate the magnitude of the resultant error, the effect is to make the computed values of X_T too small. The use of Dines tilting-siphon gauges, with a check gauge alongside, which is the standard practice at the majority of stations, has ensured that few heavy falls have been un-recorded.

The computed values of X_T are, of course, not exact figures, for each value has a certain statistical uncertainty associated with it. To obtain an estimate of this error we refer back to figure 1 in which two "control curves" have been drawn on either side of the theoretical line. The position of these curves is such that the vertical distance from the line to each curve is equal to the standard error of the mth ranked observation in a large sample drawn from a population whose cumulative probability function is represented by the theoretical line. The interval between the two curves is the .68 probability confidence band, and if nearly all the plotted observations fall within this interval the theoretical line is considered to fit the observations satisfactorily. Looked at in another way - when we read off the graph the value of X_T where the line cuts the ordinate through T (on the return period scale), the distance along this ordinate from the line to either control curve represents the standard error of the computed value of X_T.

Gumbel (1958) gives a table (Table 6.1.5) of the "reduced standard error" ($= \sqrt{n}\, \alpha\, \sigma$) from which the following are extracted -

TABLE 5

Probability	0.5	0.8	0.9	0.95	-
Return Period	2	5	10	20	n
$\sqrt{n}\ \alpha\ \sigma$	1.44	2.24	3.2	4.5	$1.14\sqrt{n}$

Substituting in (12) for T = 20 and T = 2 and then subtracting we obtain an expression for α as follows -

$$X_{20} - X_2 = (y_{20} - y_2)/\alpha = 2.603/\alpha$$

whence $\alpha = 2.603/D$

where $D = X_{20} - X_2$

Replacing α in Table 4 we find the required expressions for σ, the standard error of X_T, which are given in Table 6.

TABLE 6

Return Period	2	5	10	20	n	50
Standard error	$\frac{0.54D}{\sqrt{n}}$	$\frac{0.86D}{\sqrt{n}}$	$\frac{1.23D}{\sqrt{n}}$	$\frac{1.73D}{\sqrt{n}}$	0.43D	0.43D

Table 6 can be used as it stands only when n is not less than 20. Many of the records included in Appendix I are between 10 and 20 years in length, and X_{20} is estimated by extrapolating the theoretical line. Gumbel proposes that the control curves for the extrapolated portion should parallel the theoretical line at a vertical separation equivalent to the standard error of X_T for T = n, which is 0.43D. Consequently, when $10 \leq n < 20$ the standard error for T = 20 also has the value 0.43D. Thus, Table 6 allows us to express the probable limits within which the calculated values of X_T lie, as functions of the difference between the values for return periods of 20 and 2 years, and the length of the record.

Example

The following values are taken from the table for Station A 64 872, Auckland, duration 6 hours.

Here $X_{20} - X_2 = 1.92$; n = 19 and hence

T	2	5	10	20	50
X_T	1.84	2.68	3.23	3.76	4.45
σ	0.24	0.38	0.54	0.82	0.82

The above example serves to emphasize the large uncertainty in the computed values of X_T, especially when dealing with relatively short records; for T=10, for instance, the standard error is 17 percent.

The magnitude of the uncertainty may be illustrated in another way. From the example above, it can be stated that there is a 2/3 probability that the 10-year, 6-hour rainfall at Auckland lies between 2.69 and 3.77 (3.23 ± 0.54) or, expressed otherwise, the return period to be associated with an observed 6-hour rainfall of 3.23 has a 2/3 probability of lying between 5 and 20 years.

5.3 Note on 24, 48, and 72-hour Rainfalls

For many of the 44 stations included in Appendix I daily readings of a manual gauge have been recorded over a much longer period than that covered by the operation of the automatic gauge. These daily readings may be used to estimate 24, 48 and 72-hour extreme rainfalls. A method of doing this is described in Part 2, and the resulting estimates are included in Table 9. Before deciding which of the two estimates to adopt for a particular station, reference should be made to section 12.2

5.4 Future Revision of Appendix I

For stations where the automatic gauge has operated for only 10-15 years the computed values of X_T should be regarded as provisional approximations. The routine extraction of maximum rainfalls, as described in Section 4, is being continued, and it will not be a difficult matter to repeat the present calculations in a few years' time in order to produce a revised and extended Appendix I.

6. DEPTH-DURATION-FREQUENCY FORMULAE

In applied hydrology references will be found to rainfall intensity-duration formalae of various types, most of which are special cases of the following general formula:-

$$I_{t,T} = a(t+c)^{-b}.\ F(T,t)$$

or, converted to an equivalent depth-duration formula

$$X_{T,t} = a.t(t+c)^{-b}.F(T,t) \qquad (15)$$

where $X_{T,t}$ = rainfall of duration t and return period T.

a,b,c, are coefficients to be determined for each place.

F(T,t) is a frequency function which varies from place to place, and with t.

The rainfall data given in Appendix I can be used to test the suitability of such a formula for New Zealand conditions, and to derive values of the coefficients a,b, and c and the form of the frequency function for individual stations. For a brief discussion of the general properties of the depth-duration -frequency relation we first re-write question (13) in the form :

$$X_{T,t} = \bar{x}_t(1 + K(T,n).V_t) \qquad (16)$$

where $V = s/\bar{x}$ = coefficient of variation.

For any station included in Appendix I values of $\bar{x}_t$ are given for t = 0.167, 0.33, 0.5, 1, 2, 6, 12, 24, 48 and 72 hours. Obviously, if the general equation (15) is suitable for representing the rainfall data given for a particular station it should be possible to determine values of the coefficients a, b, and c, such that the given values of $\bar{x}_t$ fit the equation $y = at\ (t+c)^{-b}$. If the fit is satisfactory the "frequency function" F(T,t), by comparing equations (15) and (16), is seen to take the form $[1 + K(T,n).V_t]$.

When graphed on log-log paper (with t as abscissa) the equation $y = at\ (t+c)^{-b}$ reduces, when c=0, to a straight line of gradient (1-b). The coefficient c determines the curvature; when c is positive (negative) the curve lies below (above) the line, log y = log a + (1-b) log t, approaching it asymtotically from below (above) with increasing t. When c is negative there is another asymptote at t = -c.

In Fig. 2 values of $\bar{x}_t$ taken from Appendix I are graphed for selected stations with reasonably long records. For durations greater than 6 hours all of the graphs show a downward curvature, indicating that a positive value of the parameter "c" is appropriate in this range. Below 6 hours most of the graphs are almost linear and little error would result by fitting an equation with = 0 as described in the next section. Some of the graphs, however, do tend to curve upwards in this range (Auckland, Blenheim, Christchurch (Fig.3)), while at Hokitika and Alexandra there is a downward curvature throughout the whole range.

Formula for Durations up to 2 hours

The use of intensity-duration formulae is usually restricted to falls of under a few hours duration. In this range it is therefore appropriate, bearing in mind the uncertainties in the values of $\bar{x}_t$, to take the coefficient as zero. The equation then reduces to

$$y = at^{1-b}$$

or

$$\log y = \log a + (1-b) \log t$$

To fit this equation to the values of $\bar{x}_t$ listed in Appendix I for any station, a simple method is to plot the values of $\bar{x}_t$ on log-log paper (t as abscissa, $\bar{x}_t$ as ordinate), fit a straight line by eye, and read off the values of y_1, y_2, and y_3 where $t_1 = 0.167$, $t_2 = 1$, and $t_3 = 2$ hours. Then it can easily be shown that -

$$a = y_2$$
$$b = 1 - 0.93 (\log y_3 - \log y_1)$$

Obviously, unless the plotted points (in this range of t) are nearly collinear there is no point in trying to fit a straight line to the data.

The "frequency function," as we have seen has the form $1 + K(T,n).V_t$. In this expression $K(T,n)$ is found from Table 3* and V_t can be obtained from Appendix I for any given station. The variation of V_t is found to be very irregular and does not appear to follow any definable pattern either with duration or with location. Some of the observed variations are probably more apparent than real because the estimates of V, the ratio of S to $\bar{x}$, both of which are estimates from small samples, is at times considerably in error. For a few stations, however, V_t is found to be roughly constant over a fair range of durations. By determining suitable values of the coefficients

* Alternatively K can be approximated very closely by means of a linear function of log (T-0.6). In equation (17) the value quoted is for n = 20.

a, b, and c, over this range a convenient depth-duration-frequency formula is obtained for that particular station.

This procedure was used to compile the following table which contains values of a, b and V applicable to selected stations in the range t = 0.167 to t = 2 hours.

Table — Depth-duration-frequency Relation - 10min. - 2hr. Values of a, b, and V to be substituted in equation (17) (C = 0).

Station	a	b	V	Station	a	b	V
Auckland	0.99	0.64	0.34	Hokitika	1.18	0.53	0.33
Chakea	0.64	0.58	0.32	Blenheim	0.55	0.52	0.46*
Wellington	0.69	0.49	0.28	Christchurch	0.45	0.54	0.36*
Nelson	0.94	0.51	0.44	Invercargill	0.44	0.55	0.32
Cobb Dam	0.83	0.35	0.43				

*V decreases with t; value given is approximate.

By substituting the above values in the formula -

$$X_{T,t} = a.t(t + c)^{-b} \left\{(1 - 0.46V) + 2.15V \log (T - 0.6)\right\} \quad (17)$$

a close fit to the data in Appendix I is obtained. For example, the formula for Mechanics Bay (Auckland) reduces to

$$X_{T,t} = 0.99\ t^{\,0.36}\left\{0.84 + 0.73 \log (T - 0.6)\right\} \quad (18)$$

In these formulae little error will result by slight extrapolation, say, for t = 0.1 to 6 hours.

The Ministry of Works Design Manual ; Water Supply and Sewerage, includes a collection of intensity-duration formula, used in various parts of New Zealand, all of which are simplified versions of equation (15). In nearly all of them b = 1 and c ranges from 0.11 (Hamilton) to 0.68 (Lower Hutt). As all of the formulae refer only to rainfalls of relatively short duration one would expect, from the foregoing discussion, that better results would be obtained by taking C = 0 and selecting suitable values of a, b, and V for substituting in equation (17), as described above.

6.2 General Formula

For some stations it is possible to obtain a satisfactory formula applicable over a much wider range of duration. At HOKITIKA, for example, where V_t is roughly constant over the range 10 minutes to 48 hours, a very good fit is obtained with the formula -

$$X_{T,t} = 1.27(t + 0.08)^{0.41}\left\{0.84 + 0.75 \log (T - 0.6)\right\} \qquad (19)$$

This formula is obtained by substituting in equation (16) a = 1.27, b = 0.59, c = 0.08 and V = 0.33. A method of computing the appropriate values of a, b, and c is described in Appendix II.

Formula (19) should be compared with the more limited formula (20) which is valid only for durations up to about 6 hours.

$$X_{T,t} = 1.18\ t^{0.47}\ 0.84 + 0.75 \log (T - 0.6) \qquad (20)$$

The values given by the two formulae for a return period of 10 years are as follows:

Duration (hours)	0.167	0.333	0.5	1	2	6	12	24	48
From Appendix I	0.71	1.14	1.43	1.95	2.6	3.8	5.6	7.4	9.5
Formula (18)	0.76	1.13	1.38	1.92	2.6	4.1	5.4	7.3	9.7
Formula (19)	0.80	1.11	1.34	1.85	2.6	(4.3)	-	-	(11.4)

Although the coefficients a, b and c have quite different values in (19) and (20) both are seen to give good results within the stated ranges. General formulae such as these are, however, dependent on V_t being reasonably constant over the range of duration to which the formula is applied.

6.3 Graphical Representation

While such formulae contain much information in a very compact form, for practical purposes it is usually more convenient and accurate to use the data in tabular form as in Appendix I, or to graph the tabulated values of $X_{T,t}$ on log-log paper and draw a family of depth-duration curves, one curve for each of the selected values of T.

As an example the Christchurch data are shown in Fig. 3. Note that the vertical distance between the curves is proportional to log $(1 + K.V_t)$ and only when V_t is constant do the curves maintain the same general shape for different values of T. The Christchurch curves are seen to have minimum separation in the range 2 to 6 hours, when V_t is a minimum. From such a diagram interpolations for intermediate values of t or T are quite straightforward.

6.4 The Problem of estimating $X_{T,t}$ at any given point

The possibility of preparing a set of maps showing the variation of a, b, and c over New Zealand was investigated as an approach to the major problem of estimating $X_{T,t}$ at any point (using formula (15)). It was found that orographical factors strongly influence the values of a and b though it was not possible to determine from the available data, the precise nature of this influence. Any attempt to map these coefficients over New Zealand's mountainous terrain would therefore give very uncertain results. However, the chief reason for abandoning this whole approach emerged when confronted with the problem of representing the variation, with duration and with location, of V_t, which occurs in the frequency term of formula (15). In Appendix I it can be seen that V_t varies considerably but not according to any regular pattern.

A similar method applied to Australian rainfall data is described in "Australian Rainfall and Run-off", First Report of the Stormwater Standards Committee of the Institution of Engineers (1958). There, the results depend on a number of simplifying assumptions. For instance, one assumption is equivalent to taking our $c=0.083$ over the whole range of durations from 5 minutes to 72 hours; another defines rather arbitrarily the nature of the variation of the frequency function with t. As these assumptions are based on data from recording raingauges at only the six capital cities, their general validity under Australian conditions is questionable. If applied under New Zealand conditions they would lead to serious error.

Nevertheless, from the nature of the problem it is inevitable that any method of solution will involve some smoothing and simplification and that the results can only be approximate. This also applies to the results obtained by the method which was finally adopted, and which is described in Part 2.

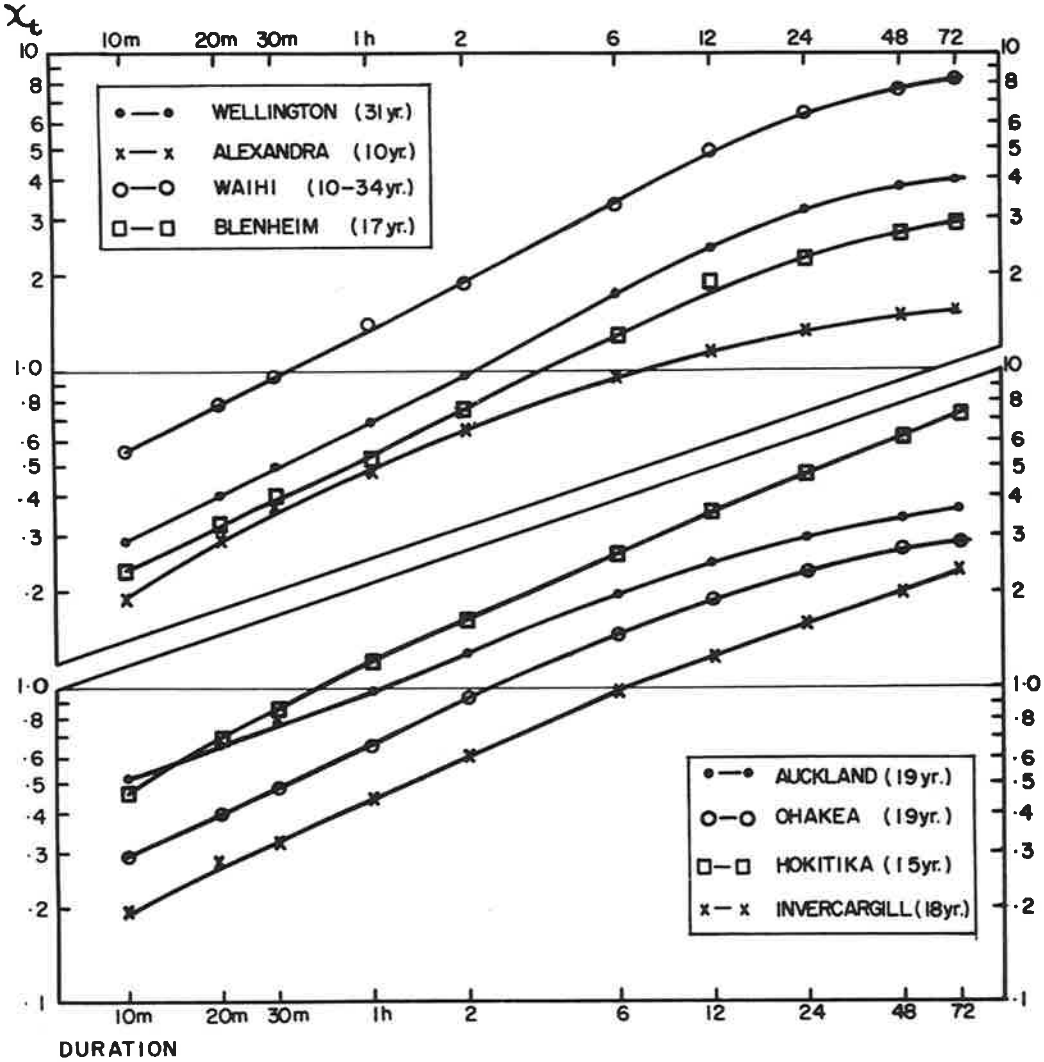


FIG. 2. $\bar{x}_t$ = MEAN ANNUAL MAXIMUM RAINFALL (IN) OF DURATION t, FOR SELECTED STATIONS

PART TWO

THE ESTIMATION OF MAXIMUM RAINFALL OF GIVEN DURATION AND RETURN PERIOD AT A GIVEN POINT

7. INTRODUCTION

Part I contains a description of the method of computing values of X(T,t)* for stations at which recording raingauges have operated for many years. The detailed results are presented in Appendix I for 44 stations for selected values of T (= return period) and t (= duration). Part I also contains a discussion of the accuracy of the results.

