SURFACE WATER RESOURCES OF THE KERIKERI REGION

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ABSTRACT

The simple water balance equation P − E = Q is used to map the average annual potential runoff of the Kerikeri region. A map of annual runoff is also produced using the hydrological region concept in which temporary gauging sites are established and discharges obtained by gauging are correlated with a base station. The two maps differ markedly because the hydrological characteristics in the monitored streams vary with the bedrock geology.

INTRODUCTION

Catchments draining into the Kerikeri Inlet, North Island, New Zealand, provide a suitable environment for sub-tropical crops, and their horticulture demands more water than other land uses in adjacent parts of Northland (Male and Roke, 1978). In some catchments demand for irrigation water has exceeded the low flow discharge and consequently a regulated supply is needed. A water resource survey was made so that water could be realistically allocated and a suitable supply scheme designed.

The surface water resources of the major subcatchments of the Kerikeri Inlet have been estimated using two methods: the simple water balance equation has been used to produce a map of potential runoff, and hydrological region concept has been used to assess the actual water resources. Comparisons between the two methods provide an understanding of runoff patterns within the region.

The hydrological region concept facilitates the collection and derivation of a large amount of information from a relatively low capital input (Morrissey 1972a, b; Scarf, 1972). Streamflow data from temporary gauging sites are correlated with concurrent data from the region's representative basin or other long term recording stations. The flow characteristics of the representative basin are assumed to be similar to those of other streams in the region. By correlating concurrent gaugings, it is possible to estimate the duration of any streamflow, given that that duration can be established for the representative basin.

DESCRIPTION OF THE KERIKERI REGION

The Kerikeri region (Fig. 1) is 175 km^2 in area, and includes four major catchments that drain to the Kerikeri Inlet—the Kapiro, Waipapa, Kerikeri and Puketotara and two smaller streams to the southeast—the Wairoa and Okura.

The bedrock of the region (Fig. 2) is predominantly Horeke basalt of Pleistocene age and some Parahaki andesitic volcanics of Pliocene age. The basalts have been laid down as a series of flows, sloping eastwards,

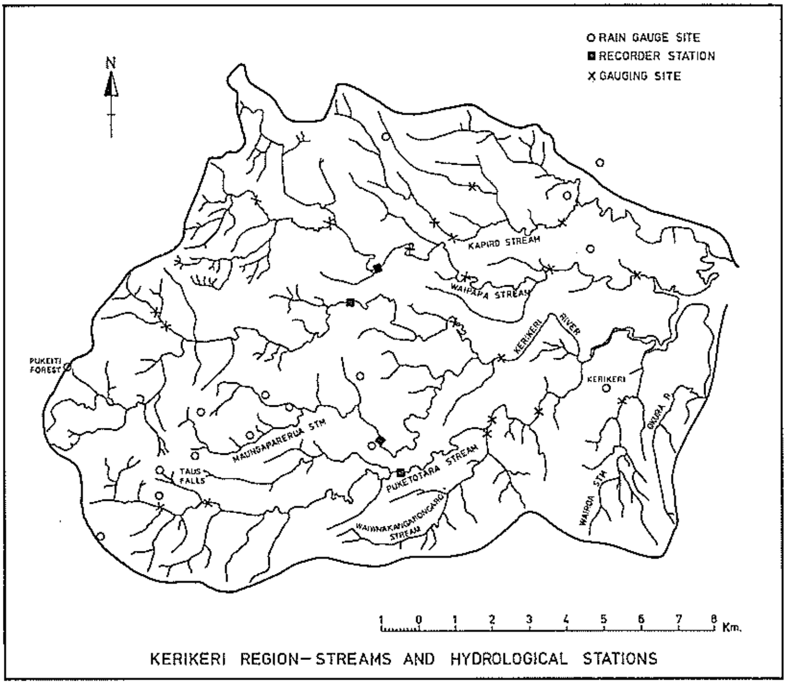

FIG. 1—Kerikeri region—streams and hydrological stations.

over an existing dissected hilly terrain of greywacke. Basement greywacke outcrops in some of the major stream channels, and to the east and west of the region. Early Tertiary sedimentary deposits in the Waitangi catchment form the southern boundary of the region. Soils derived from the basalts are mainly red and brown loams with some granular clays, and yellow brown earths occur on the greywacke and sedimentary deposits. Streams have cut through the basalt sheets which dominate the region, forming a series of large flat interfluves and steep sided valleys. The landscape is consequently moderately rolling with steep valley sides and gullies, ranging in elevation from sea level to 370 m over a distance of 14 km.

