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REGIONAL FLOOD ESTIMATION—
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WELLINGTON 1983

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Dimensionless flood frequency curves of $Q_T/\bar{Q}$ versus T, where Q_T is flood of return period T years and $\bar{Q}$ is mean annual flood, are presented for eight regions.

Nine regional regression equations relating mean annual flood to catchment area and rainfall statistics can supply estimates of $\bar{Q}$ where no records are available. A rational basis for combining regional equation estimates of $\bar{Q}$ with estimates of $\bar{Q}$ from short records is described.

Estimates of $Q_T/\bar{Q}$ and $\bar{Q}$ enable estimation of T year return period design flood Q_T for ungauged catchments. Estimation of errors of Q_T is described. A comprehensive example illustrates the method.

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REGIONAL FLOOD ESTIMATION — A DESIGN PROCEDURE

Alistair I. McKerchar*, B.E. (Hons), Ph.D.
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1. INTRODUCTION

A regional flood estimate (RFE) method for New Zealand has been developed in the Water and Soil Division of the Ministry of Works and Development. It is the result of a comprehensive study of flood peak data for gauged rural catchments and its development is fully described in the report by Beable and McKerchar[1]. This paper explains the application of the RFE method and is intended to be a more succinct and convenient set of rules and examples, but is only a supplement to that report.

The method uses a set of regional flood frequency curves in which the only unknown is the mean annual flood. Each regional curve was constructed by combining the flood peak data for a region and obtaining an average flood frequency curve. In order to use a regional curve to estimate a design flood peak, it is only necessary to know the mean annual flood for the catchment concerned. For situations where the catchment is ungauged or the flood peak data are inadequate, a set of regional equations have been developed which enable the estimation of the mean annual flood given the catchment area and rainfall data. Because each regional curve is based on a number of streamflow records it often provides a more reliable basis for extrapolation than an individual flood frequency curve fitted to the available record.

2. OUTLINE OF THE METHOD

The form of the regional flood estimation method is similar to that developed for the United Kingdom[6]. The method makes use of two sets of parameters:

(1) A set of regional flood frequency curves relating $Q_T/\bar{Q}$ to T, where Q_T is the flood with a return period T, and $\bar{Q}$ is the mean annual flood.

(2) A set of regional equations for estimating the mean annual flood from catchment area and catchment rainfall estimates.

The country is divided into eight flood frequency regions for the purpose of deriving regional curves, and into nine mean annual flood regions.

As well as the regional flood frequency curves, there are two general curves; one for eastern and one

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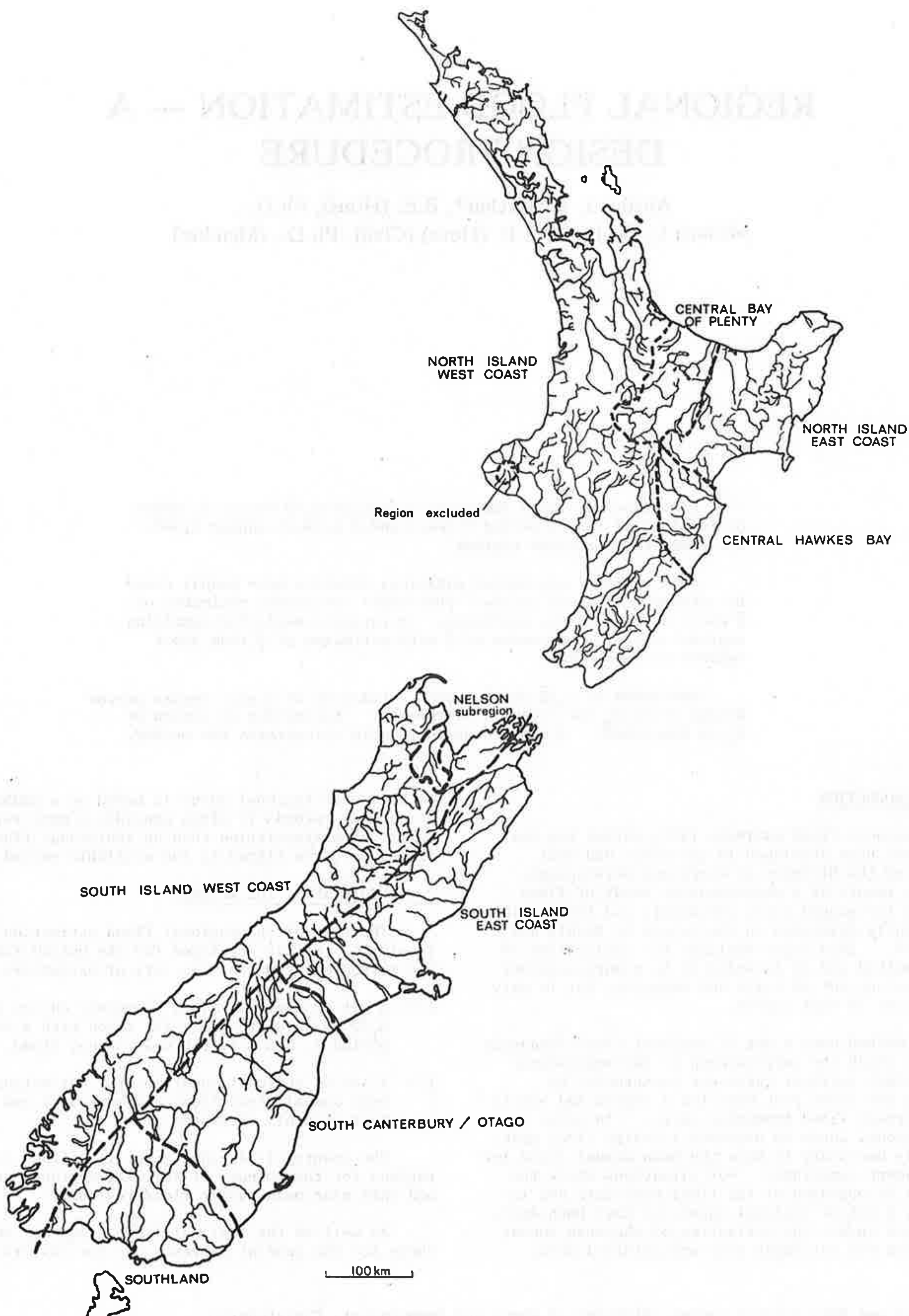
Figure 1 Frequency regions