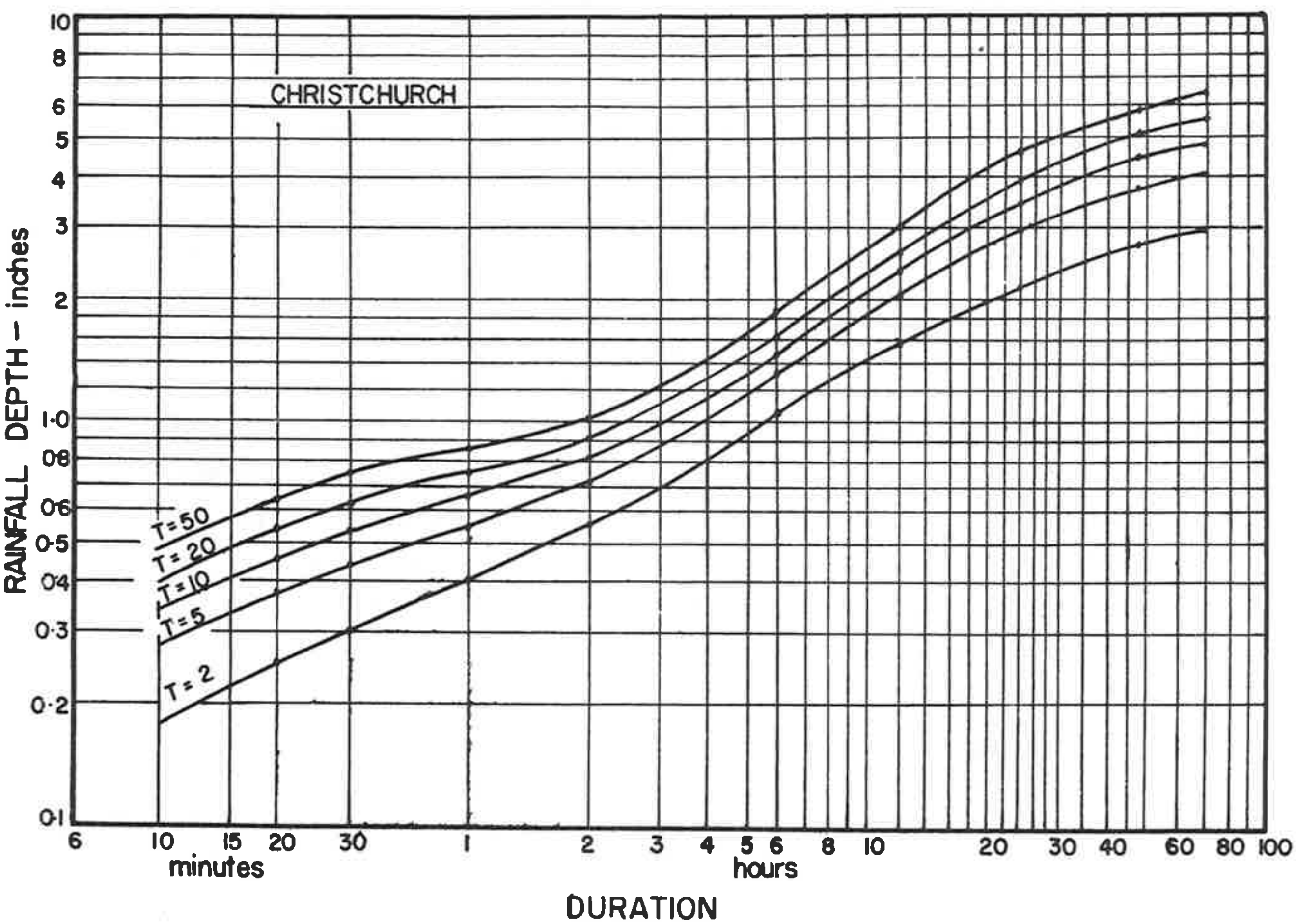
For many purposes, chiefly connected with hydrologic design problems, the value of X(T,t) is required at a given point, or over a given catchment area, where t is related to the "time of concentration", and T to such factors as the expected life of the structure of the consequences of failure. If the given point happens to coincide with one of the stations in Appendix I it will only be necessary to interpolate for the require values of t and T. Usually, however, the nearest stations are some distance away and a space interpolation is also required. Various methods of carrying out this rather complex triple interpolation were investigated, including several used in other countries. The method finally adopted is a modification of that described in United States Weather Bureau Technical Papers 28 and 29. The general solution is obtained with the aid of three interpolation diagrams, (Figs 4a, 4b, and 5), four maps, (Figs 9 and 10), and Table 9. Finally, the estimated point-rainfall, X(T,t), may be adjusted to an areal-rainfall, X(T,t,A) by means of Fig. 6. The preparation of these maps and diagrams is described in the following sections, and also the method of applying them to the solution of practical problems.

8. RAINFALL DEPTH-DURATION RELATIONSHIP

The depth-duration data for Christchurch are represented graphically by the family of curves shown in Fig. 3. By choosing logarithmic scales for both axes, the amount of curvature has been considerably reduced. By a suitable transformation of the "duration" scale, any one of these curves, say T=5, could

*NOTE: In Part 2 the notation X(T,t) is used for the expected point-rainfall of duration t with return period T or, in brief, the T-year, t-hour rainfall.

be linearised. If the data for any other value of T were then re-plotted using the transformed duration scale, the points would not lie exactly on a straight line, but would generally lie close to it. The obvious advantage of the linearising process is that a reasonable approximation to the depth-duration relation for a given value of T can be obtained if only two points are known on it. Unfortunately when data from other stations (given in Appendix I) are also plotted on the same transformed duration scale, some of the curves show appreciable departures from linearity.



DEPTH — DURATION — FREQUENCY CURVES
T = RETURN PERIOD IN YEARS

FIG. 3

9. INTERPOLATION DIAGRAMS

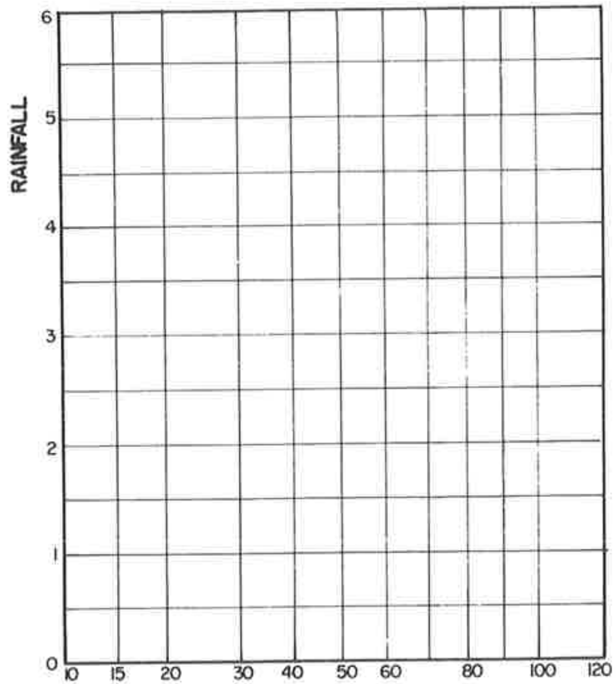
Duration 10-minutes to 24-hours. In order to take advantage of a transformed scale of duration and at the same time to avoid introducing serious error it was decided to linearise the depth-duration relation in two stages, from 10 minutes to 2 hours and from 2 hours to 24 hours. Finally, the transformed duration scales were computed by taking a weighted average of the 5-year rainfalls for all stations in Appendix I, and then linearising this composite rainfall depth-duration relation. The calibration of these scales is according to the values of B_1 and B_2 in the table below, the two intervals - 10 min. to 120 min. and 2 hours to 24 hours - being taken as unity in each case. The scales are those which appear in the depth-duration diagrams in Figs. 4, 4a and 4b.

Duration (minutes)	10	20	30	45	60	90	120		
B_1	0	0.19	0.33	0.48	0.60	0.82	1.00		
Duration (hours)	2	4	6	8	10	12	16	20	24
B_2	0	0.19	0.33	0.44	0.54	0.63	0.77	0.90	1.00

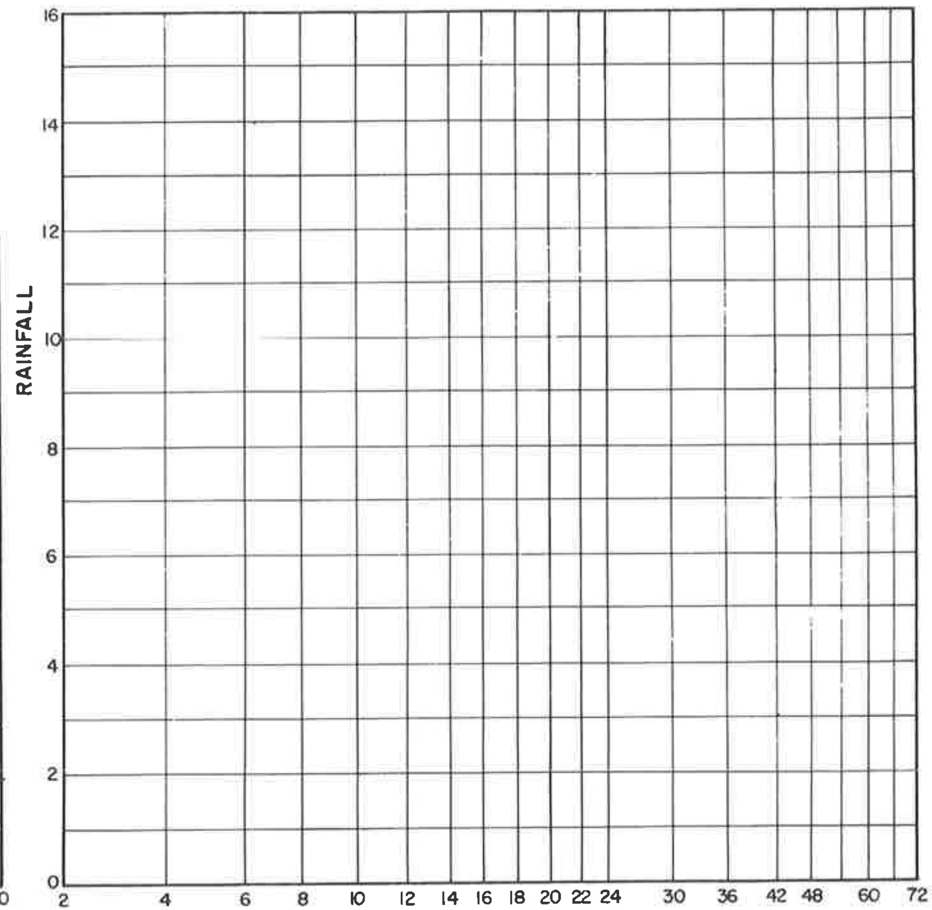
Note that the values of B_1 for 45 and 90 minutes and of B_2 for 4, 8, 10, 16 and 20 hours are interpolated.

In Figs. 7 and 8 can be seen the result of plotting the calculated values of X(T,t), taken from Appendix 1, for individual stations. Four stations with reasonably long records and in different parts of the country were selected, and the values of X(T,t) for T = 20 were plotted on diagrams of the type illustrated in Figs. 4a and 4b. Lines were then drawn through the values for t = $\frac{1}{2}$, 2 and 24 as shown. It is seen that, in general, the intermediate points lie reasonably close to their associated line.

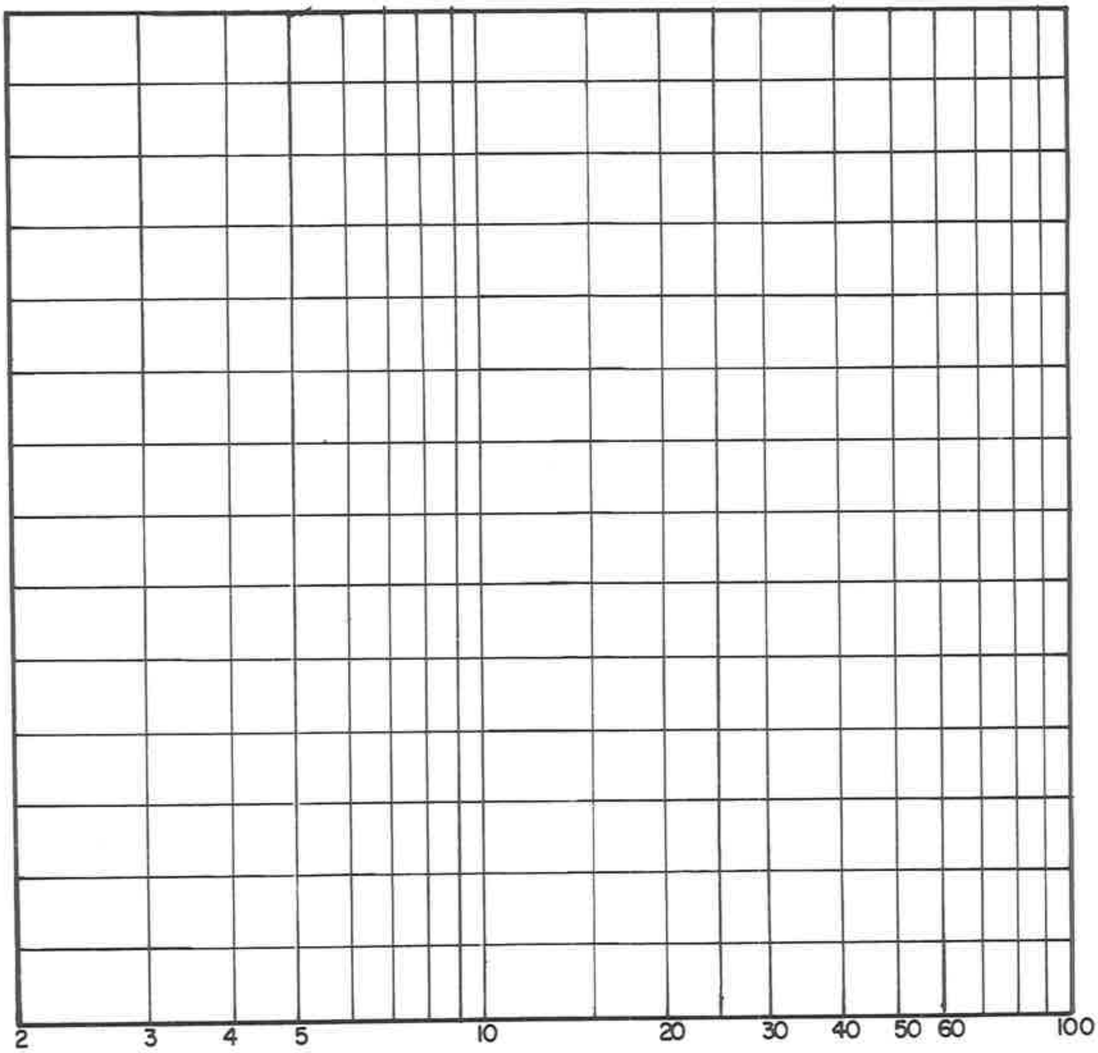
In Fig. 7 the 6-hour and 12-hour values for Tauranga and Auckland are found to lie above the depth-duration line, while those for Christchurch are below the line. This suggests that there may be a systematic variation in the depth-duration curvature from district to district, related perhaps to altitude or some climatic factors. The curvature is, however, very sensitive to errors which may exist in the estimates of X(T,t), and there errors, as we have seen, may be large when estimating from rainfall records of only 20 years in length. With such large sampling errors in the available data (from Appendix I) it was not possible to separate out the climatic factors, and so a single pair of diagrams, Figs 4a and 4b, were developed for application to the country as a whole . In U.S.A. where this problem was also investigated following the analysis of the autographic records from some 200 stations averaging 40 years in length, the conclusion was reached that"Since no regional variation is evident in this duration - depth or duration - intensity relationship, it may be used for any locality in the the United States".(* USWB Tech Paper No. 29, p.3.). However, in spite of this statement it is obvious that many of the rainfall intensity curves published in USWB Technical Paper No. 25 would still retain distinct curvature if re-plotted on the U.S. diagrams corresponding to Figs 4a and 4b (see footnote ref. Fig 1.1 A and B). It should also be noted that in the diagrams regarded as applicable throughout the United States the duration scales differ somewhat from those of Figs 4a and 4b of this paper.



(a) DURATIONS 10 TO 120 MINUTES



(b) DURATIONS 2 TO 24 HOURS
24 TO 72 HOURS



RETURN PERIOD PLOTTING DIAGRAM

FIG 5

9.2 Duration 24-hours to 72-hours. It will be seen that on Fig. 4 b the duration scale extends up to 72 hours. The calibration of the portion beyond 24 hours is based on the mean depth-duration relation derived from the 24, 48 and 72-hour values for a return period of 5 years given in Appendix I. Strictly speaking, there is a discontinuity in Fig. 4b at the 24 hour value but, as will be shown in 12.2 below this can be ignored in practical applications.

9.3 Return Period Interpolation Diagram

If values of X(T,t) are known (or can be estimated) for any two values of T, it has already been shown in Part I that Fig. 5 can be used to interpolate for other return periods. For the general solution, we concentrate on the problem of estimating the rainfall for the two fixed return periods, T = 2 years and 20 years, and for five fixed durations, t = $\frac{1}{2}$, 2, 24, 48 and 72 hours, for as many places as possible. A method of doing this is described in the next section.

10. DATA PRESENTATION

10.1 General Considerations

The variation of X(T,t) throughout the country is shown by means of four maps (Figs 9 and 10) and Table 9. The following combinations of return period and duration are represented:

	Return Period T (years)	Duration t (hours)
Fig 9a	2	0.5
Fig 9b	20	0.5
Fig 10a	2	2
Fig 10b	20	2
Table 9	2	24, 48, 72
	20	24, 48, 72

The above, combined with the interpolation diagrams, Figs 4a, 4b, and 5, provide the basic information for estimating values of the point-rainfall at a given point and for a given return period and duration. The required result is obtained by a series of steps which are described in the next section. Before proceeding to use the maps, however, we discuss the reasons for preparing these particular maps, and also some of the factors which limit their accuracy.

For mapping the short-duration rainfalls, the choice of 0.5 hours in

Fig 9 was determined by the need to make use of data from the greatest number of stations. Had the selected duration been less than 0.5 hour data would not have been available from any of the stations equipped with weekly-chart gauges. As it is, forty-four stations is a very meagre number upon which to base isohyetal patterns in a mountainous country such as New Zealand. Difficulties arising from this scarcity of data are partly offset by the fact that the influence of topography on the frequency of intense short-duration rainfalls is much less than it is on daily or monthly rainfalls.

Although the number and location of recording raingauges in New Zealand is inadequate for a detailed study of the topographical influences, the limited data available suggest that the frequency of high-intensity rainfalls is not greatly affected by local topography up to durations of one, and perhaps two hours, at least where the mountains are not higher than about 3000 feet. An illustration of this is provided by the figures in Table 8.

Table 8

Once-in-5 year Rainfalls (inches)

Station	Elevation (feet)	Duration (hours) 0.5	2	6	24	Mean Annual Rainfall
Cobb Dam	2700	0.8	1.9	4.5	11.2	83
Nelson	6	0.9	1.8	2.5	3.3	35
Takaka	40	0.8	1.6	3.3	5.4	80

These three stations in the Nelson District all have similar 5-year rainfalls for durations up to about 2 hours, but the values diverge considerably for the longer durations. Thus the choice of 2 hours, rather than 6 hours, for Figs 10a and 10b leads to simpler and more reliable maps.

For durations of 24, 48 and 72 hours use was made of additional data from several hundred stations where a manual raingauge had been read daily for at least 20 years. Rather than attempt to present all this information on a series of small scale maps, the computed values for each station are assembled together in Table 9.

10.2 Half-hour Rainfalls

The isohyetal patterns shown in Figs 9a and 9b are based on the values of 2-year and 20-year rainfalls for a duration of half-hour as computed for the 44 stations included in Appendix I. For the 2-year map (Fig 9a) additional values were computed for a further 59 stations where recording raingauges had been in operation for 5-10 years; no attempt was made to estimate 20-year rainfalls for these short records.

Maximum intensities for short durations could be expected when conditions favour the development of very deep cumulo-nimbus cloud. This requires that warm, moist air should extend upwards through a considerable depth of the atmosphere, a situation which is most likely to occur over New Zealand when a tropical-maritime air-mass arrives from the north or northeast ahead of an approaching depression. It is the areas directly exposed to northeasterlies and northerlies, such as, eastern Northland, Bay of Plenty, New Plymouth, and Westland, which are found to receive the most intense rains (see Figs 9a and 9b). The maximum half-hour rainfall received by any recording raingauge in this country was 2.67 inches at Tauranga on 18 April 1948. Many observers make a practice of reading their manual raingauges after exceptionally heavy rains, but an extensive search of past records has not revealed any half-hour fall exceeding the Tauranga maximum. More recently, during another violent thunderstorm on 6 May 1961 at Tauranga, a fall of 2.52 inches in half-hour was recorded by the same gauge.

10.3 2-Hour Rainfalls

Figs 10a and 10b represent the isohyetal patterns of the 2-hour falls with return periods of 2 and 20 years respectively. The data used in drawing these two maps were obtained from the same sources as the $\frac{1}{2}$-hour falls already described. Of the four maps, Fig 10b was the most difficult to draw and is the least reliable. The main reasons for this are -

(a) For the 20-year maps, Figs 9b and 10b, data were available for only forty-four stations, compared with about one hundred stations for which 2-year falls were computed.

(b) The estimates of 20-year rainfalls have had to be derived from small samples of data, mostly less than 20 years in length. The uncertainty in these estimates, due to "sampling error", is much greater than for the 2-year estimates; this was discussed in Part I, section 5.2

(c) When the 20-year, 2-hour rainfalls were plotted on a map it became very difficult to judge how much of the variation between adjacent stations was due to meteorological or orographical factors, and how much to sampling errors. It is evident, however, that orography influences the pattern of 2-hour falls appreciably more than that of the $\frac{1}{2}$-hour falls.

When additional records become available in the course of the next few years, it is expected that Fig 10b and, to a lesser extent, Fig 9b will require some modification.

10.4 24, 48, 72-Hour Rainfalls

10.4.1 24-Hour Rainfalls

Estimated 24-hour rainfalls with return periods of 2 and 20 years are given in Table 9. These are derived from the daily rainfall readings of 470 stations with at least 20 years of records; for 106 of them, records of 40 years of more were available. Some of this material had previously been analysed by Seelye (1947, 1) but as additional data accumulated, his calculations were later revised and extended. Both the method of analysis and of presenting the results adopted by Seelye were somewhat different from that used here for the treatment of the data from recording raingauges. For the sake of uniformity the earlier results were adjusted in the following manner.

In Seelye's work two statistics u and k were calculated for each station, these being related to $\bar{x}$ and s by the following equations:

$k = 2.3026/\alpha$, where $1/\alpha = 0.7797$ s (from equation 4) and

$u = \bar{x} - 0.4501\ s$

From equation (14) we have

$X(T) = \bar{x} + K(T,n)s$

Eliminating s, and $\bar{x}$ from the four equations above gives an expression for X(T) in terms of u and k,

$$X(T) = u + k\left[0.251 + 0.557\ K(T,n)\right]$$

$$= n + G(T, n).\ k \qquad (25)$$

Selected values of G(T,n) are as follows:

n	20	30	40	50	60	80
T = 2, G(2,n)	0.17	0.17	0.17	0.16	0.16	0.16
T = 20, G(20,n)	1.53	1.47	1.44	1.42	1.40	1.38

With values of n, u and k known from previous work, repeated substitution in equation (25) gave the 2-year and 20-year daily rainfalls.

A further adjustment was necessary to convert the values computed from annual maximum daily rainfalls measured between fixed hours (usually 9 a.m. to 9 a.m.) to maximum 24-hour falls. It is obvious that the ratio of maximum 24-hour rainfall to maximum 1-day rainfall may vary from year to year between the limits 1 and 2. For Kelburn, Seelye (1947, 2) found an average value of 1.13 for this ratio. Data from an additional 20 stations were used in the present investigation, and the over-all average of the ratio was found to be 1.14. This is the factor by which all the calculated 2-year and 20-year daily rainfalls were multiplied to produce the figures in the 24-hour section of Table 9.

Following Seelye's work on daily rainfalls, tabulations of the maximum rainfalls over intervals of two and three consecutive days (9 a.m. - 9 a.m.) for each month and year were prepared, using the same long-period records from which the maximum daily rainfalls had already been extracted. From these basic tabulations the maximum 2-day and 3-day rainfalls with return periods of 2 and 20 years were computed. Finally, these were adjusted to equivalent 48-hour and 72-hour rainfalls by increasing them in the following ratios:

$$\frac{\text{Maximum 48-hour rainfall}}{\text{Maximum 2-day rainfall}} = 1.06$$

$$\frac{\text{Maximum 72-hour rainfall}}{\text{Maximum 3-day rainfall}} = 1.05$$

The computed 48-hour and 72-hour rainfalls for about 410 stations are included in Table 9.

For many of the stations included in Appendix I daily rainfall readings are available for a much longer period than that covered by the operation of the recording raingauge. For these stations separate estimates of the 24-hour, 48-hour and 72-hour rainfalls are given in Appendix I and in Table 9. The correlation between the two sets of values is shown in Fig 11a and 11b, and it can be seen that there is no tendency for one set of estimates to be consistently higher or lower than the other. It is suggested, however, that as a general rule the figures from Table 9 should be accepted as providing the better 20-year values but, for the 2-year values, there is little to choose between the two estimates.

11. THE RELATION OF AREA-RAINFALL TO POINT-RAINFALL

A well-exposed raingauge is considered to collect a good sample of the amount of rain falling on a small area surrounding the gauge. As the area increases, the correlation between the area-rainfall and the point-rainfall gradually decreases, but at a rate which varies from storm to storm according to the character of the rainfall. Obviously the correlation will fall away most rapidly when the rain comes in short bursts of high-intensity rainfall accompanying the passage of local heavy showers or thunderstorms. By contrast, the approach of a warm front usually brings steady rain persisting for several hours and this results in a very uniform rainfall pattern over a wide area surrounding a particular gauge.

Assuming the value of X(T,t) has been computed for one or more points in a given catchment area the problem is to determine a suitable factor by which the "point-rainfall" should be multiplied in order to arrive at a reasonable estimate of the T-year, t-hour rainfall affecting the catchment area as a whole. It is a problem which has not, as yet, been investigated in New Zealand, and one which would require the setting up of a number of special very dense networks of rainfall stations to operate over a long period.

In U.S.A., however, some very useful work has been done and the main results are summarised in Fig 6 which is reproduced from U.S. Weather Bureau Technical Paper No. 29, Part 3. This diagram was derived from a study of data from seven dense networks of raingauges in the eastern half of the country.

Attention was drawn to the fact that the relations represented by the curves in Fig. 6 seemed to be independent of geographical location and hence this diagram was recommended for general use throughout U.S.A. It appears to be equally suitable for use in New Zealand, particularly as the seven dense networks which provided the basic data are all within the latitude range covered by New Zealand.

AREA — DEPTH CURVES

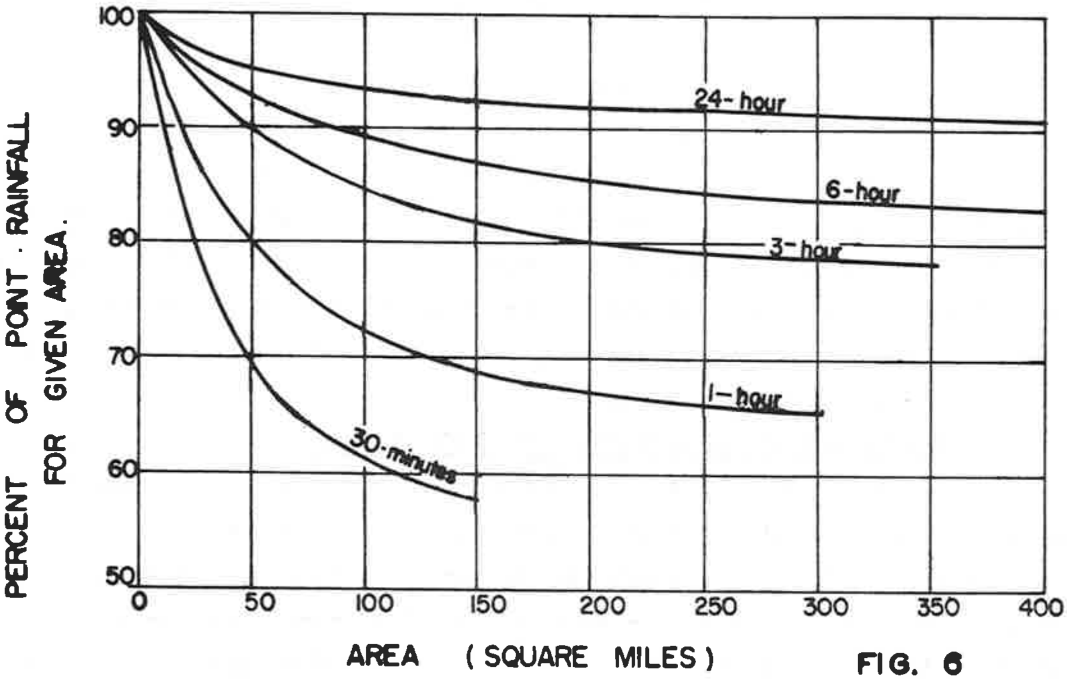
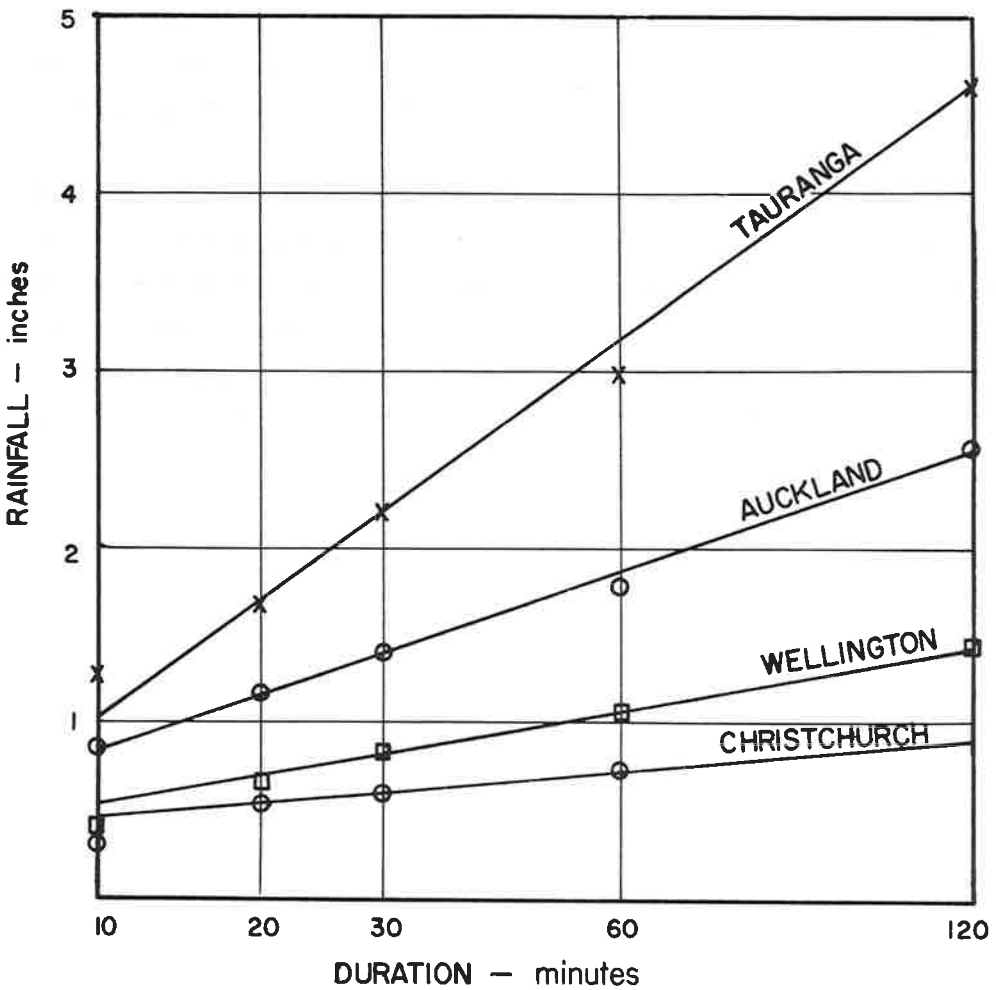


FIG. 6

The diagram shows that, with increasing area, the ratio of the areal-rainfall to the point-rainfall falls off rapidly, as expected, for short-duration rainfalls. For example, the 30-minute point-rainfall is to be reduced to 70 percent for a catchment area of 50 sq. miles. On the other hand, a 24-hour areal-rainfall over an area of 300 sq. miles is taken as 91 percent of the point-rainfall.

Reference to U.S. Weather Bureau Technical Paper No. 29, Part I, Fig 1-5, shows that each of the four curves reproduced in our Fig 6 has been fitted to a set of plotted points which show considerable scatter. Thus, the results obtained from its use, either in U.S.A. or New Zealand, are somewhat uncertain. Nevertheless, it does provide a working diagram which can be modified as necessary when more observations become available in the future.

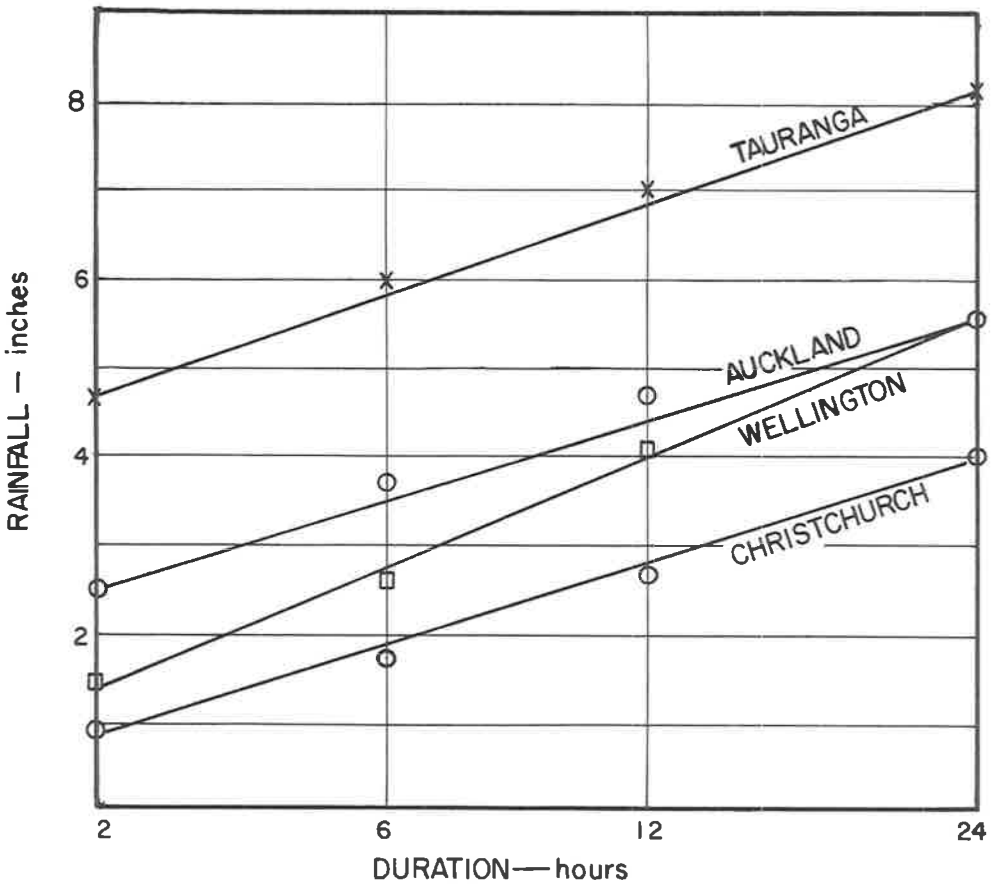


20 — YEAR RAINFALLS PLOTTED ON

FIG. 2

(Lines join values for durations of 30 & 120 minutes)

FIG. 7



20 — YEAR RAINFALLS PLOTTED ON FIG. 3

(Lines join values for 2 and 24 hours)

FIG. 8

12. USE OF MAPS AND DIAGRAMS

As stated in the introduction, the primary purpose of this paper is to present rainfall information in a form suitable for application to problems of hydrologic design. In the preceding sections the preparation of various maps, tables and diagrams is described, together with their limitations and the reasons for choosing this particular form of presentation. It is desirable that the user should become familiar with this background information, but the actual calculation of the required point-rainfall or areal-rainfall of given duration and frequency X(T, t, A) can be carried out in simple steps following the scheme shown by the two examples in Table 10.

12.1 Durations 10-minutes to 24-hours

Step I (Table 10) involves locating the given point on Fig 9a and interpolating the 2-year $\frac{1}{2}$-hour rainfall from the isohyets. To locate the point on Fig 9a it is convenient to use the latitude and longitude pre-determined from, say, the 1.500,000 Hydrologic Key Map (NZMS 19B). The points marked on Fig 9a locate the 44 stations for which detailed results are given in Appendix I.

For steps 2, 3 and 4 the procedure is the same as for step 1. Note, however, that if the value of X(T, t, A) is not required for durations less than 2 hours, steps 1 and 2 are omitted.

The values scaled from the maps will be least reliable in those parts where the rainfall gradient is greatest, for example on the West Coast of the South Island and in Taranaki. The maps should not be used for elevations above about 2000 ft., as no rainfall intensity observations at high levels were available.

Steps 5 and 6 are required if X(T, t, A) is to be computed for durations greater than 2 hours. The order in which stations appear in Table 9 is based on the rainfall station indicator. This consists of a rainfall district letter (A to I) followed by a five figure number as explained in the legend on the Hydrologic Key Map. In Table 9 the stations are grouped into rainfall districts, and in numerical order within districts. Normally it will be necessary to interpolate from the nearest listed stations. For a few stations two values of the 24-hour rainfalls are available - one from Table 9, and the other from Appendix I. As discussed previously in Section 10.4 preference should normally be given to the value included in Table 9. As the 24-hour

Table 10

EXAMPLES OF RAINFALL DEPTH-DURATION-FREQUENCY-AREA COMPUTATIONS

T = return period t = duration A = area (square miles)			Pukekohe 5 years 1 hour 20 sq m.	Ashburton 10 years 6 hours 200 sq m.
1.	2-year, ½-hour rainfall	Fig 9a	0.7	-
2.	20-year, ½-hour rainfall	Fig 9b	1.4	-
3.	2-year, 2-hour rainfall	Fig 10a	1.3	0.6
4.	20-year, 2-hour rainfall	Fig 10b	2.5	1.0
5.	2-year, 24-hour rainfall	Table 9	-*	2.4
6.	20-year, 24-hour rainfall	Table 9	-*	4.9
7.	Join (1) and (2) and read where line intersects given return period.	Fig 5	1.0	-
8.	Join (3) and (4) and read where line intersects given return period.	Fig 5	1.9	0.9
9.	Join (5) and (6) and read where line intersects given return period.	Fig 5	-*	4.2
10.	Join (7) and (8) and read where line intersects given duration.	Fig 4a	1.4	-
11.	Join (8) and (9) and read where line intersects given duration	Fig 4b	-*	2.0
12.	Percentage of point-rainfall	Fig 6	90	85
13.	X(T,t,A) = (10) x (12) or = (11) x (12)	-	1.2	1.7

* not needed when X(T,t,A) is required for t = 1 hour.

NOTE: The line (7) to (8) on Fig 4a is the depth-duration curve for the given return period; values of X(T,t) for other durations can be read from it.