for western New Zealand, which were derived by combining all of the flood peak data used to derive the regional frequency curves. These curves may be used when estimating a design flood peak with a return period that is greater than the upper limit of the relevant regional curve.

Formulae are provided for evaluating the reliability of a design flood peak.

3. APPLICATION OF THE METHOD

3.1 Applicability

The applicability of the method is constrained by the following restrictions that were applied to the data used in deriving the parameters:

(1) The method should only be used for rural catchments.

(2) The method should only be applied to catchments in which snowmelt, glaciers, springs, lake storage or ponding do not significantly affect the flood peak characteristics.

(3) The complete method is applicable for catchments with areas in the range 20-1100 km^2. However the equations for mean annual flood can be applied to smaller catchments (area greater than 0.1 km^2), and the regional flood frequency curves can be applied to larger catchments (area greater than 1100 km^2). Also, in the Northland area the regional flood frequency curve can be applied to smaller catchments (area greater than 2.5 km^2).

3.2 Method of Application

The steps in the application of the RFE method are as follows:

(1) Decide on the return period of the design flood. The choice of return period will depend on several factors including: the expected life of the structure; the economic consequences of failure; and the loss of life and livelihood that might result[3,5,6].

(2) Collect all the annual and historical flood peak data for the catchment. Note that the data sample must possess certain properties if flood frequency analysis is to make the proper inferences about the population's distribution. The series of annual flood peaks should be: continuous, if possible; homogeneous (ie, all of the peaks should have occurred under the same conditions); and reliably estimated.

(3) To determine $Q_T/\bar{Q}$ use one of three methods. If there are flood peak data and $N \geq 10$ and $T \leq 5N$, then

   (a) analyse the flood peak data directly,

otherwise

   (b) if $T > 200$ use a generalised frequency curve in Table 1

or

   (c) if $T \leq 200$ use a regional frequency curve in Table 1.

(4) Estimate the mean annual flood $\bar{Q}$ from the appropriate regional mean annual flood equation (Section 5), or from the record if a record of sufficient length is available. $\bar{Q}$ is the arithmetic mean of the annual flood peaks. That is,

$$\bar{Q} = \frac{1}{N} \sum_{i=1}^{N} Q_i \qquad \ldots(1)$$

where Q_1 = an individual annual flood peak.

Where the record is short, it may be appropriate to combine estimates of $\bar{Q}$ from the mean annual flood equation and the record.

(5) If the regional or generalised flood frequency curve has been used, multiply the $Q_T/\bar{Q}$ value estimated from the curve (step 3) by the $\bar{Q}$ estimate (step 4) to determine Q_T.

(6) Evaluate the reliability of the $\bar{Q}$, $Q_T/\bar{Q}$ and Q_T estimates using the formulae provides in Section 6.

4. REGIONAL FLOOD FREQUENCY CURVES

4.1 Flood Frequency Regions

The eight flood frequency regions into which the country has been divided are shown in Fig. 1. Part of the area south of Mt Egmont was excluded from the regionalisation because flood peak data were only available for one station in this area and the data displayed a trend markedly different from the regional one. It is uncertain whether this is a real difference or simply the result of using short records, and the region has been excluded from the North Island West Coast region until more flood peak data area available. An area in the northern part of the South Island West Coast region has also been identified as a sub-region. Using all the data for this Nelson region, it appears that its average flood frequency curve is noticeably steeper than that developed for the whole region. Until longer and more reliable flood records are available to derive a regional curve for this area, the South Island East Coast curve should be used for catchments in the area.