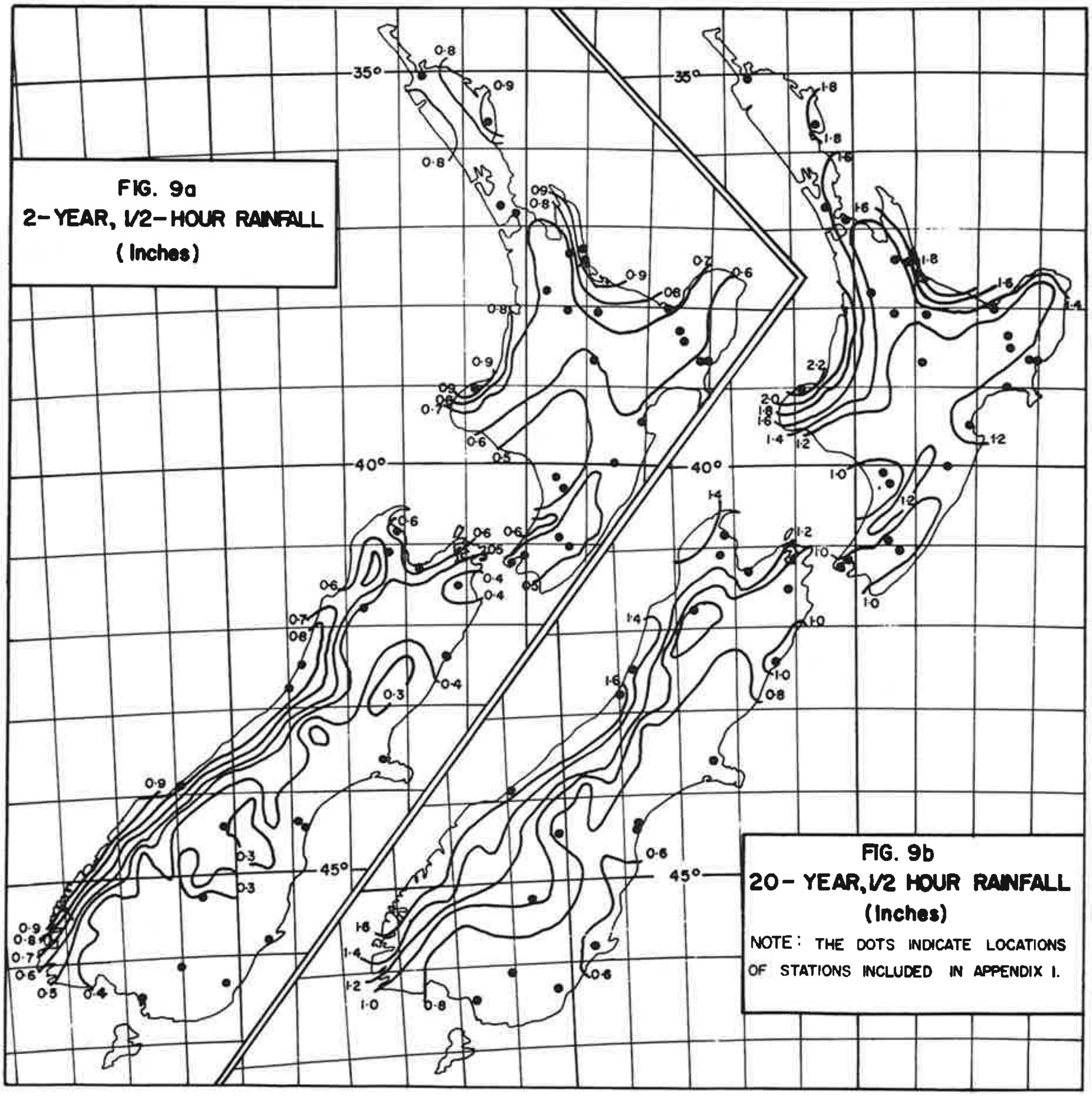


FIG. 9a
2-YEAR, 1/2-HOUR RAINFALL
(Inches)

FIG. 9b
20-YEAR, 1/2 HOUR RAINFALL
(Inches)

NOTE: THE DOTS INDICATE LOCATIONS OF STATIONS INCLUDED IN APPENDIX I.

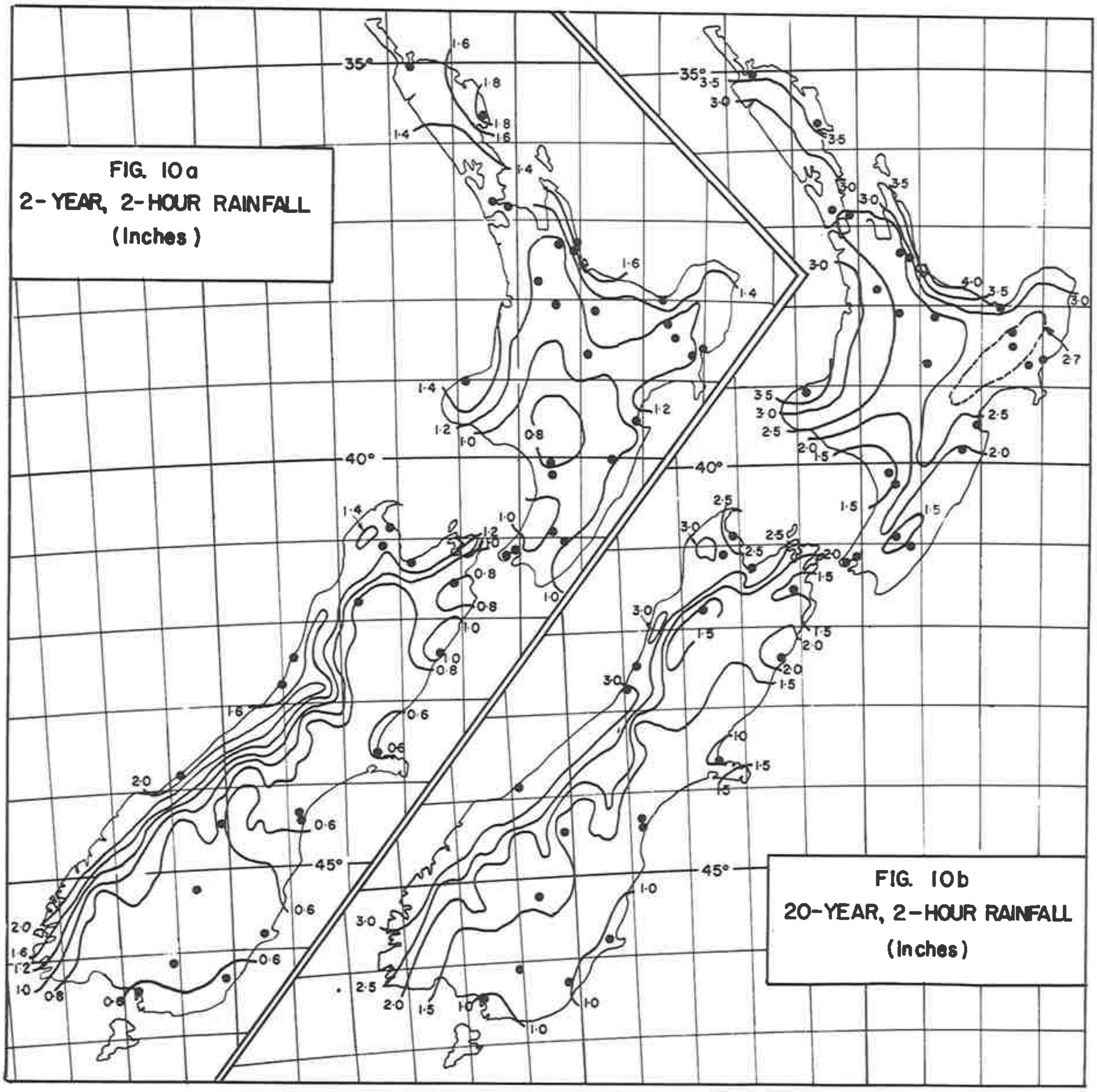


FIG. 10a
2-YEAR, 2-HOUR RAINFALL
(Inches)

FIG. 10b
20-YEAR, 2-HOUR RAINFALL
(Inches)

rainfalls are strongly influenced by orographical effects, large differences may be found between the tabulated values from neighbouring stations, especially when they differ appreciably in elevation or aspect. Sampling errors, as well as orographical effects contribute to the inter-station variations, and the user must exercise his own judgment and local knowledge in arriving at satisfactory values for the 2-year and 20-year rainfalls at the given point.

The next five steps in the computation, 7 to 11, are straight-forward graphical interpolations using Figs. 4a, 4b and 5 as described in Table 10. Steps 7 and 10, or 9 and 11, are omitted according as the required duration is over or under 2 hours. The areal adjustment to the point-rainfall is then read from Fig 6 and used as the multiplier in the final step of the computation.

If all the steps are followed through from 1 to 11 the two lines obtained in steps 10 and 11 approximate the rainfall depth-duration relation from 10 minutes to 24 hours for the given return period.

12.1.1. Alternative Method of Interpolation

Alternatively the interpolations involved in steps 7 to 11 can be made arithmetically in the following way:

(a) The values interpolated from the maps in Figs 9 and 10 and Table 9 (Table 10, steps 1-6) are used to evaluate:

$$j = e + C_T\,(f - e)$$

$$l = g + C_T\,(h - g)$$

where C_T is read from Table 12 below and e, f, g, and h are defined as follows, depending on whether the required duration is (i) less than 2 hours or (ii) greater than 2 hours.

(i) t less than 2 hours	(ii) t greater than 2 hours
$e = X(2, \frac{1}{2})$	$e = X(2, 2)$
$f = X(20, \frac{1}{2})$	$f = X(20, 2)$
$g = X(2, 2)$	$g = X(2, 24)$
$h = X(20, 2)$	$h = X(20, 24)$

(b) Having evaluated j and l we have finally:

(i) $X(T,t) = j + A_1(l-j)$ or (ii) $X(T,t) = j + A_2(l-j)$

depending again on whether t is less than or greater than 2 hours. The values of A_1 and A_2 are given in Table 13 below.

Table 12 (c.f. Table 4)

T(years)	2	5	10	15	20	25	30	40	50	75	100
C_T	0	0.44	0.72	0.89	1.00	1.09	1.16	1.28	1.36	1.52	1.63
T (years)	150	200	250	500	1000						
C_T	1.78	1.89	1.98	2.24	2.52						

Table 13

t(minutes)	10	20	30	45	60	90	120		
A_1	−0.49	−0.21	0	+0.22	+0.40	+0.73	1.00		
t(hours)	2	4	6	8	10	12	16	20	24
A_2	0	0.19	0.33	0.44	0.54	0.63	0.77	0.90	1.00

EXAMPLE To calculate X(10,6) for Ashburton using data given in Table 10. Here, T = 10years, t = 6 hours, e = 0.6, f = 1.0, g = 2.4
h = 4.9, C_T = 0.72 (Table 12), A_2 = 0.33 (Table 13)

hence $j = 0.6 + 0.72 \times 0.4 = 0.89$

$l = 2.4 + 0.72 \times 2.5 = 4.2$

Therefore $X(10,6) = 0.89 + 0.33 \times 3.31$

$= 1.98$

12.2 Durations 24-hours to 72-hours

Should estimates of X(T,t) be required for t between 24 hours and 72 hours these can be obtained in the following way :

(a) Estimate for the given point the 2-year and 20-year rainfalls for durations of 24, 48, and 72 hours from the data for the nearest stations included in Table 9.

(b) Interpolate for the required return period by plotting each pair of points on Fig. 5.

(c) Plot on Fig. 4b the three values of X(T,24), X(T,48) and X(T,72) obtained from step (b) and join with a smooth curve. The required value of X(T,t) is read off this curve.

Note that the calibration of the duration scale is such that the curve joining the above three points will be close to a straight line. This line is, however, not simply an extension of the line joining the points (T, 2) and (T, 24); there is usually a discontinuity at 24 hours.

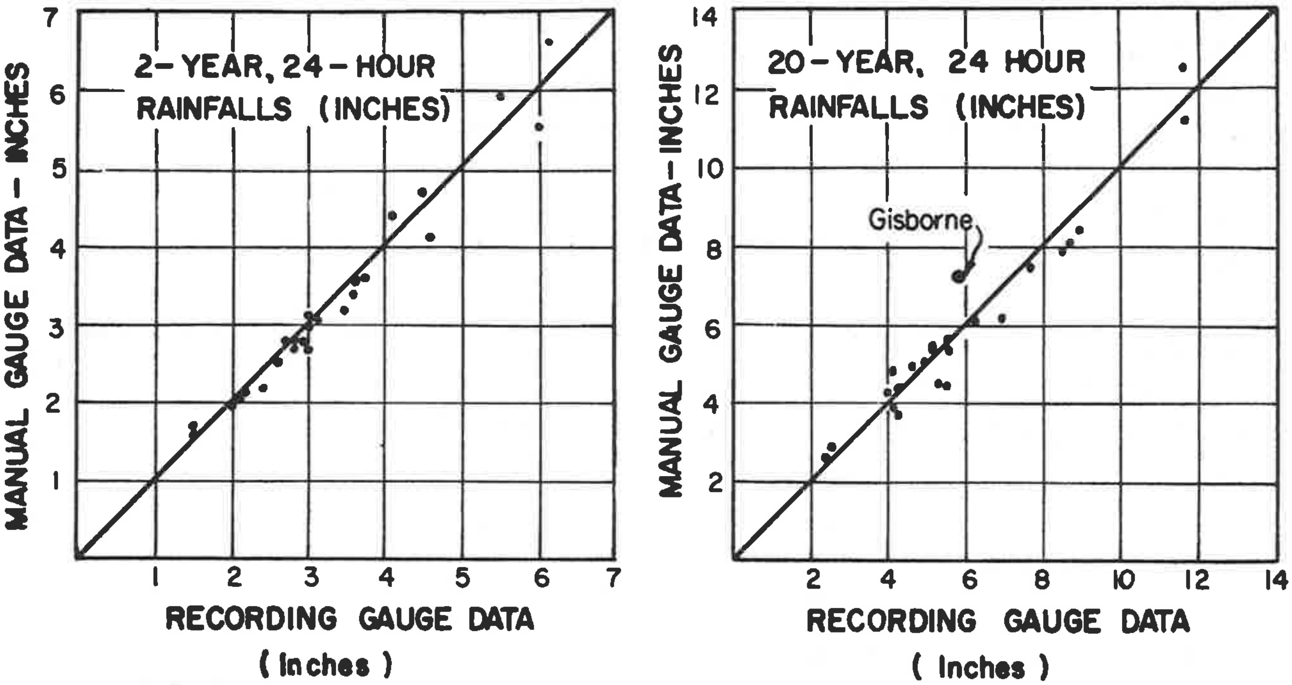


FIG. 11

CORRELATION OF 24-HOUR FALLS OBTAINED FROM RECORDED RAINGAUGES WITH CORRESPONDING VALUES ESTIMATED FROM DAILY (9 A.M. - 9 A.M.) MANUAL GAUGE READINGS AT THE SAME STATION OVER A MUCH LONGER PERIOD.

No attempt has been made to relate point-rainfall to areal-rainfall for falls of duration greater than 24-hours. Long duration falls such as these are normally considered only in connection with very large catchment areas, and the technique involving the use of Fig. 6 is not suitable for such large areas.

13. ACKNOWLEDGMENTS

The results presented in this paper have involved a considerable amount of painstaking work in selecting, checking, and processing data from hundreds of long-period rainfall records. This work has been spread over many years, and many of the staff of the Climatological Section have contributed. Special thanks are due to F. Bondy, who supervised the analysis of the autographic charts from recording raingauges and has carried out many of the calculations; to D.C. Meldrum who supervised the preparation of the maximum 1-day, 2-day, and 3-day statistics; and to B.C. Ereckson who performed the punched-card calculations using the IBM machines at the Central Accounting Bureau of The Treasury.

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APPENDIX I Depth-Duration-Frequency Tables for 44 Stations equipped with Recording Raingauges.

n = No of years of recordings. (no data given for n less than 9)

t = duration (M = minutes, H = hours)

T = return period (years)

$\bar{x}$ = mean of annual maximum rainfalls for given duration (inches)

s = standard deviation of annual maximum rainfalls.

V = coefficient of variation = $s/\bar{x}$

A 53022 KAITAIA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
8	10M								
8	20M								
11	30M	.77	1.17	1.43	1.68	2.01	.82	.34	.42
11	1H	1.06	1.70	2.12	2.52	3.04	1.14	.54	.47
11	2H	1.45	2.32	2.89	3.44	4.16	1.55	.74	.48
11	6H	2.44	3.64	4.44	5.21	6.21	2.58	1.03	.40
11	12H	3.04	4.52	5.50	6.43	7.66	3.22	1.26	.39
11	24H	3.60	5.10	6.10	7.05	8.29	3.78	1.28	.34
11	48H	4.15	5.99	7.21	8.37	9.90	4.37	1.57	.36
11	72H	4.55	6.41	7.65	8.83	10.37	4.78	1.59	.33

A 54631 GLENBERVIE

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.55	.75	.88	1.01	1.18	.57	.17	.30
10	20M	.81	1.13	1.33	1.53	1.78	.85	.26	.31
10	30M	1.01	1.46	1.75	2.03	2.39	1.07	.37	.35
10	1H	1.5	2.1	2.5	2.8				
10	2H	2.00	2.67	3.12	3.54	4.09	2.08	.56	.27
10	6H	3.35	4.40	5.09	5.75	6.60	3.48	.87	.25
10	12H	4.70	5.90	6.69	7.45	8.43	4.84	1.00	.21
10	24H	6.33	8.39	9.75	11.06	12.74	6.57	1.72	.26
10	48H	7.42	9.55	10.95	12.29	14.03	7.67	1.77	.23
10	72H	8.39	11.74	13.94	16.06	18.79	8.78	2.79	.32

A 64761 WHENUAPAI

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
13	10M	.39	.59	.71	.83	.99	.42	.17	.41
13	20M	.60	.87	1.05	1.23	1.45	.63	.24	.38
13	30M	.81	1.15	1.38	1.59	1.87	.85	.30	.35
13	1H	1.09	1.46	1.70	1.93	2.22	1.14	.32	.28
13	2H	1.38	1.80	2.08	2.35	2.69	1.43	.37	.26
13	6H	2.04	2.60	2.97	3.32	3.78	2.11	.49	.23
13	12H	2.60	3.49	4.07	4.63	5.36	2.71	.78	.29
13	24H	3.12	4.48	5.37	6.22	7.33	3.29	1.19	.36
13	48H	3.80	5.43	6.51	7.54	8.87	4.00	1.43	.36
13	72H	4.47	6.55	7.91	9.22	10.91	4.73	1.82	.39

A 64872 MECHANICS BAY

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
19	10M	.49	.65	.76	.86	.99	.51	.15	.29
19	20M	.64	.88	1.03	1.18	1.38	.67	.22	.33
19	30M	.75	1.03	1.21	1.39	1.62	.78	.26	.33
19	1H	.89	1.27	1.52	1.76	2.07	.95	.35	.37
19	2H	1.14	1.74	2.14	2.52	3.02	1.22	.56	.46
19	6H	1.84	2.68	3.23	3.76	4.45	1.95	.78	.40
18	12H	2.37	3.38	4.06	4.70	5.54	2.51	.94	.37
18	24H	2.74	3.94	4.74	5.50	6.49	2.91	1.11	.38
19	48H	3.23	4.57	5.45	6.29	7.38	3.42	1.24	.36
19	72H	3.51	4.89	5.80	6.67	7.80	3.70	1.28	.35

B 75361 PAEROA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M								
10	20M								
18	30M	.65	.93	1.12	1.29	1.53	.69	.26	.38
18	1H	.81	1.10	1.29	1.48	1.72	.85	.27	.32
18	2H	1.08	1.37	1.57	1.75	1.99	1.12	.27	.24
18	6H	2.19	2.73	3.09	3.43	3.87	2.26	.50	.22
18	12H	3.12	4.26	5.02	5.74	6.69	3.27	1.06	.32
18	24H	4.29	5.84	6.88	7.86	9.14	4.50	1.44	.32
18	48H	5.35	7.99	9.74	11.40	13.57	5.72	2.44	.43
18	72H	5.69	8.56	10.46	12.27	14.63	6.09	2.65	.43

B 75381 WAIHI

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.54	.70	.82	.92	1.06	.56	.14	.25
10	20M	.74	.96	1.10	1.24	1.42	.77	.18	.23
34	30M	.93	1.25	1.46	1.67	1.93	.97	.32	.33
34	1H	1.32	1.85	2.20	2.54	2.98	1.40	.53	.38
34	2H	1.78	2.49	2.96	3.42	4.00	1.88	.71	.38
34	6H	3.14	4.31	5.10	5.85	6.82	3.32	1.17	.35
34	12H	4.63	6.82	8.29	9.69	11.51	4.96	2.19	.44
34	24H	6.10	8.50	10.11	11.64	13.64	6.46	2.40	.37
34	48H	7.20	10.07	11.99	13.83	16.21	7.63	2.87	.38
34	72H	7.72	11.31	13.72	16.02	19.00	8.26	3.59	.43

B 75471 WAITAWHETA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
	10M								
	20M								
21	30M	.60	.75	.85	.94	1.06	.62	.14	.23
21	1H	.86	1.15	1.34	1.52	1.75	.90	.27	.30
21	2H	1.24	1.62	1.86	2.10	2.40	1.30	.35	.27
21	6H	2.17	2.73	3.11	3.47	3.93	2.25	.53	.24
21	12H	3.07	4.25	5.02	5.78	6.74	3.24	1.11	.34
21	24H	4.06	5.33	6.17	6.98	8.03	4.24	1.20	.28
21	48H	4.98	6.56	7.61	8.62	9.92	5.21	1.49	.29
21	72H	5.31	6.97	8.07	9.14	10.50	5.54	1.57	.28

B 76621 TAURANGA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
15	10M	.6	.9	1.1	1.3				
15	20M	.8	1.2	1.5	1.7				
15	30M	1.0	1.5	1.8	2.2				
15	1H	1.3	2.0	2.5	3.0				
15	2H	2.0	3.2	3.9	4.6				
15	6H	2.9	4.2	5.1	6.0				
15	12H	3.7	5.1	6.1	7.0				
15	24H	4.5	6.1	7.1	8.1				
15	48H	5.0	6.8	8.0	9.1				
15	72H	5.7	7.6	8.8	10.0				

B 86124 WHAKAREWAREWA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.41	.54	.63	.71	.82	.43	.11	.26
10	20M	.60	.79	.92	1.04	1.20	.63	.16	.26
10	30M	.72	.96	1.12	1.27	1.47	.75	.20	.27
10	1H	1.01	1.39	1.63	1.87	2.17	1.06	.31	.29
10	2H	1.37	1.84	2.15	2.45	2.83	1.43	.39	.27
10	6H	2.02	2.47	2.77	3.06	3.43	2.07	.38	.18
10	12H	2.68	3.30	3.71	4.11	4.61	2.75	.52	.19
10	24H	3.61	4.59	5.24	5.86	6.67	3.72	.82	.22
10	48H	5.00	6.19	6.97	7.72	8.69	5.14	.99	.19
10	72H	5.46	6.82	7.71	8.57	9.68	5.62	1.13	.20

B 86602 TAUPO

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.34	.43	.50	.56	.64	.35	.08	.23
9	20M	.47	.62	.71	.81	.93	.49	.12	.25
9	30M	.58	.80	.95	1.09	1.27	.61	.18	.30
9	1H	.82	1.15	1.36	1.57	1.84	.85	.27	.32
9	2H	1.17	1.67	2.01	2.32	2.73	1.23	.41	.33
9	6H	1.68	2.28	2.68	3.05	3.54	1.75	.49	.28
9	12H	2.07	2.79	3.26	3.72	4.31	2.14	.59	.28
9	24H	2.80	3.89	4.62	5.32	6.22	2.91	.90	.31
9	48H	3.64	5.07	6.02	6.92	8.09	3.79	1.17	.31
9	72H	3.84	5.34	6.34	7.28	8.51	4.00	1.23	.31

B 87031 OPOTIKI

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
5	10M								
5	20M								
18	30M	.69	.96	1.14	1.31	1.54	.73	.25	.34
18	1H	1.03	1.42	1.68	1.92	2.24	1.08	.36	.33
18	2H	1.48	2.14	2.58	2.99	3.54	1.57	.61	.39
18	6H	2.50	3.63	4.39	5.10	6.03	2.65	1.05	.40
18	12H	3.11	4.44	5.34	6.18	7.28	3.29	1.24	.38
18	24H	3.72	5.10	6.01	6.87	8.00	3.92	1.27	.32
18	48H	4.38	5.87	6.86	7.80	9.03	4.58	1.38	.30
18	72H	4.84	6.69	7.92	9.08	10.60	5.10	1.71	.34

B 87232 MOTU

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
	10M								
	20M								
12	30M	.62	.83	.97	1.10	1.27	.65	.18	.28
12	1H	.94	1.15	1.29	1.42	1.59	.97	.18	.19
12	2H	1.55	2.05	2.39	2.71	3.13	1.61	.44	.27
12	6H	3.08	4.04	4.68	5.28	6.07	3.20	.83	.26
12	12H	4.38	5.64	6.49	7.29	8.34	4.53	1.10	.24
12	24H	5.97	7.46	8.46	9.41	10.65	6.15	1.30	.21
12	48H	7.32	9.25	10.55	11.77	13.37	7.56	1.68	.22
12	72H	7.64	9.92	11.44	12.89	14.77	7.92	1.98	.25

B 87351 MATAWAI

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
8	10M								
8	20M								
11	30M	.61	.83	.98	1.12	1.30	.63	.19	.30
11	1H	.85	1.13	1.32	1.50	1.73	.89	.24	.27
11	2H	1.16	1.62	1.92	2.21	2.59	1.22	.39	.32
11	6H	1.98	2.68	3.15	3.60	4.18	2.07	.60	.29
11	12H	2.80	4.05	4.89	5.68	6.72	2.95	1.07	.36
11	24H	3.75	5.67	6.95	8.17	9.76	3.98	1.64	.41
11	48H	4.89	7.04	8.48	9.84	11.62	5.15	1.84	.36
11	72H	5.69	7.88	9.34	10.72	12.54	5.96	1.87	.31

C 75731 RUAKURA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
12	10M	.37	.50	.58	.66	.77	.39	.11	.28
12	20M	.53	.74	.88	1.01	1.18	.56	.18	.32
12	30M	.66	.96	1.16	1.35	1.60	.70	.26	.37
12	1H	.93	1.52	1.91	2.28	2.77	1.00	.51	.51
12	2H	1.19	1.89	2.36	2.81	3.38	1.27	.61	.48
12	6H	1.80	2.68	3.28	3.84	4.57	1.91	.77	.40
12	12H	2.23	3.15	3.77	4.35	5.11	2.34	.80	.34
12	24H	2.70	3.92	4.73	5.51	6.52	2.85	1.06	.37
12	48H	3.23	4.66	5.61	6.52	7.69	3.40	1.24	.36
12	72H	3.32	4.93	6.01	7.03	8.36	3.51	1.40	.40

C 85061 ARAPUNI

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
8	10M								
8	20M								
19	30M	.71	1.04	1.25	1.45	1.72	.76	.30	.40
19	1H	.86	1.22	1.47	1.70	2.00	.91	.34	.37
19	2H	1.11	1.65	2.00	2.34	2.78	1.18	.50	.42
19	6H	1.76	2.37	2.78	3.17	3.67	1.84	.57	.31
19	12H	2.24	3.01	3.51	4.00	4.62	2.35	.71	.30
19	24H	3.00	4.06	4.75	5.42	6.28	3.15	.98	.31
19	48H	3.50	4.77	5.61	6.41	7.45	3.67	1.18	.32
19	72H	3.92	5.33	6.26	7.16	8.31	4.12	1.31	.32

D 05964 WAINGAWA, MASTERTON

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
11	10M	.25	.36	.44	.52	.61	.26	.10	.38
11	20M	.34	.55	.69	.82	1.00	.36	.18	.49
11	30M	.40	.63	.77	.92	1.10	.43	.19	.44
11	1H	.53	.74	.88	1.01	1.18	.55	.18	.33
11	2H	.68	.87	1.00	1.11	1.27	.71	.16	.23
11	6H	1.31	1.59	1.78	1.96	2.19	1.34	.24	.18
11	12H	1.87	2.26	2.51	2.76	3.08	1.92	.33	.17
11	24H	2.55	3.57	4.25	4.89	5.74	2.68	.87	.33
11	48H	3.07	4.30	5.12	5.89	6.91	3.22	1.05	.33
11	72H	3.54	4.64	5.38	6.07	6.98	3.68	.94	.26

D 06051 WAIPUKURAU

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.37	.58	.72	.86	1.04	.39	.18	.46
10	20M	.5	.7	.9	1.0				
10	30M	.6	.8	1.0	1.1				
10	1H	.8	1.0	1.2	1.3				
10	2H	1.0	1.2	1.4	1.6				
10	6H	1.45	2.06	2.46	2.85	3.35	1.52	.51	.34
10	12H	2.11	2.88	3.39	3.87	4.50	2.20	.64	.29
10	24H	2.81	3.61	4.13	4.63	5.28	2.91	.66	.23
10	48H	3.83	4.79	5.42	6.03	6.81	3.94	.80	.20
10	72H	4.38	5.63	6.45	7.24	8.26	4.53	1.04	.23

D 15081 NGAUMU MASTERTON

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.23	.32	.39	.45	.53	.24	.08	.33
10	20M	.34	.48	.56	.65	.75	.36	.11	.31
10	30M	.41	.54	.63	.71	.82	.43	.11	.26
10	1H	.61	.81	.95	1.08	1.24	.63	.17	.27
10	2H	.92	1.19	1.37	1.55	1.77	.95	.23	.24
10	6H	1.84	2.30	2.60	2.88	3.26	1.89	.38	.20
10	12H	2.87	3.91	4.60	5.26	6.12	2.99	.87	.29
10	24H	4.42	6.39	7.68	8.93	10.54	4.65	1.64	.35
10	48H	5.65	7.94	9.45	10.90	12.78	5.92	1.91	.32
10	72H	6.20	8.79	10.50	12.14	14.26	6.50	2.16	.33

D 87681 WAERENGAOKURI

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.33	.51	.62	.74	.88	.35	.15	.43
10	20M	.49	.79	.99	1.18	1.42	.52	.25	.48
10	30M	.59	.97	1.22	1.47	1.78	.63	.32	.51
10	1H	.84	1.55	2.02	2.47	3.05	.93	.59	.64
10	2H	1.19	2.03	2.58	3.11	3.80	1.29	.70	.54
10	6H	2.02	2.89	3.47	4.03	4.74	2.12	.73	.34
10	12H	2.84	3.73	4.32	4.88	5.60	2.95	.74	.25
10	24H	3.76	4.97	5.77	6.54	7.53	3.90	1.01	.26
10	48H	5.32	7.01	8.13	9.20	10.58	5.52	1.41	.26
10	72H	5.88	7.84	9.13	10.36	11.96	6.11	1.63	.27

D 87692 GISBORNE AIRFIELD

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
11	10M	.32	.40	.46	.51	.58	.33	.07	.21
11	20M	.47	.61	.70	.79	.91	.49	.12	.25
11	30M	.58	.74	.84	.93	1.06	.60	.13	.22
11	1H	.86	1.08	1.22	1.35	1.52	.89	.18	.20
11	2H	1.19	1.78	2.17	2.54	3.02	1.26	.50	.40
11	6H	1.95	2.60	3.03	3.43	3.97	2.03	.55	.27
11	12H	2.69	3.27	3.65	4.01	4.49	2.76	.49	.18
11	24H	3.49	4.50	5.18	5.83	6.67	3.61	.87	.24
11	48H	4.30	5.93	7.01	8.04	9.39	4.50	1.39	.31
11	72H	4.94	6.77	7.98	9.14	10.65	5.16	1.56	.30

D 96481 WESTSHORE, NAPIER

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.33	.51	.62	.74	.89	.35	.15	.43
10	20M	.5	.7	.9	1.1				
20	30M	.6	.9	1.2	1.4				
20	1H	.76	1.19	1.47	1.74	2.09	.82	.40	.49
20	2H	1.03	1.64	2.04	2.43	2.93	1.11	.57	.51
20	6H	1.71	2.58	3.15	3.70	4.41	1.84	.81	.44
20	12H	2.29	3.13	3.69	4.22	4.92	2.41	.79	.33
20	24H	2.97	4.01	4.69	5.35	6.20	3.12	.97	.31
20	48H	3.55	4.83	5.67	6.49	7.55	3.73	1.20	.32
20	72H	3.80	5.11	5.98	6.81	7.89	3.98	1.23	.31

D 97041 WAIROA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.31	.45	.55	.64	.76	.32	.12	.37
9	20M	.51	.80	1.00	1.18	1.42	.54	.24	.45
27	30M	.53	.82	1.02	1.21	1.46	.57	.29	.51
27	1H	.78	1.17	1.43	1.67	2.00	.83	.38	.46
27	2H	1.10	1.70	2.09	2.47	2.96	1.19	.58	.49
27	6H	2.10	3.14	3.82	4.48	5.34	2.25	1.01	.45
27	12H	2.81	4.12	4.98	5.81	6.89	3.00	1.27	.42
27	24H	3.66	5.28	6.36	7.38	8.73	3.89	1.58	.41
27	48H	4.61	6.82	8.27	9.66	11.48	4.93	2.14	.43
27	72H	5.10	7.66	9.34	10.95	13.06	5.47	2.48	.45

E 05231 OHAKEA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
19	10M	.27	.36	.42	.47	.54	.29	.08	.28
19	20M	.37	.50	.58	.67	.77	.39	.12	.31
19	30M	.46	.62	.73	.83	.96	.48	.15	.31
19	1H	.60	.82	.96	1.10	1.27	.63	.20	.32
19	2H	.78	1.09	1.30	1.50	1.75	.83	.29	.35
19	6H	1.4	1.9	2.3	2.7				
19	12H	1.76	2.48	2.96	3.41	4.00	1.86	.67	.36
19	24H	2.19	3.00	3.53	4.04	4.70	2.30	.75	.33
19	48H	2.53	3.37	3.92	4.45	5.14	2.65	.78	.29
19	72H	2.74	3.64	4.23	4.79	5.52	2.86	.83	.29

E 05363 PALMERSTON NORTH

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
13	10M	.31	.49	.61	.72	.87	.33	.16	.49
13	20M	.42	.58	.69	.79	.92	.44	.14	.32
13	30M	.48	.64	.74	.84	.97	.50	.14	.28
13	1H	.68	.88	1.00	1.13	1.29	.71	.17	.24
13	2H	.91	1.18	1.36	1.53	1.76	.94	.24	.25
13	6H	1.43	1.78	2.02	2.24	2.53	1.47	.31	.21
13	12H	2.0	2.4	2.8	3.0				
13	24H	2.40	3.20	3.72	4.23	4.88	2.50	.70	.28
13	48H	2.74	3.90	4.67	5.40	6.35	2.88	1.02	.35
13	72H	2.91	4.10	4.88	5.62	6.59	3.06	1.04	.34

E 14272 KELBURN

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
31	10M	.27	.35	.41	.46	.53	.29	.08	.28
31	20M	.38	.51	.60	.69	.80	.40	.13	.32
31	30M	.48	.63	.73	.83	.95	.50	.15	.30
31	1H	.66	.83	.94	1.05	1.20	.68	.17	.25
31	2H	.93	1.14	1.28	1.41	1.59	.96	.21	.22
31	6H	1.69	2.10	2.38	2.64	2.99	1.75	.41	.23
31	12H	2.31	3.06	3.57	4.05	4.68	2.42	.75	.31
31	24H	2.99	4.08	4.82	5.51	6.42	3.15	1.08	.34
31	48H	3.53	4.93	5.87	6.76	7.93	3.73	1.39	.37
31	72H	3.82	5.21	6.14	7.01	8.17	4.03	1.37	.34

E 14291 LOWER HUTT

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
11	10M	.30	.42	.50	.57	.67	.32	.10	.32
11	20M	.40	.54	.63	.72	.84	.42	.12	.29
11	30M	.49	.61	.68	.76	.86	.50	.10	.20
11	1H	.68	.89	1.03	1.17	1.34	.71	.18	.25
11	2H	.94	1.21	1.39	1.56	1.79	.98	.23	.24
11	6H	1.69	2.00	2.21	2.41	2.68	1.73	.27	.16
11	12H	2.23	2.71	3.03	3.34	3.73	2.29	.41	.18
11	24H	2.89	3.86	4.51	5.13	5.93	3.01	.83	.28
11	48H	3.67	5.04	5.95	6.82	7.95	3.84	1.17	.31
11	72H	4.27	5.76	6.75	7.69	8.92	4.45	1.27	.29

F 02871 TAKAKA AIRFIELD

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
	10M								
	20M								
12	30M	.59	.78	.92	1.04	1.20	.61	.17	.28
12	1H	.87	1.13	1.31	1.48	1.70	.90	.23	.26
12	2H	1.32	1.63	1.84	2.04	2.30	1.36	.27	.20
12	6H	2.68	3.28	3.68	4.06	4.55	2.75	.52	.19
12	12H	3.40	4.32	4.94	5.52	6.28	3.51	.80	.23
12	24H	4.17	5.40	6.22	7.00	8.02	4.32	1.07	.25
12	48H	5.30	7.98	9.77	11.47	13.69	5.63	2.33	.41
12	72H	5.84	9.33	11.66	13.87	16.75	6.27	3.03	.48

F 12162 COBB DAM

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
12	10M	.25	.36	.44	.51	.61	.26	.10	.38
12	20M	.38	.58	.71	.83	.99	.41	.17	.42
12	30M	.51	.81	1.01	1.20	1.45	.55	.26	.48
12	1H	.76	1.12	1.37	1.60	1.91	.80	.32	.40
12	2H	1.23	1.91	2.36	2.79	3.35	1.31	.59	.45
12	6H	2.68	4.50	5.72	6.87	8.37	2.90	1.58	.54
12	12H	4.04	7.19	9.30	11.30	13.91	4.43	2.74	.62
12	24H	5.92	11.15	14.66	17.98	22.30	6.56	4.55	.69

NOTE: Values for durations of 12 hours or more are too high due to the influence of one exceptionally heavy rainfall during which 12.2 inches fell in 12 hours and 20.1 inches in 24 hours.