Frequency curves corresponding to the eight flood frequency regions are shown in Fig. 2.

The curves are plots of $Q_T/\bar{Q}$ versus the return period T. Table 1 lists values of $Q_T/\bar{Q}$ for commonly specified values of T.

Because of the subjective and, at times, rather coarse definition of the regional boundaries it is suggested that, for catchments in close vicinity of a boundary line, the curves for the regions either side of the line should be used in estimating $Q_T/\bar{Q}$. As in a design situation where different methods yield different estimates, the different $Q_T/\bar{Q}$ estimates then need to be compared, ie, the merits of each should be assessed and the choice of an estimate should be made after a rationalisation of the known facts.

4.2 Frequency Analysis Methods

In the derivation of the flood frequency curves, several standard frequency analysis methods were investigated. Detailed explanations of the methods are given by Maguiness[4], who describes a computer program which fits a frequency curve to a series of annual extremes by seven different methods.

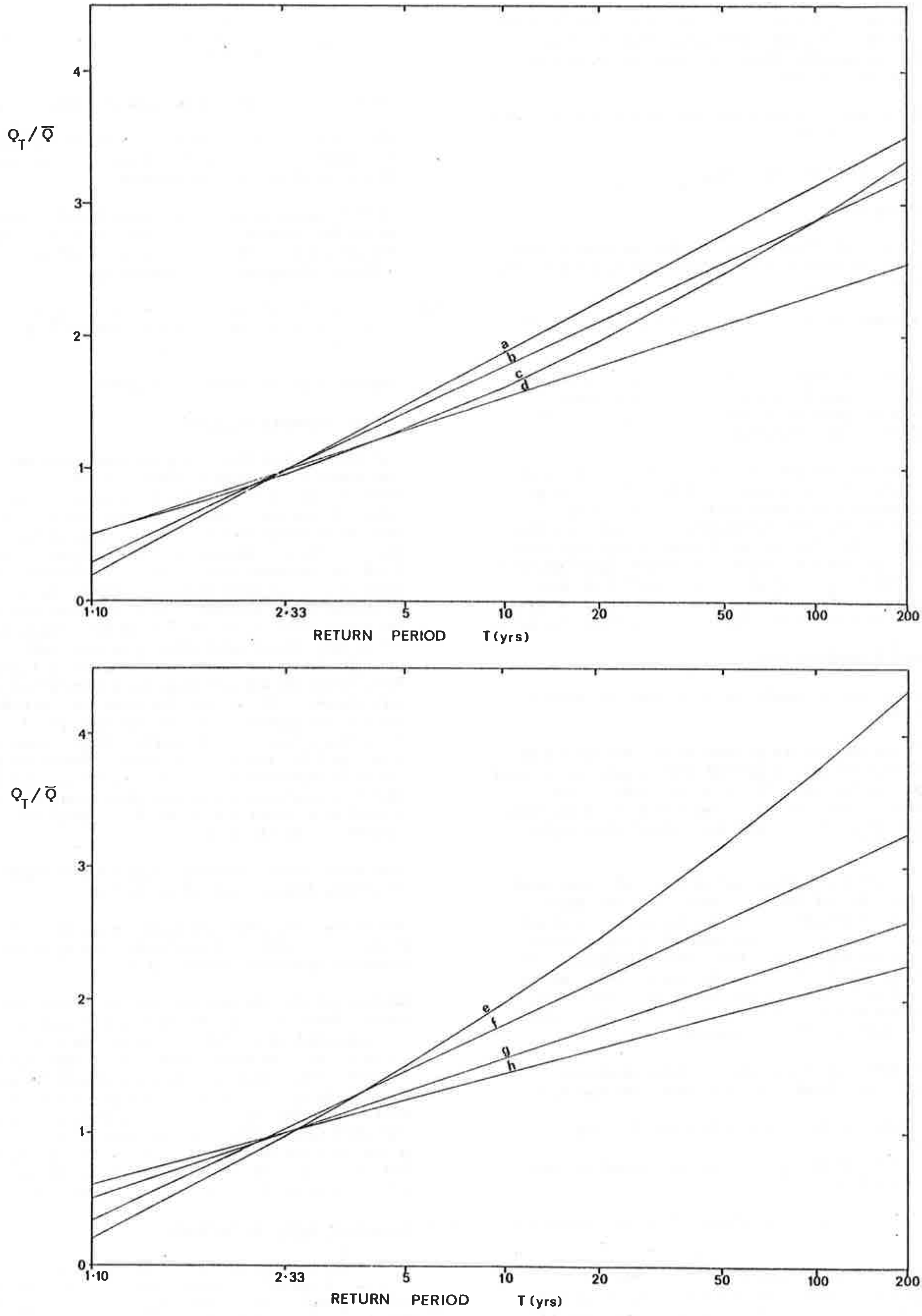


Figure 2 Frequency curves: Curve (a) is for Central Hawkes Bay; (b) NI East Coast; (c) Bay of Plenty; (d) NI West Coast; (e) South Canterbury-Otago; (f) Southland; (g) SI East Coast; (h) SI West Coast