F 12831 MURCHISON

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
8	10M								
8	20M								
29	30M	.35	.51	.62	.73	.86	.37	.16	.43
29	1H	.49	.65	.76	.86	1.00	.51	.16	.31
29	2H	.70	.90	1.04	1.17	1.33	.73	.20	.28
29	6H	1.29	1.72	2.01	2.28	2.63	1.36	.42	.31
29	12H	1.86	2.53	2.98	3.41	3.96	1.95	.66	.34
29	24H	2.55	3.33	3.85	4.34	4.98	2.67	.76	.28
29	48H	3.16	4.16	4.83	5.46	6.29	3.31	.98	.30
29	72H	3.70	4.83	5.57	6.29	7.21	3.87	1.10	.28

F 20791 HOKITIKA SOUTH

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
15	10M	.45	.61	.71	.81	.94	.47	.14	.30
15	20M	.66	.95	1.14	1.32	1.56	.70	.26	.37
15	30M	.82	1.19	1.43	1.66	1.96	.87	.33	.38
15	1H	1.14	1.63	1.95	2.27	2.67	1.21	.44	.36
15	2H	1.54	2.16	2.57	2.97	3.48	1.62	.56	.35
15	6H	2.55	3.32	3.82	4.31	4.94	2.65	.69	.26
15	12H	3.46	4.74	5.59	6.41	7.47	3.62	1.16	.32
15	24H	4.50	6.25	7.39	8.51	9.94	4.72	1.57	.33
15	48H	6.00	8.13	9.53	10.89	12.64	6.27	1.92	.31
15	72H	6.99	9.01	10.34	11.64	13.29	7.25	1.82	.25

F 21422 GREYMOUTH

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.44	.59	.70	.80	.93	.45	.13	.29
9	20M	.61	.80	.93	1.06	1.22	.63	.16	.25
9	30M	.79	1.05	1.23	1.40	1.62	.82	.22	.27
9	1H	1.07	1.51	1.80	2.08	2.44	1.12	.36	.32
9	2H	1.44	1.87	2.15	2.42	2.77	1.49	.35	.24
9	6H	2.22	2.89	3.34	3.76	4.31	2.29	.55	.24
9	12H	3.21	4.26	4.96	5.62	6.48	3.32	.86	.26
9	24H	4.59	5.88	6.74	7.56	8.62	4.73	1.06	.22
9	48H	6.00	8.18	9.62	10.99	12.77	6.24	1.78	.29
9	72H	6.91	9.38	11.01	12.57	14.59	7.18	2.02	.28

F 39801 HAAST

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.46	.63	.75	.85	.99	.48	.14	.29
9	20M	.61	.84	.99	1.14	1.33	.63	.19	.30
9	30M	.71	1.00	1.20	1.38	1.62	.74	.24	.32
9	1H	.96	1.33	1.59	1.82	2.13	1.00	.31	.31
9	2H	1.49	2.19	2.66	3.11	3.69	1.56	.58	.37
9	6H	3.13	4.54	5.47	6.35	7.50	3.28	1.15	.35
9	12H	4.24	6.18	7.47	8.70	10.29	4.45	1.59	.36
9	24H	5.51	8.15	9.90	11.56	13.72	5.80	2.16	.37
9	48H	6.75	9.66	11.60	13.44	15.83	7.06	2.39	.34
9	72H	7.63	10.90	13.07	15.13	17.81	7.98	2.68	.34

G 13321 RODING RIVER

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
15	10M	.35	.50	.61	.71	.83	.37	.14	.38
15	20M	.48	.76	.94	1.12	1.34	.51	.25	.49
15	30M	.60	.92	1.13	1.34	1.60	.64	.29	.46
15	1H	.88	1.36	1.67	1.98	2.37	.94	.43	.46
15	2H	1.21	1.80	2.19	2.57	3.05	1.29	.53	.41
15	6H	1.86	2.50	2.92	3.33	3.86	1.94	.58	.30
15	12H	2.22	2.89	3.32	3.75	4.30	2.30	.60	.26
15	24H	2.67	3.28	3.68	4.07	4.57	2.75	.55	.20
15	48H	3.28	3.92	4.33	4.74	5.26	3.36	.57	.17
15	72H	3.62	4.44	4.98	5.50	6.18	3.72	.74	.20

G 13592 BLENHEIM

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
17	10M	.21	.38	.50	.61	.75	.23	.16	.69
17	20M	.30	.52	.67	.81	.98	.33	.20	.60
17	30M	.36	.58	.73	.87	1.04	.39	.20	.51
17	1H	.49	.72	.87	1.01	1.20	.52	.21	.40
17	2H	.73	1.02	1.20	1.39	1.62	.77	.26	.34
17	6H	1.20	1.75	2.11	2.46	2.90	1.28	.50	.39
17	12H	1.73	2.51	3.02	3.51	4.15	1.84	.71	.39
17	24H	2.14	3.00	3.57	4.12	4.83	2.26	.79	.35
17	48H	2.53	3.60	4.30	4.99	5.86	2.68	.98	.37
17	72H	2.75	3.92	4.69	5.44	6.39	2.91	1.07	.37

G 23471 KAIKOURA AERADIO

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.23	.46	.62	.76	.95	.26	.19	.74
9	20M	.33	.57	.74	.89	1.09	.36	.20	.56
9	30M	.41	.65	.80	.95	1.14	.44	.19	.43
9	1H	.65	.94	1.14	1.32	1.56	.68	.24	.35
9	2H	1.02	1.48	1.79	2.08	2.46	1.07	.38	.36
9	6H	1.98	2.91	3.52	4.11	4.87	2.08	.76	.37
9	12H	2.93	4.30	5.21	6.07	7.19	3.08	1.12	.36
9	24H	3.79	5.30	6.31	7.26	8.50	3.95	1.24	.31
9	48H	4.34	5.70	6.61	7.47	8.59	4.48	1.12	.25
9	72H	4.55	5.88	6.76	7.60	8.69	4.69	1.09	.23

H 32561 CHRISTCHURCH

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
25	10M	.18	.28	.34	.40	.48	.20	.09	.45
25	20M	.25	.38	.46	.54	.64	.27	.12	.44
25	30M	.30	.44	.54	.63	.75	.32	.14	.44
25	1H	.41	.55	.65	.74	.86	.43	.14	.33
25	2H	.56	.71	.81	.90	1.02	.59	.14	.24
25	6H	1.06	1.32	1.50	1.66	1.87	1.10	.25	.23
25	12H	1.57	2.02	2.33	2.61	2.99	1.63	.44	.27
25	24H	2.15	2.93	3.45	3.93	4.58	2.26	.75	.33
25	48H	2.76	3.74	4.39	5.00	5.81	2.90	.94	.32
25	72H	2.98	4.12	4.88	5.60	6.54	3.14	1.10	.35

H 41411 ADAIR

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.20	.35	.46	.56	.69	.21	.13	.61
9	20M	.27	.49	.64	.78	.96	.30	.18	.60
9	30M	.33	.54	.67	.80	.97	.35	.17	.49
9	1H	.45	.68	.83	.98	1.17	.47	.19	.40
9	2H	.63	.90	1.08	1.25	1.47	.66	.22	.33
9	6H	.97	1.24	1.42	1.59	1.81	1.00	.22	.22
9	12H	1.35	1.90	2.27	2.61	3.06	1.41	.45	.32
9	24H	1.75	2.69	3.31	3.90	4.67	1.85	.77	.42
8	48H								
8	72H								

H 41421 TIMARU

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
11	10M	.18	.28	.35	.42	.50	.19	.09	.48
11	20M	.26	.39	.48	.56	.66	.28	.11	.40
11	30M	.32	.46	.55	.64	.76	.34	.12	.36
11	1H	.5	.6	.7	.8				
11	2H	.61	.78	.90	1.01	1.16	.63	.15	.24
11	6H	.98	1.30	1.51	1.71	1.97	1.02	.27	.27
11	12H	1.42	2.01	2.41	2.79	3.28	1.49	.51	.34
11	24H	1.98	2.85	3.44	3.99	4.72	2.08	.75	.36
11	48H	2.61	3.37	3.88	4.36	4.99	2.70	.65	.24
11	72H	2.77	3.53	4.04	4.52	5.15	2.87	.65	.23

I 49591 TARA HILLS

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.14	.26	.35	.42	.52	.16	.10	.65
9	20M	.20	.35	.45	.54	.66	.22	.12	.55
9	30M	.25	.41	.52	.62	.75	.27	.13	.49
9	1H	.38	.55	.66	.77	.91	.40	.14	.35
9	2H	.59	.77	.89	1.01	1.16	.61	.15	.25
9	6H	1.05	1.40	1.64	1.86	2.15	1.09	.29	.27
9	12H	1.35	1.78	2.06	2.33	2.68	1.40	.35	.25
9	24H	1.57	2.21	2.63	3.03	3.55	1.64	.52	.32
9	48H								
9	72H								

I 50831 TAIERI

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.19	.25	.29	.33	.38	.20	.05	.25
10	20M	.25	.32	.37	.42	.48	.26	.06	.23
10	30M	.30	.39	.46	.52	.60	.31	.08	.26
10	1H	.41	.50	.57	.63	.71	.42	.08	.19
10	2H	.63	.80	.91	1.02	1.15	.65	.14	.22
10	6H	1.10	1.48	1.74	1.98	2.29	1.14	.32	.28
10	12H	1.61	2.22	2.62	3.01	3.51	1.68	.51	.30
10	24H	2.01	2.84	3.39	3.91	4.59	2.11	.69	.33
10	48H	2.36	3.69	4.57	5.41	6.50	2.52	1.11	.44
10	72H	2.46	3.91	4.87	5.79	6.98	2.63	1.21	.46

I 59242 ALEXANDRA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
10	10M	.17	.34	.45	.55	.69	.19	.14	.74
10	20M	.26	.57	.77	.97	1.23	.29	.26	.89
10	30M	.33	.72	.98	1.23	1.56	.37	.33	.88
10	1H	0.5	1.0	1.3	1.6				
10	2H	0.7	1.2	1.6	1.9				
10	6H	.91	1.40	1.72	2.03	2.43	.96	.41	.43
10	12H	1.07	1.55	1.87	2.17	2.56	1.13	.40	.35
10	24H	1.28	1.71	2.00	2.27	2.62	1.33	.36	.27
10	48H	1.33	1.76	2.05	2.32	2.67	1.38	.36	.26
10	72H	1.40	1.90	2.23	2.55	2.96	1.46	.42	.29

I 68191 GORE

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.21	.35	.44	.52	.63	.23	.11	.49
9	20M	.29	.43	.53	.62	.74	.30	.12	.40
9	30M	.33	.47	.57	.66	.78	.34	.12	.35
9	1H	.43	.57	.67	.76	.88	.44	.12	.27
9	2H	.64	.89	1.05	1.20	1.40	.67	.20	.30
9	6H	1.04	1.32	1.51	1.69	1.92	1.07	.23	.21
9	12H	1.29	1.57	1.76	1.93	2.16	1.32	.23	.17
9	24H	1.50	1.89	2.15	2.39	2.71	1.54	.32	.21
9	48H	1.66	2.08	2.35	2.62	2.96	1.71	.34	.20
9	72H	1.88	2.47	2.86	3.23	3.71	1.95	.48	.25

I 68433 INVERCARGILL AIRPORT

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
13	10M	.18	.24	.28	.31	.36	.19	.05	.26
13	20M	.27	.37	.44	.50	.59	.28	.09	.32
18	30M	.30	.43	.52	.60	.71	.32	.12	.37
18	1H	.42	.57	.67	.77	.89	.44	.14	.32
18	2H	.58	.75	.87	.97	1.12	.60	.16	.27
18	6H	.97	1.17	1.31	1.44	1.61	1.00	.19	.19
18	12H	1.24	1.55	1.76	1.96	2.22	1.28	.29	.23
18	24H	1.50	1.94	2.22	2.50	2.85	1.56	.40	.26
18	48H	1.91	2.45	2.81	3.15	3.59	1.98	.50	.25
18	72H	2.27	2.96	3.42	3.85	4.42	2.36	.64	.27

I 69272 BALCLUTHA

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
9	10M	.20	.28	.34	.39	.46	.21	.07	.34
9	20M	.26	.38	.46	.54	.64	.27	.10	.37
9	30M	.30	.48	.60	.72	.87	.32	.15	.48
9	1H	.39	.61	.75	.89	1.07	.41	.18	.44
9	2H	.50	.72	.87	1.00	1.18	.52	.18	.34
9	6H	.81	1.12	1.32	1.51	1.76	.85	.25	.30
9	12H	1.1	1.4	1.6	1.8				
9	24H	1.27	1.60	1.82	2.03	2.30	1.31	.27	.21
9	48H	1.50	1.97	2.29	2.59	2.98	1.55	.39	.25
9	72H	1.75	2.24	2.56	2.87	3.27	1.80	.40	.22

J 28 CAMPBELL ISLAND (BEEMAN COVE)

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
17	10M	.12	.15	.17	.19	.22	.12	.03	.24
17	20M	.17	.19	.21	.22	.24	.17	.02	.11
17	30M	.21	.25	.28	.31	.35	.22	.04	.19
17	1H	.32	.40	.45	.50	.56	.34	.07	.21
17	2H	.51	.64	.73	.82	.92	.53	.12	.23
17	6H	.98	1.29	1.49	1.68	1.93	1.02	.28	.27
17	12H	1.44	1.88	2.16	2.44	2.80	1.50	.40	.27
17	24H	1.90	2.54	2.97	3.38	3.90	1.99	.59	.30
17	48H	2.31	3.15	3.71	4.25	4.93	2.43	.77	.32
17	72H	2.66	3.84	4.63	5.39	6.36	2.82	1.09	.39

APPENDIX II **On fitting the equation $y = at\,(t+c)^{-b}$ to rainfall depth-duration data**

Given that (t_1,y_1), (t_2,y_2), (t_3,y_3) each satisfy the equation

$$y = at\,(t+c)^{-b} \qquad (21)$$

solve for a, b, and c

Taking logarithms:-

$$\log y_1 = \log a + \log t_1 - b \log (t_1+c) \qquad (22)$$

$$\log y_2 = \log a + \log t_2 - b \log (t_2 + c)$$

Hence

$$b = \frac{(\log t_2 - \log t_1) - (\log y_2 - \log y_1)}{\log (t_2+c) - \log (t_1+c)} \qquad (23)$$

Similarly

$$b = \frac{(\log t_3 - \log t_1) - (\log y_3 - \log y_1)}{\log (t_3+c) - \log (t_1+ c)}$$

Hence

$$\frac{\log (t_3+c) - \log (t_1+c)}{\log (t_2+c) - \log (t_1+c)} = \frac{(\log t_3 - \log t_1) - (\log y_3 - \log y_1)}{(\log t_2 - \log t_1) - (\log y_2 - \log y_1)} = m \qquad (24)$$

In this equation m can be evaluated since all the terms on the right hand side are known. But m may also be tabulated as a function of c for any set of values of t_1, t_2, and t_3.

EXAMPLE Taking $t_1 = 2$, $t_2 = 12$, $t_3 = 48$

we find the following pairs of values for C and M.

c	0	0.2	0.4	0.6	0.8	1.0
m	1.77	1.80	1.83	1.85	1.88	1.91

Using INVERCARGILL data given in Appendix I we take y_1, y_2, y_3 the values listed for $\bar{x}_t$ at 2, 12 and 48 hours, namely, $y_1 = 0.60$, $y_2 = 1.28$, $y_3 = 1.98$. Substituting these values in (24) gives M = 1.91 and hence c = 1.0. Substituting c = 1.0 in (23) gives b = 0.71, and finally from (22) we find a = 0.65. The equation fitted to these three Invercargill rainfalls is therefore

$$y = 0.65\, t\, (t + 1)^{-0.71}$$

Substituting t = 6 in this equation gives y = 1.00 and, t = 24 gives y = 1.59. The corresponding values for $\bar{x}_6$ and $\bar{x}_{24}$ at Invercargill listed in Appendix I are 1.00 and 1.56 respectively indicating that the equation

$$\bar{x}_t = 0.65\ t\ (t + 1)^{-0.71}$$

is a satisfactory representation of the depth-duration relation between $t = 2$ and $t = 48$ at Invercargill.

NOTE: In the range from $t = 0.1$ to $t = 2$ hours as was shown in 6.3, the appropriate equation for Invercargill is obtained with the following values for the parameters

$$a = 0.44, \quad b = 0.55, \quad c = 0.$$

Both equations, in spite of the different values of a, b, and c, give the same value of $y = 0.60$, when $t = 2$.

If it is desired to calculate c over any other range of durations a new (C, M) table is easily prepared. For example, if

$$t_1 = 0.5, \quad t = 1.0, \quad t_3 = 2.0 \text{ we find}$$

c	- 0.2	- 0.1	0	+ 0.1	+ 0.2	+ 0.3
M	1.83	1.92	2.00	2.07	2.12	2.18

APPENDIX III

TABLE 9

24-hour, 48-hour and 72-hour Rainfalls (inches) with Return Periods of 2 years and 20 years.

A Section

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72 hour 2yr	72 hour 20yr
Cape Reinga	A 42461	30	2.5	5.5	3.1	6.5	3.3	7.0
Te Paki	A 42581	21	3.9	6.5	4.9	9.1	5.2	9.5
Mangonui	A 43951	60	3.8	7.3	4.4	7.8	4.9	9.2
Kaitaia	A 53121	54	3.6	6.7	4.0	7.7	4.5	8.4
Rangitihi	A 53131	31	3.7	7.5	4.1	7.8	4.5	7.9
Herekino	A 53222	36	4.0	7.1	4.4	7.5	4.8	8.0
Kohukohu	A 53351	40	3.0	7.0	3.6	8.0	4.0	8.7
Rangiahua	A 53361	44	3.8	6.9	4.5	8.6	4.9	9.0
Kaikohe	A 53471	30	4.5	8.5	4.8	8.6	5.2	9.9
Wekaweka	A 53551	37	4.6	8.1	5.7	9.2	6.0	9.9
Waipoua	A 53651	25	3.4	6.0	4.0	6.9	4.3	7.1
Whatoro	A 53661	31	4.8	10.0	5.3	10.7	6.5	11.8
Waimatenui	A 53672	30	4.1	7.7	5.1	9.6	5.7	10.3
Dargaville	A 53981	30	2.9	6.2	3.8	8.1	4.1	8.8
Kawakawa	A 54301	34	4.3	7.6	5.1	8.7	5.8	9.4
Puhipuhi	A 54521	40	5.8	10.3	6.9	12.9	7.7	14.3
Ruatangata	A 54613	32	4.0	8.2	5.4	10.3	5.7	11.4
Wairua Falls	A 54701	30	3.4	7.4	4.3	9.4	4.7	10.3
Whangarei	A 54732	36	4.0	8.8	5.4	10.5	6.0	11.5
Mangawai	A 64151	30	3.2	7.6	4.0	8.3	4.4	9.1
Warkworth	A 64461	30	4.3	9.1	4.8	10.2	5.0	10.5
Helensville	A 64641	32	2.8	5.5	3.6	7.0	4.1	7.4
Riverhead	A 64751	25	3.4	7.2	4.3	8.5	5.1	9.2
Henderson	A 64861	30	3.1	6.1	4.1	7.7	4.6	8.3
Auckland	A 64871	82	2.7	5.6	3.3	6.7	3.7	7.2
Mt. Eden	A 64874	25	3.1	6.3	3.7	7.5	4.1	8.4
Huia	A 64951	29	4.8	9.9	5.4	10.4	6.1	11.4
Little Barrier	A 65201	21	5.0	10.5	5.5	11.3	5.7	12.6
Cuvier Is.	A 65471	58	2.7	5.1	3.3	6.3	3.8	7.2
Rocky Bay, Waiheke Is.	A 65801	32	3.1	5.9	3.4	6.8	3.9	7.2

Table 9 (contd.)

B. SECTION

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Tairua	B 75081	32	4.3	8.3	6.0	12.0	6.4	13.9
Thames	B 75151	29	3.3	6.2	-	-	-	-
Turua	B 75251	51	2.6	4.6	3.1	5.7	3.6	6.4
Kerepehi	B 75351	30	2.7	4.2	3.0	4.9	3.4	5.1
Paeroa	B 75361	32	3.7	7.8	4.2	9.2	4.6	9.6
Waihi	B 75381	53	6.6	12.5	8.0	14.5	8.9	15.8
Springdale	B 75551	33	3.0	5.2	3.1	5.5	3.4	6.0
Belle Vue	B 75561	35	2.8	5.4	3.1	5.5	3.5	6.3
Te Aroha	B 75571	54	3.8	7.7	4.8	9.7	5.1	10.4
Katikati	B 75591	21	5.2	10.7	6.2	12.7	7.1	13.4
Morrinsville	B 75651	36	2.6	4.7	3.0	5.7	3.2	5.9
Tauranga	B 76621	51	4.1	8.1	4.7	9.2	5.3	9.8
Whakatane	B 76993	32	3.5	6.6	5.0	9.8	5.4	10.4
Raukokore	B 77681	23	3.4	7.8	4.6	10.4	5.1	11.5
Maraehako	B 77682	28	3.7	7.4	5.1	10.4	5.2	11.0
C. Runaway	B 78501	24	4.0	6.6	4.8	7.8	5.4	8.7
Matarau	B 78601	35	5.7	9.3	8.1	13.9	8.6	15.4
Lichfield	B 85181	21	2.6	4.4	3.4	5.8	3.6	6.6
Lake Rotoma	B 86051	20	5.8	10.8	7.1	13.3	7.7	15.4
Mamaku	B 86101	23	4.4	9.4	5.3	10.9	5.9	11.8
Rotorua	B 86123	60	3.4	7.0	4.3	8.0	4.8	8.7
Whakarewarewa	B 86124	54	3.4	6.5	4.2	7.4	4.6	8.2
Waiotapu	B 86341	52	3.0	5.4	4.0	7.0	4.1	7.6
Kaingaroa	B 86361	24	3.8	7.2	4.8	9.7	5.2	11.3
Murupara	B 86471	22	3.9	8.9	4.6	10.3	4.9	11.1
Wairapukao	B 86561	21	3.3	7.2	4.4	10.1	4.9	11.1
Taupo	B 86601	50	2.7	4.5	3.1	5.3	3.5	5.9
Rotokawa	B 86611	24	2.6	4.1	3.4	5.7	3.7	6.4
Waimihia	B 86821	21	3.3	5.6	4.1	7.6	4.7	8.8
Huntress Creek	B 87021	26	3.6	6.2	4.6	8.1	4.8	9.2
Taneatua	B 87104	28	4.0	8.2	5.1	9.5	5.8	10.8
Opotiki	B 87031	23	4.0	8.1	-	-	-	-
Wairata-Inveraan	B 87231	30	4.9	8.8	6.0	10.0	6.5	10.8
Marumoko	B 87252	31	5.0	8.5	6.2	9.8	6.7	11.0

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Koranga Valley	B 87441	28	3.6	6.4	4.5	8.5	5.2	9.7
Tarawera	B 96051	33	3.0	5.9	3.8	7.3	4.5	8.6
C. SECTION								
Paerata	C 74191	29	2.7	4.1	3.3	5.6	3.7	6.5
Waiuku	C 74261	40	3.2	5.6	3.8	6.7	4.0	7.2
Onewhero	C 74391	32	2.7	4.6	3.1	5.2	3.4	5.8
Te Karaka	C 74581	22	3.0	6.5	3.6	7.6	4.0	7.7
Te Kauwhata	C 75411	32	2.7	5.2	3.1	6.3	3.5	7.3
Ngaruawahia	C 75611	31	3.3	6.3	3.7	6.9	3.9	7.5
Ruakura	C 75731	32	2.8	5.4	3.3	6.2	3.6	6.5
Hamilton	C 75821	53	2.6	4.6	3.1	5.4	3.5	5.9
Roto-o-rangi	C 75941	33	2.3	4.1	2.7	4.5	2.9	4.8
Horahora (Karapiro)	C 75951	34	2.7	5.2	3.4	5.8	3.7	6.4
Kawhia	C 84081	40	2.5	4.5	3.0	5.3	3.2	5.6
Mangatoi	C 84681	28	3.0	5.6	4.2	7.4	4.8	8.8
Te Matai, Aria	C 84691	33	3.5	5.9	4.4	7.5	4.6	8.6
Mohakatino	C 84701	22	3.1	5.7	3.7	7.7	4.2	8.5
Ohura	C 84891	34	3.5	6.5	4.5	8.0	5.1	9.6
Uruti	C 84951	24	4.0	6.8	4.8	7.7	5.6	8.9
Arapuni	C 85061	30	2.7	4.5	3.3	5.3	3.8	6.0
Otorohanga	C 85121	24	3.0	5.0	3.5	5.4	3.8	5.5
Waikeria	C 85141	31	2.4	4.3	3.2	4.8	3.4	5.0
Waitomo	C 85211	30	3.5	5.7	4.4	6.4	5.1	7.1
Te Kuiti	C 85312	35	2.9	5.0	3.4	5.1	3.8	5.7
Rangitoto	C 85331	20	3.2	5.5	3.9	6.1	4.4	6.8
Paekaka	C 85401	38	3.0	5.0	3.5	5.6	4.0	6.8
Taumaranui	C 85821	31	2.6	5.1	3.3	6.4	3.6	6.9
Hautu	C 85981	25	2.9	5.4	3.6	6.4	4.0	7.4
New Plymouth	C 94011	77	3.1	5.6	3.7	6.7	4.1	7.3
Waitara	C 94021	32	3.0	6.1	3.7	6.9	3.9	7.0
Tangarakau	C 94081	27	3.1	6.0	4.2	7.3	4.8	9.0
Lower Mangorei	C 94111	30	3.3	6.7	4.1	6.9	4.7	7.8

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Lepperton	C 94121	30	3.8	7.1	5.0	8.9	5.5	9.6
Inglewood	C 94122	36	4.9	9.0	5.8	10.7	6.3	11.2
Purangi	C 94151	32	3.8	6.4	4.7	8.0	5.2	8.8
Whangamomona	C 94172	36	3.4	5.9	4.6	7.9	5.0	8.6
Upper Mangorei	C 94201	38	6.0	10.2	7.8	14.5	8.8	16.2
Riversdale	C 94221	58	5.3	10.8	6.7	11.6	7.1	13.1
Tariki Hydro	C 94222	30	4.2	7.6	5.4	8.9	6.2	9.8
Ngatimaru	C 94261	30	4.3	6.2	5.3	8.9	6.0	10.4
Rangipo	C 95082	27	4.0	7.1	4.8	9.3	5.6	10.8
D. SECTION								
East Cape	D 78751	35	3.7	7.8	4.8	9.2	5.2	9.8
Pakihiroa	D 78811	32	6.3	9.8	8.2	14.4	9.5	17.9
Waiorongomai	D 78821	20	7.2	12.7	9.3	17.0	10.4	19.6
Whatatutu	D 87381	27	3.2	7.7	4.5	11.9	5.1	12.8
Otoko	D 87462	32	3.1	5.8	4.0	7.6	4.6	9.3
Puha	D 87481	30	2.9	5.7	3.8	7.8	3.9	8.5
Te Karaka	D 84482	32	3.1	7.1	4.0	8.8	4.3	9.9
Eastwood Hill	D 87571	27	3.2	7.2	4.1	8.0	4.5	9.1
Ormond	D 87591	22	4.2	8.4	4.7	9.5	5.3	10.9
Patutahi	D 87691	51	3.0	6.0	3.7	7.8	4.1	8.9
Gisborne	D 87692	51	3.2	7.2	4.1	8.9	4.6	10.0
Te Kura(Erepiti)	D 87731	26	4.3	8.0	5.8	11.2	6.9	13.1
Pihanga	D 87742	22	4.1	9.2	-	-	-	-
Whakapunake	D 87761	22	4.6	9.1	-	-	-	-
Onepoto	D 87811	29	4.6	8.1	6.0	10.5	6.8	13.0
Tuai	D 87812	30	4.1	7.8	5.0	9.8	5.9	11.6
Tahora	D 87921	32	3.4	6.8	-	-	-	-
Mangaone Valley	D 87962	30	6.1	12.6	8.0	17.5	9.6	21.1
Paritu	D 87981	30	5.8	12.2	7.8	16.0	9.2	18.6
Owhena	D 88001	30	5.1	9.7	6.8	11.9	7.8	13.9
Ruangarehu	D 88011	30	5.5	10.1	7.3	13.1	8.0	15.5
Mangatarata	D 88111	29	5.3	9.9	7.3	12.1	8.4	14.2
Tokomaru Bay	D 88131	24	5.4	10.9	6.5	11.5	7.2	13.7
Tolaga Bay	D 88331	53	4.3	8.2	5.5	10.8	6.2	12.6

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Waihau	D 88432	32	3.9	9.3	5.3	11.9	5.9	12.8
Maungaorangi	D 88512	30	5.4	11.2	6.1	13.8	7.4	15.6
Maungaharuru	D 96091	34	4.2	9.7	5.7	12.4	6.3	13.8
Putorino	D 96191	28	4.0	10.4	5.6	16.7	6.3	18.8
Tutira	D 96281	50	5.0	11.1	6.7	16.2	7.1	18.1
Hedgeley	D 96381	50	3.8	8.8	5.0	11.0	5.3	12.3
Rissington	D 96471	39	4.0	10.8	5.3	14.2	5.6	15.5
Napier	D 96491	67	3.1	6.7	3.6	8.0	4.0	8.9
Whanawhana	D 96541	40	3.4	7.0	4.1	8.1	4.5	9.0
Wahine,Sherenden	D 96561	32	3.5	8.6	4.5	10.2	5.3	11.6
Maraekakaho	D 96653	36	3.0	5.8	3.9	8.0	4.2	8.6
Hastings	D 96681	51	3.0	6.7	3.5	7.6	3.8	8.2
Te Mata	D 96691	30	2.6	6.3	3.6	9.4	4.1	10.2
Mangakuri	D 96693	23	3.6	7.7	4.9	9.9	5.3	10.6
Gwavas	D 96741	56	3.3	6.4	4.2	8.1	4.5	9.0
Glencoe Station	D 96752	21	3.1	5.9	3.7	6.4	4.1	6.9
Poukawa	D 96771	51	2.5	5.3	3.3	6.7	3.7	7.3
Mokopeka	D 96792	32	3.6	8.0	4.9	10.8	5.6	12.3
Blackburn	D 96831	32	3.6	7.7	4.9	9.1	5.4	9.7
Pukehou	D 96861	50	2.8	6.4	3.7	7.2	4.0	7.9
Otane (Te Kura)	D 96862	26	2.6	5.8	3.1	6.2	3.6	7.5
Hapua	D 96881	28	4.0	8.7	5.4	11.3	6.2	13.0
Waimarama	D 96891	56	3.3	6.8	4.4	8.7	4.8	9.2
Anawai	D 96892	26	7.2	13.0	9.6	20.5	11.1	23.6
Mt. Vernon	D 96951	57	2.6	5.0	3.4	6.2	3.8	6.8
Waipawa	D 96961	24	2.8	5.3	3.4	5.9	3.8	6.4
Wairoa	D 97041	24	3.7	7.4	4.6	9.7	5.1	11.0
Portland Island	D 97381	35	2.4	4.5	2.8	5.1	3.6	6.4
Waipuna	D 05381	29	2.7	4.8	-	-	-	-
Pahiatua	D 05481	52	2.6	5.2	3.2	6.1	3.5	6.7
Mangamaire	D 05541	27	2.6	5.5	-	-	-	-
Putara	D 05651	26	4.8	8.9	6.0	10.5	7.0	12.7
Eketahuna	D 05671	55	2.6	4.6	3.5	6.1	4.1	7.0

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour		48-hour		72-hour	
			2yr	20yr	2yr	20yr	2yr	20yr
Eastry	D 05681	53	2.6	4.7	3.1	5.6	3.7	6.5
Tawataia	D 05682	38	2.3	4.1	3.0	5.2	3.6	5.8
Bagshot	D 05872	30	2.8	6.1	3.9	7.2	4.5	8.2
Ditton	D 05874	25	3.0	5.2	3.5	5.9	3.9	6.8
Llandaff	D 05961	28	2.5	5.2	3.2	6.3	3.6	6.6
Masterton	D 05964	57	2.6	5.1	3.2	6.5	3.6	6.9
Bush Grove	D 05991	39	3.0	6.0	4.1	8.4	4.6	9.1
Takapau	D 06031	41	2.8	5.8	3.7	6.8	3.9	7.0
Waipukurau	D 06053	40	2.8	5.0	3.4	6.0	3.9	6.9
Rangitapu	D 06081	34	4.0	8.0	4.4	9.5	4.9	10.3
Rua Roa	D 06101	28	3.1	6.3	3.6	7.1	4.7	8.2
Ormondville	D 06122	26	3.5	6.4	4.4	8.5	5.0	9.8
Motuotaraia	D 06151	35	3.2	7.2	3.8	8.1	4.2	8.7
Aramoana	D 06181	39	3.0	5.6	3.8	7.4	4.4	8.3
Dannevirke	D 06211	35	2.6	4.7	3.1	5.5	3.4	5.9
Pine Grove	D 06431	40	3.6	7.7	5.0	9.9	5.5	11.0
Woodbank	D 06451	50	3.9	7.8	5.1	9.8	5.4	10.3
Annedale	D 06701	41	3.3	6.7	4.6	9.7	5.4	11.0
Ovingdean	D 06721	21	3.3	6.0	4.3	8.2	4.6	8.7
The Taipos	D 06811	21	4.9	10.1	-	-	-	-
Marangai	D 06901	37	3.1	6.4	4.1	9.1	4.4	9.4
Tinui	D 06902	24	3.9	8.4	5.1	10.6	5.7	11.1
Castlepoint	D 06921	41	3.0	5.9	3.3	6.8	3.4	7.0
Greytown	D 15041	38	2.4	4.5	3.0	5.6	3.4	6.2
Waihakeke	D 15053	34	2.2	4.3	2.7	6.2	3.0	6.8
Summit	D 15121	56	3.9	7.1	5.2	9.3	6.0	10.3
Featherston	D 15131	60	2.9	5.5	3.4	6.2	3.9	6.9
Eringa	D 15162	32	2.8	5.4	3.6	7.2	4.4	8.8
Wairongomai	D 15211	25	3.0	5.3	3.7	6.7	4.1	7.4
Te Hopai	D 15221	22	2.8	5.3	3.5	7.0	3.9	7.6
Martinborough	D 15242	33	2.1	4.0	2.4	4.6	2.8	5.2
Riverside	D 15243	27	2.2	3.8	-	-	-	-
Orongorongo	D 15301	28	6.2	11.7	8.3	15.5	9.5	17.5

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Pukeatua	D 15351	21	4.5	10.2	5.5	12.0	6.1	12.7
Lagoon Hill	D 15352	30	4.2	10.9	5.9	12.5	6.3	14.0
Te Awaite	D 15451	29	3.3	5.5	3.9	6.8	4.3	7.4
Cape Palliser	D 15631	25	3.1	5.6	3.8	6.6	4.2	7.2
E. SECTION								
Cape Egmont	E 93271	24	3.5	6.5	3.9	7.3	4.2	7.5
Opunake	E 93481	34	2.8	5.7	3.2	6.0	3.6	6.3
Mangapurua Ldg	E 94291	21	3.4	6.7	4.2	7.7	4.6	8.2
Stratford	E 94332	61	4.0	7.2	5.0	9.8	6.0	10.7
Riverlea	E 94401	34	3.1	6.7	4.0	8.3	4.4	8.5
Eltham	E 94421	28	2.9	5.5	3.5	7.3	3.9	7.7
Manaia	E 94511	27	2.5	6.3	-	-	-	-
Ohawe	E 94521	41	2.6	5.0	3.0	5.4	3.3	5.8
Hawera	E 94621	32	2.5	5.1	3.0	5.9	3.4	6.0
Kakaramea	E 94651	20	2.7	4.7	-	-	-	-
Patea	E 94741	38	2.6	4.5	3.2	5.6	3.6	5.8
Waverley	E 94761	28	2.3	3.5	3.0	5.7	3.3	6.1
Moumahaki	E 94762	20	2.3	3.6	-	-	-	-
Waitahinga	E 94791	30	2.9	5.5	3.5	6.6	3.9	6.9
Horopito	E 95331	23	2.8	4.9	3.6	6.3	4.1	7.2
Raetihi	E 95421	32	2.6	4.7	3.4	6.3	4.0	7.0
Ohakune	E 95441	30	2.8	5.6	3.2	5.7	3.6	6.0
Karioi	E 95451	26	2.2	4.5	2.7	5.3	3.2	5.7
Waiouru	E 95461	32	2.0	4.0	2.6	4.5	3.0	5.0
Hihitahi	E 95571	22	2.4	5.0	3.1	6.2	3.5	6.8
Erewhon	E 95591	30	2.2	4.1	-	-	-	-
Ruanui	E 95662	23	2.3	5.4	3.1	7.5	3.5	8.0
Taihape	E 95681	41	2.1	3.3	2.5	4.4	2.7	4.8
Wanganui	E 95902	60	2.1	3.7	2.5	4.3	2.8	4.7
Okoia	E 95911	27	2.2	4.2	2.7	4.9	3.0	5.4
Marybank	E 95913	21	1.8	3.2	-	-	-	-
Hunterville	E 95951	45	2.2	3.9	2.6	4.8	2.9	5.0
Mangaohane	E 96501	31	2.1	4.8	2.7	5.5	3.2	5.9

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Kapiti Is.	E 04891	37	2.7	4.6	3.2	5.5	3.4	5.7
Thoresby	E 05032	23	1.9	3.6	2.5	4.6	2.8	4.9
Waituna West	E 05061	34	2.0	3.3	-	-	-	-
Dalvey	E 05111	35	2.0	3.7	2.4	4.2	2.7	4.5
Burleigh, Bulls	E 05131	31	1.8	3.2	-	-	-	-
Komako	E 05191	31	3.1	6.1	3.9	7.5	4.4	8.1
Flockhouse	E 05221	27	2.1	3.2	2.4	3.9	2.7	4.5
Waitatapia	E 05232	50	1.9	3.1	2.4	4.1	2.8	4.8
Feilding	E 05251	59	2.0	3.4	2.5	4.3	2.7	4.7
Glen Orua	E 05341	38	1.9	3.0	2.4	4.1	2.7	4.6
Kairanga	E 05351	37	2.0	3.5	2.3	3.7	2.6	4.3
Palmerston N.	E 05362	33	2.1	3.5	2.5	3.8	2.6	4.0
Grasslands Palmerston Nth.	E 05363	25	2.2	3.6	2.4	3.9	2.6	4.0
Turitea	E 05365	30	2.3	4.3	2.9	5.1	3.3	5.7
Foxton	E 05421	34	2.0	3.2	2.4	3.6	2.6	4.1
Fitzherbert W.	E 05461	24	2.3	4.8	-	-	-	-
Mangaore	E 05542	30	2.5	4.7	2.9	5.4	3.4	5.9
Ohau	E 05623	29	2.2	4.1	-	-	-	-
Upper Mangahao	E 05642	30	5.8	10.9	7.4	15.4	8.7	17.8
Otaki	E 14111	54	2.2	3.5	2.6	4.4	3.0	4.8
Pauatahanui	E 14194	22	2.7	6.0	3.5	7.7	4.0	8.9
Karori	E 14271	67	3.0	5.7	3.6	6.8	3.9	7.4
Kelburn	E 14272	83	3.0	5.5	3.7	6.6	4.0	7.2
Petone	E 14283	20	3.0	5.7	4.0	7.7	4.4	8.4
Ridgeside	E 14284	23	2.8	5.3	-	-	-	-
Waiwhetu	E 14293	43	3.1	5.6	4.1	7.9	4.5	9.0
Wainui-o-mata	E 14294	53	5.1	10.3	6.4	15.4	7.1	17.2
Brooklyn	E 14371	34	3.1	5.5	4.0	7.1	4.4	7.6
Trentham	E 15101	24	2.6	5.1	3.7	7.0	4.0	7.6
Wallaceville	E 15102	26	2.8	5.5	3.6	7.0	4.0	7.4

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
F. SECTION								
Collingwood	F 02662	23	5.1	8.3	6.0	10.1	6.8	11.3
Bainham	F 02751	30	7.8	14.4	9.7	20.3	11.2	23.9
Farewell Spit	F 03501	60	2.8	5.6	3.5	6.5	3.7	7.1
Millerton	F 11681	21	6.0	9.8	7.2	11.7	8.3	13.3
Westport	F 11761	53	3.4	5.9	4.2	7.3	4.5	7.8
Asbestos Cottage	F 12171	27	5.1	8.5	6.3	10.7	7.1	12.1
Karamea	F 12211	34	3.1	5.3	3.7	6.9	4.2	7.3
Kahurangi Point	F 12721	22	4.1	7.3	5.2	9.2	5.8	10.8
Gowan	F 12751	20	2.9	4.5	-	-	-	-
Twynham	F 12772	27	3.2	4.8	-	-	-	-
Lake Rotoiti	F 12781	22	2.7	4.7	3.5	5.6	4.2	7.0
Murchison	F 12832	20	2.5	4.4	3.3	5.7	3.9	6.0
Hokitika	F 20791	67	4.7	7.9	5.7	9.3	6.6	10.4
Ross	F 20981	36	6.0	9.7	7.6	12.2	8.3	13.4
Reefton	F 21181	42	3.2	5.1	4.1	6.4	4.5	7.4
Rewanui	F 21331	20	5.6	9.5	7.6	12.6	9.1	13.8
Greymouth	F 21421	46	4.1	7.4	5.3	9.2	6.0	10.4
Lake Kanieri	F 21812	27	7.3	12.0	8.8	16.6	10.3	18.9
Otira	F 21851	40	9.1	13.9	12.5	20.2	13.8	23.4
Okuru	F 38991	34	5.9	11.2	8.2	13.7	9.2	15.4
Karangarua	F 39581	20	6.5	10.0	8.5	13.2	9.6	15.7
Milford Sound	F 47691	24	11.9	20.4	14.6	25.5	16.5	28.1
Puysegur Point	F 66161	31	3.1	5.3	3.8	6.3	4.4	7.2
G. SECTION								
Waitata Bay	G 03991	37	3.0	5.1	4.2	6.8	4.6	7.5
Stephens Is.	G 04601	54	2.7	5.8	-	-	-	-
Motueka	G 12192	36	3.7	7.2	-	-	-	-
Stanley Brook	G 12381	35	3.2	6.3	4.0	7.4	4.2	8.1
Golden Downs	G 12581	23	2.9	5.1	3.8	6.5	4.2	7.1
Yncyca Bay	G 13191	32	5.0	8.2	6.0	12.1	6.7	13.1
Harakeke	G 13201	32	2.7	5.7	3.8	6.8	4.3	7.8
Mapua	G 13203	30	2.6	4.1	3.4	5.4	3.5	6.3