In the Bay of Plenty and South Canterbury-Otago flood frequency regions, the three parameter distributions were preferred, but elsewhere the two parameter Extreme Value type 1 (EV1, Gumbel) distribution was generally satisfactory. In general, these methods are not reliable for $T>5N$ and the regional procedure described in this report should then be used.

A second program allowed large historical floods to be included. Such floods are unusually large events known to have been the largest in $(N + J)$ years, where N is the period of continuous record and J is an additional period of years, usually prior to recording.

4.3 Generalised Flood Frequency Curves

In some design situations, an indication of the design flood peak of high return period (greater than 100-200 years) may be required. When a sufficiently long series of annual flood peaks is available $(5N > T)$, standard frequency analysis methods should produce a suitable design flood peak estimate. However where there are insufficient annual flood peak data, one of two generalised curves may be used instead, up to a maximum return period of 1000 years. Co-ordinates for these curves are given in Table 1.

The western curve was constructed for the two West Coast flood frequency regions and the eastern curve for the rest of New Zealand, using all of the data used in the regional analysis study. All the available historical flood peaks were included, except four peaks for which realistic return periods could not be assigned because of insufficient record lengths. The western curve is based on a total of 1210 flood peaks from 89 flow stations, and the eastern curve is based on a total of 1020 flood peaks from 61 stations. While these are seemingly large data bases, it is emphasised that the curves should be regarded as a first attempt to obtain generalised flood frequency curves that extend to high return periods and they should be applied cautiously in design.

Because of probable differences between a generalised curve and the corresponding regional curve, a spurious discontinuity which should be smoothed out will appear in a catchment's flood frequency curve at $T = 200$ years.

5. ESTIMATION OF MEAN ANNUAL FLOOD

5.1 Regional Mean Annual Flood Equations

The nine mean annual flood regions into which the country has been divided are shown in Fig. 3. Equation (2) estimates the mean annual flood (m^3/s) in each of these regions using the coefficients a,b,c and d given in Table 2:

$$\bar{Q}_R = aA^b I^c P^d \quad \dots (2)$$

The variables contained in the regional equations, their symbols, units and method of measurement are explained below.

(1) Catchment Area, km^2 (A):

This is measured by planimetering around the catchment boundary on a suitably scaled map (eg, NZMS1 series).

(2) Rainfall Intensity, m per 24 hours (I):

Estimates of the rainfall intensity statistic used in deriving the equations for $\bar{Q}$ were obtained by taking the arithmetic mean of the 2-year, 24-hours data listed by Robertson[8] for rainfall stations located within, or near to, the catchment concerned. (Note: Robertson adjusted 9 am-9 am daily rainfalls by a factor of 1.14 to give 24 hour maxima). Estimates can be made from the maps and tables in Tomlinson[9] and tables in Coulter and Hessell[2] which contain frequency analyses of rainfall intensity data. These revisions of Robertson[8] used data from twice as many stations and so better estimates of I for individual catchments should be possible.

An areal reduction factor should not be applied to point estimate of I because in many situations, especially for the high country catchments, the estimates of I that are available in Robertson[8] are likely to be biased, and this bias is allowed for in the equations. For the same reason the intensity estimates should not be adjusted for altitudinal effects when the equations are used to estimate mean annual flood. As Tomlinson's maps include adjustments for altitude, they may not provide suitable intensity estimates in sparsely gauged high country areas.

(3) Mean Annual Rainfall, m/a (P):

The mean annual rainfall for a catchment may be estimated directly from rainfall records from stations within, or near to, a catchment. Where no such rainfall records exist, estimates of P should be obtained from the 1:500,000 isohyetal maps of 1941-1970 annual rainfall normals published by the NZ Meteorological Service.

5.2 Combination of Mean Annual Flood Estimates

When a short flood record is available, the estimate of $\bar{Q}$ from the record (Eqn 1) can be combined with the estimate from the regional mean annual flood equation (Eqn 2, denoted $\bar{Q}_R$). The concept used treats the regional equation estimate as equivalent to having a further N_R years of record. Values of N_R for each region are given in Table 2. The combined estimate is given by Eqn 3.

$$\bar{Q} = (\Sigma Q_i + \bar{Q}_R N_R)/(N + N_R) \quad \dots (3)$$

6. RELIABILITY

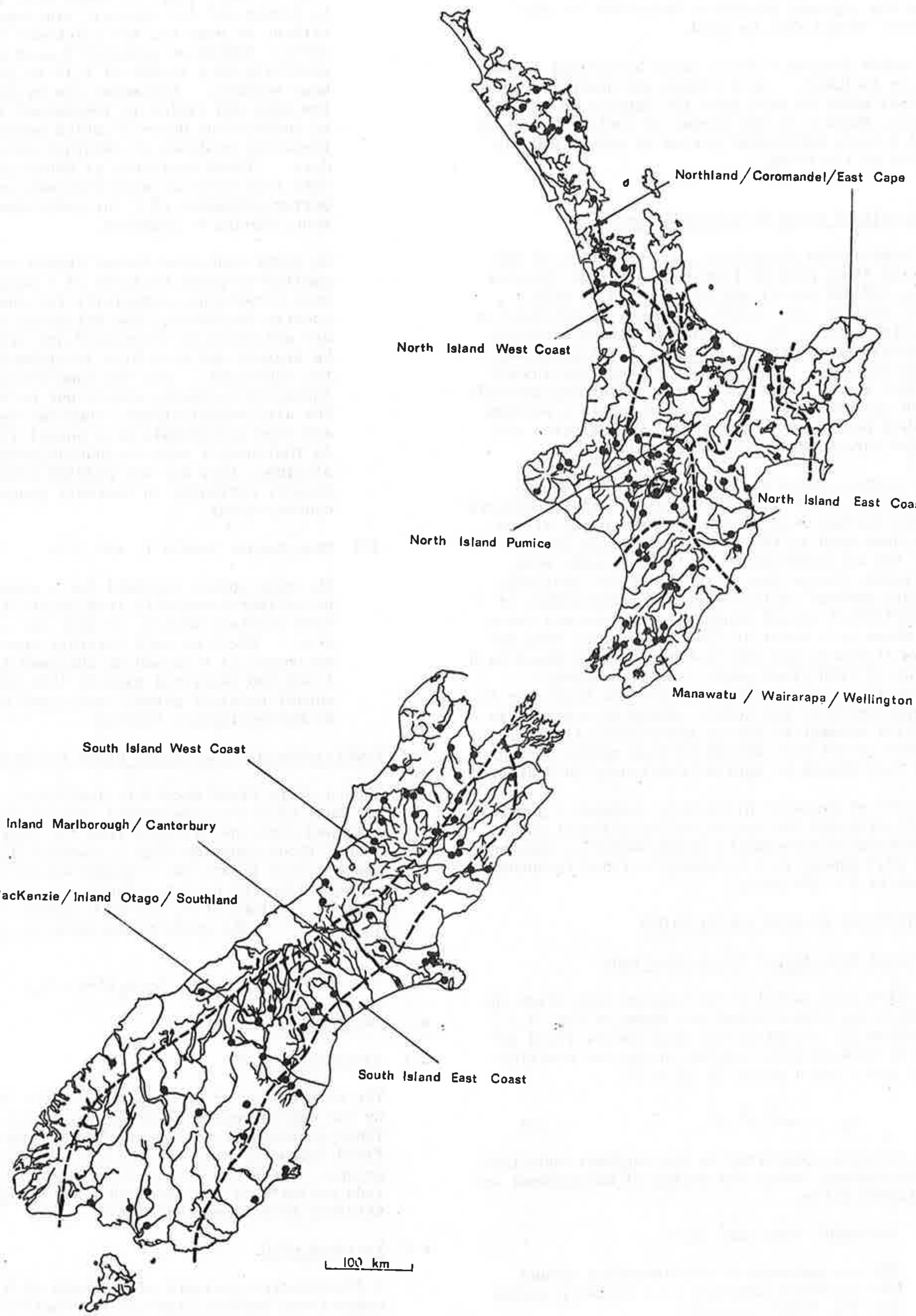
6.1 Variance of $Q_T/\bar{Q}$

The reliability of the regional curves is given by the expressions for var $(Q_T/\bar{Q})$ in Table 3. These expressions were derived after pooling the flood frequency data for the various regions into groups. Each expression is an order of magnitude estimate of the standard error of $Q_T/\bar{Q}$ obtained from a regional curve.

6.2 Variance of $\bar{Q}$

A dimensionless measure of variance of $\bar{Q}$ for comparisons between sites is the coefficient of variation Cv defined by Eqn 4:

Figure 3 Mean annual flood regions and locations of stations used in deriving Table 2



$$Cv = \{var\ (Q_i)\}^{1/2}/\bar{Q} \qquad ...(4)$$

Because of sampling error, an estimate of Cv from a single record is not as reliable for that record as a regional estimate obtained from many records. The regional estimates, Cv_R, given in Table 2 are the average of Cv from all sites in the mean annual flood regions weighted by the length of record. Alternative regional estimates are possible from the flood frequency curves. Because of Cv_R values in Table 2 relate to the same region as $\bar{Q}_R$, they are preferred for estimating var $(\bar{Q})$ using Eqn 5.

$$var\ (\bar{Q}) = var\ (Q_i)/N \simeq (Cv_R\bar{Q})^2/N \qquad ...(5)$$

This estimate is appropriate when $\bar{Q}$ is estimated using Eqn 1.