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Appleby	G 13211	22	2.6	4.7	3.2	5.1	3.6	5.5
Nelson	G 13231	55	2.8	4.9	3.4	6.0	3.6	6.6
Opouri Valley	G 13261	32	5.4	10.7	7.0	14.7	7.8	16.4
Maitai Valley	G 13331	24	4.9	9.2	6.6	13.8	7.4	16.0
Spring Creek	G 13492	37	2.5	4.3	–	–	–	–
Erina	G 13552	35	2.7	4.6	3.6	6.3	3.9	6.6
Seven Oaks	G 13582	37	2.2	3.9	2.6	5.0	2.9	5.4
Blenheim	G 13592	21	2.1	3.9	2.4	4.1	2.6	4.7
Ranui	G 13631	30	2.9	4.6	3.5	5.6	3.9	6.1
Waihopai	G 13651	22	2.4	3.7	2.8	4.3	3.3	5.3
Avondale	G 13661	51	2.1	4.0	2.6	4.9	2.8	5.2
Marama	G 13792	21	2.5	4.2	2.8	4.6	3.0	4.9
Upcot	G 13951	22	2.2	4.0	2.8	4.5	3.0	4.8
Duntroon	G 13871	30	2.7	5.3	3.2	6.7	3.6	7.7
Manaroa	G 14101	52	3.9	7.4	5.2	9.7	5.5	9.9
The Brothers	G 14141	60	2.2	4.3	2.4	5.1	2.5	5.5
Picton, Freezing Works	G 14201	25	4.0	8.1	5.4	12.4	5.6	12.7
Ocean Bay	G 14311	29	3.6	5.7	4.5	8.0	5.0	9.2
Marshlands	G 14401	36	2.4	4.2	3.0	5.6	3.3	6.0
Seddon	G 14601	32	2.4	4.1	3.1	5.7	3.2	6.4
Wai-iti	G 14702	20	2.6	4.7	2.9	5.8	3.0	6.4
Cape Campbell	G 14721	65	2.8	5.9	3.4	7.5	3.7	8.0
Ward	G 14811	36	3.1	6.4	3.8	7.8	4.4	8.9
Hanmer	G 22581	39	3.0	6.4	3.8	8.3	4.5	10.0
Ellerton	G 23091	37	4.0	9.3	4.8	10.1	5.3	11.7
Mounsdale	G 23341	30	4.0	7.7	4.8	9.3	5.5	11.2
Hapuku	G 23361	30	5.2	11.3	6.3	14.3	7.3	15.9
Kaikoura West	G 23461	32	4.1	7.7	4.7	8.4	5.2	9.1
H. SECTION								
Arthurs Pass	H 21951	32	8.7	14.8	11.0	20.7	12.0	22.0
Riverside	H 22781	30	2.4	4.9	2.7	6.0	3.2	7.4
Culverden	H 22782	31	2.2	5.5	2.5	6.4	2.7	7.0

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Balmoral	H 22861	27	2.3	5.4	3.1	7.3	3.3	9.9
Glenallen, Waikari	H 22961	32	2.8	5.9	3.3	7.3	3.6	8.7
Keinton Combe	H 23501	33	3.4	9.2	4.4	11.5	5.1	12.6
Emscote	H 23531	28	4.2	8.7	4.8	10.4	5.5	11.2
Waiau	H 23601	32	2.9	7.0	3.3	8.7	3.7	9.5
Highfield	H 23602	54	2.9	5.9	3.7	8.2	4.1	9.0
Hawkeswood	H 23632	23	4.6	9.1	6.4	11.9	7.0	13.7
Spotswood	H 23721	33	2.8	7.5	-	-	-	-
Gore Bay	H 23831	30	3.0	7.1	3.7	7.9	4.2	8.9
Kilmarnock	H 23911	29	3.2	7.5	-	-	-	-
Mt. Cook	H 30711	27	9.3	14.3	-	-	-	-
Godley Peak	H 30841	23	2.2	4.7	2.6	4.8	2.9	5.3
Braemar	H 30921	35	2.6	4.5	3.1	5.6	3.4	5.8
Bealey	H 31061	62	3.9	7.5	4.4	8.2	4.9	8.8
Mt. White	H 31091	28	2.5	4.6	3.1	5.3	3.4	5.6
Glenthorne	H 31141	27	3.2	5.8	4.0	7.0	4.4	7.8
Flockhill	H 31171	26	3.2	5.7	3.6	6.3	4.1	7.2
Craigieburn	H 31181	23	2.3	3.8	2.6	4.8	2.9	5.3
Harper River	H 31241	24	2.9	5.6	3.2	5.9	3.6	6.7
Double Hill	H 31321	34	2.9	5.3	3.8	6.4	4.3	7.3
Lake Coleridge	H 31351	35	2.9	5.6	3.0	5.8	3.4	6.6
Lake Coleridge	H 31352	35	2.2	3.7	2.6	5.0	2.9	5.4
Mt. Torlesse	H 31381	37	2.6	4.8	3.1	6.5	3.5	7.3
Coalgate	H 31491	34	2.7	5.6	2.9	7.6	3.2	8.1
Rudstone	H 31562	32	2.7	5.3	3.3	6.9	3.7	7.4
Hororata	H 31591	55	2.0	4.1	2.5	5.0	2.8	5.5
Evandale	H 31641	33	2.7	5.3	2.9	5.9	3.2	6.5
Staveley	H 31642	30	3.0	5.6	3.4	6.8	3.8	7.5
Springburn	H 31643	33	2.5	5.3	3.0	6.6	3.3	7.3
Singletree	H 31651	30	3.0	5.8	4.0	8.9	4.5	9.9
Methven	H 31661	37	2.8	5.2	3.6	7.5	3.8	8.0
Mt. Somers	H 31731	36	2.6	5.3	3.0	6.0	3.3	6.7
Winchmore	H 31873	56	2.3	5.0	3.0	6.3	3.4	7.2
Peel Forest	H 31921	53	2.8	4.7	3.6	6.0	4.1	6.9

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Mt. Peel	H 31924	21	2.7	5.0	3.1	5.6	3.5	5.9
Ashburton	H 31971	36	2.4	4.9	3.1	6.6	3.4	7.0
Weka Pass	H 32071	31	2.7	5.4	2.9	5.6	3.4	6.7
Waipara	H 32072	29	2.3	5.7	2.9	7.1	3.4	8.9
Amberley	H 32171	37	2.9	6.7	3.4	8.2	3.7	8.9
Oxford	H 32222	42	2.7	5.0	3.5	6.7	3.9	7.8
Pukeura	H 32401	21	2.6	5.4	-	-	-	-
Homebush	H 32402	25	2.4	5.4	-	-	-	-
Darfield	H 32442	33	2.1	4.8	2.9	6.7	3.2	7.3
Paparua	H 32551	28	2.2	3.7	2.6	4.8	2.8	5.2
Christchurch	H 32561	77	2.1	3.9	2.7	5.3	2.9	5.9
Rhodes Conval. Home	H 32562	53	2.4	5.3	2.8	6.5	3.1	7.2
Lincoln	H 32641	65	2.1	4.0	2.4	4.8	2.8	5.6
Taitapu(Otahuna)	H 32651	42	2.6	5.0	3.2	6.0	3.7	6.7
Allandale	H 32661	33	3.2	7.3	3.7	8.5	4.2	9.9
Puaha	H 32681	20	4.0	9.7	4.8	11.2	5.1	12.5
Rakaia	H 32701	50	2.4	4.5	3.0	6.1	3.2	6.6
Okuti	H 32781	30	4.1	9.5	5.4	11.3	6.0	13.0
Southbridge	H 32821	38	2.1	4.6	2.6	5.6	2.8	5.7
Magnet Bay	H 32871	32	2.6	6.9	2.9	8.2	3.1	8.4
Akaroa	H 32891	51	4.1	9.8	5.4	12.8	5.8	14.0
Brockworth	H 33601	27	2.7	6.2	3.5	7.4	4.0	8.4
Lake Tekapo	H 40041	27	2.2	4.0	2.4	5.5	2.7	5.6
Horwell Downs	H 40171	34	2.5	4.6	3.1	5.7	3.7	6.7
Lambrook	H 40181	55	2.3	4.2	2.7	5.7	2.9	6.2
Fairlie	H 40182	24	2.4	4.7	3.0	6.2	3.5	7.5
Bedeshurst	H 40183	30	2.3	4.4	3.0	6.0	3.5	7.2
Te Ngawai	H 40281	39	2.2	4.3	2.8	6.2	3.3	6.8
Cave	H 40391	21	1.9	3.8	2.5	5.3	2.8	5.8
Haka Downs	H 40461	25	1.9	3.6	2.4	4.6	2.6	5.0
Waikora	H 40671	22	2.8	4.8	3.5	6.7	3.8	7.2
Station Peak	H 40751	32	1.8	3.1	-	-	-	-
Orari Gorge	H 41021	54	3.5	6.2	4.4	8.2	5.0	9.1

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Lynnford	H 41061	33	2.5	5.2	3.1	6.4	3.4	6.6
Kakahu Bush	H 41111	35	2.5	6.2	3.2	7.0	3.6	8.2
Waitui	H 41121	30	2.7	5.6	3.4	7.0	3.6	7.4
Orari Estate	H 41131	54	2.8	5.7	3.5	7.0	4.0	7.6
Pleasant Point	H 41201	48	2.1	4.2	2.7	5.3	3.0	5.8
Kapunatiki	H 41241	41	1.9	3.7	2.5	4.8	2.6	5.2
Seadown	H 41321	32	2.3	4.8	2.7	5.5	2.9	5.6
Smithfield	H 41322	31	2.4	5.0	2.8	5.6	2.9	5.8
Timaru	H 41421	53	2.0	4.3	2.8	5.4	3.0	5.8
Timaru Reservoir	H 41423	51	2.2	4.4	2.9	5.6	3.1	5.8
Waimate	H 41701	53	2.1	4.1	2.9	5.5	3.1	6.2
I. SECTION								
Waitaki	I 40461	23	1.8	3.4	-	-	-	-
Otiake	I 40851	30	1.6	3.0	2.0	3.7	2.1	4.1
Duntroon	I 40861	32	1.9	3.9	2.4	5.2	2.6	5.6
Stewart Settlmt.	I 41801	30	2.2	5.8	2.9	6.9	3.1	7.4
Glenorchy	I 48741	22	2.7	5.1	3.4	6.6	3.8	7.0
Arrowtown	I 48981	26	2.0	3.6	2.4	4.0	2.6	4.3
Makarora	I 49321	30	4.1	7.4	5.3	8.3	5.7	9.0
Benmore	I 49391	39	2.2	3.8	2.4	4.6	2.6	4.8
Hawea Flat	I 49631	31	2.2	4.0	2.5	4.4	2.7	4.7
Maungawera	I 49632	27	2.3	4.0	2.8	4.8	3.1	5.3
Pembroke	I 49711	28	2.1	3.6	2.4	4.4	2.6	4.8
Luggate	I 49721	21	1.9	3.6	2.2	4.0	2.3	4.3
Tarras	I 49841	35	1.9	3.3	1.9	3.6	2.1	3.8
Blackstone Hill	I 49991	30	1.9	3.1	2.2	3.6	2.4	4.0
Naseby Forest	I 50001	56	1.6	3.0	2.1	3.9	2.4	4.2
Naseby	I 50011	40	1.8	3.2	2.2	4.3	2.4	4.8
Oamaru	I 50091	65	1.8	4.1	2.4	5.1	2.6	5.5
Kauroo Hill	I 50172	36	1.8	3.9	2.3	4.5	2.5	4.7
Totara Station	I 50182	25	2.1	5.4	-	-	-	-
Patearoa	I 50201	29	1.3	2.2	1.5	2.5	1.6	2.7
Waipiata San.	I 50112	30	1.3	2.4	1.6	2.7	1.8	2.9

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour		48-hour		72-hour	
			2yr	20yr	2yr	20yr	2yr	20yr
Waipiata	I 50212	28	1.4	2.4	1.7	2.8	1.8	2.9
Kokonga	I 50221	25	1.6	2.8	1.8	3.2	1.9	3.3
Robertslee, Gladbrook	I 50411	52	2.0	3.6	2.4	4.4	2.8	5.0
Te Awa-Hill Grove	I 50471	38	2.0	4.9	2.6	5.9	2.9	6.2
Bushey Park	I 50472	38	2.0	4.9	2.6	5.8	2.9	6.4
Garthmyl, Middlemarch	I 50512	36	1.8	3.1	-	-	-	-
Whare Flat	I 50843	26	3.4	7.7	4.4	9.8	4.9	10.5
Ross Creek	I 50851	24	2.7	6.3	3.8	8.0	4.1	8.7
Sawyers Bay	I 50861	26	2.9	5.9	3.7	7.0	4.1	7.5
Dunedin	I 50862	93	2.4	5.0	3.2	6.8	3.4	7.2
Portobello	I 50862	41	2.1	4.4	2.3	5.2	2.8	5.4
Burnside	I 50941	35	2.5	4.9	3.1	6.5	3.4	6.9
Musselburgh	I 50951	34	2.1	4.7	2.5	6.4	2.9	6.7
Manapouri	I 57561	24	2.2	4.2	2.8	4.8	3.1	5.4
Monowai	I 57761	33	2.6	5.0	2.9	5.2	3.3	5.7
Queenstown	I 58061	56	1.9	3.2	2.4	4.2	2.6	4.4
Frankton	I 58071	32	1.8	3.1	2.1	3.6	2.3	3.8
Kingston	I 58371	23	2.4	5.6	2.7	6.2	3.0	7.0
Castle Hill (Athol)	I 58551	21	2.0	3.5	2.2	3.7	2.5	4.0
Glenfalloch	I 58561	25	1.8	3.5	2.2	4.0	2.4	4.3
Dipton	I 58831	50	2.0	3.6	2.3	3.8	2.5	3.9
Wendon	I 58881	35	1.6	2.8	1.9	3.5	2.1	3.6
Nightcaps	I 58901	33	2.0	3.3	2.6	4.6	3.0	4.9
Ripponvale	I 59011	28	1.6	2.8	1.7	2.9	1.8	3.2
Clyde	I 59131	56	1.4	2.5	1.6	2.9	1.7	3.0
Ophir	I 59161	30	1.5	2.2	1.7	2.9	1.8	3.3
Moa Creek	I 59162	32	1.4	2.5	1.6	2.9	1.8	3.1
Galloway	I 59241	43	1.4	2.6	1.5	2.7	1.6	3.0
Alexandra	I 59242	31	1.3	2.6	1.5	3.0	1.5	3.1
Manorburn Dam	I 59361	33	1.5	2.9	1.7	3.2	1.8	3.5
Paerau	I 59491	30	2.1	4.4	2.3	5.1	2.6	5.6
Roxburgh East	I 59531	25	1.6	2.7	1.8	3.0	1.9	3.2

Table 9 (contd.)

Station	Index No.	Years of Record	24-hour 2yr	24-hour 20yr	48-hour 2yr	48-hour 20yr	72-hour 2yr	72-hour 20yr
Roxburgh	I 59532	55	1.4	2.3	1.6	2.8	1.9	3.2
Great Moss Swamp	I 59581	20	1.6	3.3	1.8	3.7	1.9	3.8
Tapanui	I 59921	55	1.9	3.5	2.4	5.0	2.8	5.7
Lawrence	I 59961	33	1.6	2.8	2.2	3.6	2.3	3.9
Centre Island	I 67481	37	2.0	3.8	2.4	4.0	2.8	4.6
Gore	I 68091	37	1.6	2.7	1.9	3.2	2.2	3.4
Otautau	I 68101	41	2.1	3.7	2.6	4.1	2.8	4.5
Riverton	I 68301	34	1.8	3.4	2.4	3.9	2.8	4.2
Roslyn Estate	I 68351	36	1.6	2.7	2.0	3.4	2.4	3.8
Invercargill	I 68431	55	1.7	2.9	2.2	3.5	2.6	3.8
Awarua	I 68531	35	1.7	3.0	2.2	3.7	2.6	4.1
Waimahaka	I 68582	38	1.7	2.6	2.1	3.4	2.4	3.8
Half Moon Bay	I 68911	31	2.0	4.1	2.6	4.4	3.2	4.8
Ulva Island	I 68912	23	2.1	3.7	2.9	4.5	3.4	5.2
Milton	I 69191	23	1.7	3.4	2.1	4.2	2.4	4.7
Balclutha	I 69271	55	1.7	3.6	2.0	4.3	2.0	4.4
Owaka	I 69461	31	1.9	3.6	2.5	4.7	2.6	5.1
Nugget Pt.	I 69481	22	1.5	3.0	2.0	3.6	2.3	3.9
Quarry Hills	I 69501	50	2.0	4.0	2.6	5.0	3.0	5.4
Tahakopa	I 69541	28	2.3	5.4	3.1	6.7	3.6	7.2

AMENDMENTS to N.Z. Met.S. Misc Pub. 118

"The Frequency of High Intensity Rainfalls in New Zealand"

p 13 line 12, amend to read: ..... y_n and σ_n depend .....
in the table, amend heading of right hand column to read: σ_n

p 25 line 4, should begin: with c = 0 as .....
last paragraph, line 6: for "estimates", read "estimate".

p 27 in formula (20), enclose 0.84 + 0.75 log (T-0.6) in curly brackets.
beginning of line 15, alter "Formula 18" to "Formula 19".
" " " 16, alter "Formula 19" to "Formula 20".

p 30 para 2, line 4, amend to read: ..... structure or the consequences ....
para 2, line 6, amend: "require", to "required"

p 39 equation (25), amend to read: $X(T) = u + G(T,n)k$

Appendix I add following table for New Plymouth at beginning of Appendix I, and amend heading to read ..... 46 Stations .....

C 94011 NEW PLYMOUTH

n	t	T=2	5	10	20	50	$\bar{x}$	s	V
14	10M	.45	.64	.77	.89	1.05	.47	.17	.37
14	20M	.72	1.11	1.36	1.61	1.93	.77	.35	.45
14	30M	.93	1.55	1.97	2.37	2.88	1.01	.56	.56
14	1H	1.24	2.00	2.50	2.99	3.62	1.33	.68	.51
14	2H	1.44	2.26	2.79	3.32	3.98	1.55	.73	.47
14	6H	2.07	2.76	3.22	3.66	4.23	2.16	.62	.29
14	12H	2.57	3.33	3.83	4.31	4.93	2.67	.68	.25
14	24H	3.30	4.57	5.41	6.23	7.27	3.46	1.14	.33
14	48H	4.03	5.54	6.54	7.52	8.76	4.22	1.35	.32
14	72H	4.28	5.79	6.79	7.76	9.00	4.46	1.35	.30

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