The scatter of data about the regression line that defines each mean annual flood equation in Table 2 is also measuring var $(\bar{Q}_R)$, that is the lack of goodness-of-fit. If it is assumed that this variance arises only because records are short and cover different periods of time, the variance may be represented by an equivalent length of record N_R defined by Eqn 6:

$$var\ (\bar{Q}_R) = (Cv_R\bar{Q}_R)^2/N_R \qquad ...(6)$$

This estimate is appropriate when $\bar{Q}_R$ is estimated from Eqn 2.

When $\bar{Q}$ is estimated by combining observed flow data with a regional estimate using Eqn 3, the variance of this combined estimate is given by Eqn 7:

$$var\ (\bar{Q}) = Cv_R^2/\{N/(\Sigma Q_i/N)^2 + N_R/\bar{Q}_R^2\} \qquad ...(7)$$

6.3 Variance of Q_T

The variance of a design flood peak Q_T estimate may be obtained from the relationship

$$var\ (Q_T) = var\ (\bar{Q}.Q_T/\bar{Q}) \qquad ...(8)$$

Equation 8 may be expanded to give:

$$var\ (Q_T) \simeq (\bar{Q})^2.var\ (Q_T/\bar{Q}) + (Q_T/\bar{Q})^2.var\ (\bar{Q}) \qquad ...(9)$$

All the terms on the right-hand side of Eqn 9 are defined above.

7. EXAMPLE

As an illustration of the method, consider site 16501, the Motu River at Houpoto. This site was not included in the derivation of the RFE method because of some early but unjustified doubts about its rating curves. A description of the flood hydrology is given by Riddell[7].

The area of the catchment is 1393 km^2 and the mean annual rainfall P, as estimated from the New Zealand Meteorological Service 1:500,000 mean annual rainfall isohyetal maps, is 2.55 m/a. The annual flood peaks for the 21 years of record at the site are:

Year	Peak (m^3/s)	Year	Peak (m^3/s)
1958	2238	1969	613
1959	562	1970	2387
1960	1506	1971	2019
1961	702	1972	1924
1962	1552	1973	1094
1963	1644	1974	1357
1964	2201	1975	1690
1965	2859	1976	1311
1966	2689	1977	865
1967	1802	1978	2875
1968	1082		

The three cases following, estimate the 100-year flood peak Q_{100} assuming that;

(1) no flood record is available

(2) only five years of record, for the years 1974-1978, are available;

(3) the full length of record from 1958 to 1978 is available.

Case 1 : N=0

(a) With no record, $\bar{Q} = \bar{Q}_R$ must be estimated from the regional equation. As indicated from Fig. 3, the catchment lies in the Northland/Coromandel East Cape mean annual flood region. Using the coefficients from Table 2 in Eqn 2 with the values of A and P above;

$$\bar{Q} = 2.13 \times 1393^{0.64} \times 2.55^{2.33}$$
$$= 1940\ m^3/s$$

(b) The site is in the North Island East Coast flood frequency region (Fig. 1), and hence, from Fig. 2 or Table 1, the regional curve ordinate is

$$Q_{100}/\bar{Q} = 2.89$$

(c) Combining the estimates for $\bar{Q}$ and $Q_{100}/\bar{Q}$ produces Q_{100}. Thus

$$Q_{100} = 1940 \times 2.89$$
$$= 5610\ m^3/s$$

(d) The corresponding standard error of estimate is obtained from Eqn 9. The RHS terms of this equation are estimated as follows:

$$\bar{Q} = 1940$$

From Table 3,

$$var\ (Q_{100}/\bar{Q}) = \{(-1.25 + 5.74\ ln100)/100\}^2 \times 2.89^2$$
$$= 0.25^2 \times 2.89^2 = 0.522$$

The third term is:

$$(Q_{100}/\bar{Q}) = 2.89$$

The final term var $(\bar{Q})$ is obtained using Eqn 6 with $\bar{Q}_R = \bar{Q}$ above, and Cv_R and N_R from Table 2:

$$\text{var}(\bar{Q}) = \text{var}(\bar{Q}_R) = (0.54 \times 1940)^2/3 = 370000$$

Hence:

$$\text{var}\, Q_{100} \simeq 1940^2 \times 0.522 + 2.89^2 \times 370000 \simeq 5.1 \times 10^6$$

and the standard error of Q_{100} is;

$\{\text{var}\,(Q_{100})\}^{\frac{1}{2}} \simeq 2300$, which is 40% of Q_{100}.

Case 2 Assuming five years of record (1974-1978)

(a) The regional curve ordinate is unchanged, so that $Q_{100}/\bar{Q} = 2.89$.

(b) $\bar{Q}$ may be estimated from the five years of record.

Thus,

$\bar{Q} = (1357 + 1690 + 1311 + 865 + 2875)/5 = 1620\ m^3/s$.

(c) A weighted mean estimate of $\bar{Q}$ is calculated from Eqn 3 with $\bar{Q}_R = 1940$ (Case 1), $N_R = 3$ (Table 2), $\Sigma Q_i = 1620 \times 5$ ((b) above) and $N = 5$. Thus,

$\bar{Q} = (1620 \times 5 + 1940 \times 3)/(5 + 3) = 1740\ m^3/s$

(d) The estimates of $Q_{100}/\bar{Q}$ and $\bar{Q}$ give;

$Q_{100} = 1740 \times 2.89 = 5030\ m^3/s$

(e) Evaluating the terms of Eqn 9

(i) $(\bar{Q})^2 = 1740^2$

(ii) $(Q_{100}/\bar{Q})^2 = 2.89^2$

(iii) $\text{var}\,(Q_{100}/\bar{Q}) = 0.522$, as in Case 1.

(iv) $\text{var}\,(\bar{Q})$ is estimated using Eqn 7; noting that $\Sigma Q_i/N = 1620$,
$\text{var}\,(\bar{Q}) = 0.54^2/\{5/1620^2 + 3/1940^2\} = 110000.$

(v) Applying Eqn 9 gives

$$\text{var}\,(Q_{100}) = 1740^2 \times 0.522 + 2.89^2 \times 110000 = 2.5 \times 10^6$$

and the standard error of Q_{100}, $\{\text{var}\,(Q_{100})\}^{\frac{1}{2}} = 1600\ m^3/s$, which is 32% of Q_{100}.

Case 3 Assuming full record 1958-1978

(a) As in Case 2, $\bar{Q}$ can be estimated directly from the annual series.

$\therefore \bar{Q} = \frac{1}{21} \sum_{i=1}^{21} Q_i = 1665\ m^3/s$, and the standard deviation is $711\ m^3/s$.

The Cv for the 21 years of record is 711/1665 = 0.43 which compares well with the regional estimate of $Cv_R = 0.54$.

(b) (i) Since T< 5N and N > 20, frequency analyses may be performed on the annual series using two and three-parameter distributions. The EV1 distribution gives a good fit to the data (Riddell[7]) and yields

$Q_{100} = 4170\ m^3/s$

and an approximate standard error of estimate of $800\ m^3/s$. (This is calculated using the formula on p. 170 in Natural Environment Research Council (1975), and assuming Cv = 0.54).

(ii) The corresponding estimate using the regional curve is

$Q_{100} = 1665 \times 2.89 = 4810\ m^3/s$

and the associated standard error of estimate is obtained from Equation 9 as

$$\text{var}\,(Q_{100}) = (1665)^2 \times 0.522 + 2.89^2 \times (0.54 \times 1665)^2/21 = 1.77 \times 10^6$$

so that

$\{\text{var}\,(Q_{100})\}^{\frac{1}{2}} = 1330\ m^3/s$, which is 28% of Q_{100}.

Results Summary

The estimates of $\bar{Q}$ and Q_{100} obtained for the three cases are listed in Table 4.

Estimates of $\bar{Q}$ for the first two cases (with nil and 5 years record respectively) are fortuitously close to the $\bar{Q}$ estimate from the full 21 years of record. The dimensionless prediction error for $\bar{Q}_R$ from the regional mean annual flood equation is (1940 - 1665)/1665 = 0.17 which is significantly less than the standard error from this equation of 0.31 (Table 4). Although the corresponding error in $\bar{Q}$ from the 5 years of record is only (1620-1665)/1665 = -0.03, the variation in estimates of $\bar{Q}$ from short records is evident if other 5 year samples are drawn from the 21 year record. For example, using maxima for the years 1958-1963, 1964-1968, and 1969-1973, the errors compared with $\bar{Q}$ from the full record are respectively -0.28, 0.28 and -0.04. For independent 5 year samples, the coefficient of variation of estimates is expected to be $Cv_R/N^{\frac{1}{2}} = 0.54/5^{\frac{1}{2}} = 0.24$, which is greater than the standard error of the final weighted estimate of 0.19 (Table 4).

In the third case, with 21 years of record, it is not obvious whether Q_{100} should be estimated from frequency analysis and extrapolation of the 21 years of record, or whether the regional flood frequency curve ordinate $Q_{100}/\bar{Q}$ (Table 1) should be used with the mean annual flood estimate. Although error estimates seem to favour estimates of Q_{100} from the record, they were obtained by different methods and their difference should be discounted. Conservatism must favour the estimate obtained using the regional flood frequency curve ordinate, namely $Q_{100} = 4810\ m^3/s$.

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NOTATION

SYMBOL	DEFINITION
A	Catchment area in km^2
Cv	Coefficient of variation of a single series of annual flood peaks
Cv_R	Regional estimate of coefficient of variation of annual maxima
E( )	Expected value
EV1	Extreme Value Type 1 frequency distribution
I	2 year return period, 24 hour duration rainfall intensity in m per 24 h
J	Period of years, additional to period of continuous record N, for which the stated floods have not been exceeded
N	Number of annual flood peaks in a continuous series
N_R	Equivalent length of record for a regional estimate
P	Mean annual rainfall in m/a
Q_i	Flood peak in year "i" (m^3/s)
Q_T	T-year flood (m^3/s)
$\bar{Q}$	Mean annual flood (m^3/s)
$\bar{Q}_R$	Estimate of $\bar{Q}$ from regional mean annual flood equation (m^3/s)
T	Return period in years
var ( )	Variance

TABLE 1

CO-ORDINATES FOR REGIONAL FLOOD FREQUENCY CURVES

Region	Curve Ordinates							
	$Q_5/\overline{Q}$	$Q_{10}/\overline{Q}$	$Q_{20}/\overline{Q}$	$Q_{50}/\overline{Q}$	$Q_{100}/\overline{Q}$	$Q_{200}/\overline{Q}$	$Q_{500}/\overline{Q}$	$Q_{1000}/\overline{Q}$
North Island								
North Island West Coast	1.30	1.55	1.78	2.09	2.32	2.55	-	-
Bay of Plenty	1.31	1.62	1.96	2.46	2.87	3.33	-	-
North Island East Coast	1.43	1.78	2.12	2.56	2.89	3.21	-	-
Central Hawkes Bay	1.49	1.89	2.27	2.77	3.14	3.51	-	-
South Island								
South Island West Coast	1.24	1.45	1.64	1.89	2.08	2.27	-	-
South Island East Coast	1.31	1.56	1.80	2.12	2.35	2.58	-	-
South Canterbury-Otago	1.51	1.99	2.48	3.17	3.73	4.33	-	-
Southland	1.47	1.82	2.17	2.61	2.94	3.27	-	-
Generalised Curve								
Western NZ	-	-	-	-	-	2.71	3.23	3.68
Eastern NZ	-	-	-	-	-	3.42	3.88	4.24

TABLE 2

REGIONAL MEAN ANNUAL FLOOD EQUATION COEFFICIENTS

AND VALUES OF N_R AND Cv_R

Mean annual flood region (Fig 3) (1)	a (2)	b (3)	c (4)	d (5)	N_R (yrs) (6)	Cv_R (7)
North Island West Coast	513	0.82	2.18	0	1	0.40
Northland/Coromandel/East Cape	2.13	0.64	0	2.33	3	0.54
North Island Pumice	229	0.74	2.54	1.75	2	0.54
North Island East Coast	464	0.76	2.24	0	5	0.54
Manawatu/Wairarapa/Wellington	80	0.92	1.53	0.94	1	0.40
South Island West Coast	22	0.94	0.99	0	1	0.36
Inland Marlborough/Canterbury	0.964	0.88	0	0	5	0.66
South Island East Coast	1.11	0.89	0	3.0	7	0.98
Mackenzie/Inland Otago/Southland	15	0.94	1.3	0	3	0.66

Note that any number with zero exponent equals unity. Columns 2...5 contain coefficients to estimate mean annual flood using eqn 2:

$\overline{Q} = aA^bI^cP^d$ with $\overline{Q}$ m^3/s, A km^2, I m/24h, P m/a.

TABLE 3

REGIONAL EXPRESSIONS FOR VAR ($Q_T/\overline{Q}$)

Regions	$\{var\ (Q_T/\overline{Q})\}^{\frac{1}{2}}/(Q_T/\overline{Q})$
Combined NI West Coast	(0.94 + 3.93 lnT)/100
Bay of Plenty North Is. East Coast Central Hawkes Bay	(-1.25 + 5.74 lnT/100
South Is. West Coast	(2.46 + 2.25 lnT)/100
South Is. East Coast South Canterbury/Otago and Southland	(2.61 + 4.54 lnT)/100

TABLE 4

SUMMARY OF MOTU FLOOD ESTIMATES

Length of record used	(yrs)	0	5	21	21*
Estimate of $\overline{Q}$	(m^3/s)	1940	1740	1665	-
(Standard error of $\overline{Q}$)/$\overline{Q}$	(%)	31	19	12	-
Estimate of Q_{100}	(m^3/s)	5610	5030	4810	4170
(Standard error of Q_{100})/Q_{100}	(%)	40	32	28	19

* Estimate from flood peak data without reference to the regional flood estimation method.

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