Along with the rest of Northland, Kerikeri has a modified Mediterranean type of climate, with mild wet winters and a marked tendency towards summer drought. The mean temperature of 17.2°C for the period November to April, the virtual absence of frosts in winter, and over 2,000 hours of sunshine annually contribute to the area's suitability for sub-tropical horticulture. In addition to horticulture, dairying and sheep and beef grazing are the dominant land uses of the region. Some scrub and native bush occur in the headwaters of the major catchments.

DATA COLLECTION

Rainfall records have been collected by the N.Z. Meteorological

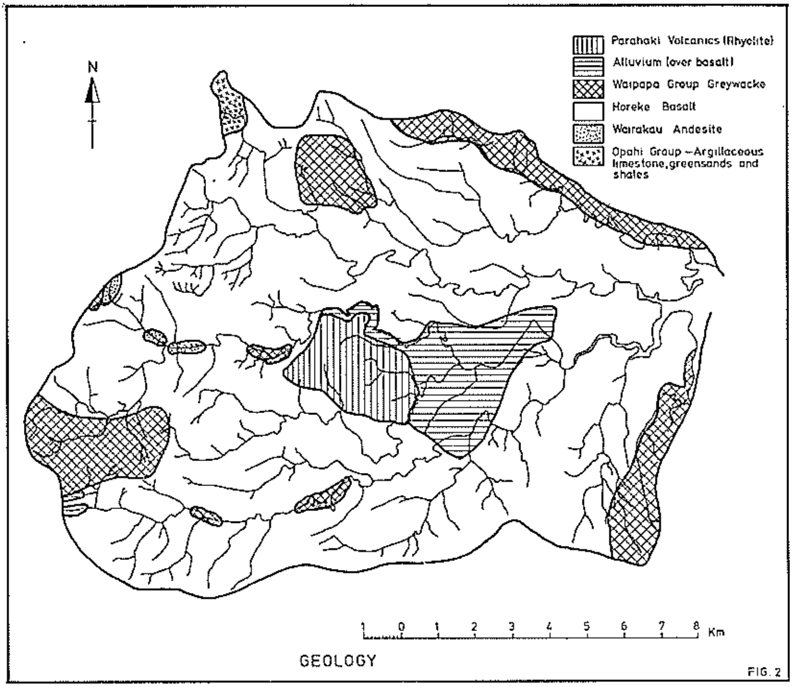

FIG. 2—Bedrock geology of the Kerikeri region.

Service (NZMS), and by the Water and Soil Division, Ministry of Works and Development (MWD) at 16 various stations throughout the region (Fig. 1). Long term normals for the period 1941-1970 for each station have been derived by NZMS (1972), and by Water and Soil Division for stations not included in the NZMS network. Most of the rain gauges are read daily although an automatic recording rain gauge and network of storage rain gauges is located in the Maungaparerua catchment.

Evapotranspiration data have been provided by the NZMS for the Kerikeri station, and for other stations throughout Northland. These were used to derive a relationship between evapotranspiration and altitude.

Streamflow data were collected by the Water and Soil Division from a continuous recorder and associated weir on Maungaparerua Stream (N11 : 391555), which was established in 1967 as the representative basin for the region. Continuous recorders are also located on Puketotara Stream (N11 : 395544), Kerikeri Stream (N11 : 385595) and Waipapa Stream (N11 : 393604), but as they were not operating when regional gauging began, their records are not suitable for the correlation of discharges.

Nine months of record were suitable for comparison of flow duration characteristics for the four major streams of the region. A series of 20 sites were selected for the collection of additional stream flow data within the Kerikeri region. Concurrent gauging from these sites were correlated with the representative basin, Maungaparerua Stream, using the relationship

$$q_t = kq_r^n$$

where q_t is the flow at the site and q_r is the flow at the representative basin.

RAINFALL

Rainfall normals were calculated for all short term stations by correlation with long term NZMS stations at Kerikeri, Taus Falls and Puketi Forest. Average annual rainfall (Fig. 3) increases westward from below 1500 m at sea level to 2580 mm at the top of the Kerikeri catchment. The rainfall pattern is influenced by two major factors; fronts or cyclones passing from west to east which are orographically modified by the higher land mass to the west, and by depressions bringing intense rainfall which originate north of New Zealand and move down the Northland peninsula.

SIMPLE WATER BALANCE

The expected average annual runoff of the Kerikeri region (Fig. 4) is derived using the simple water balance equation

$$P - E = Q$$

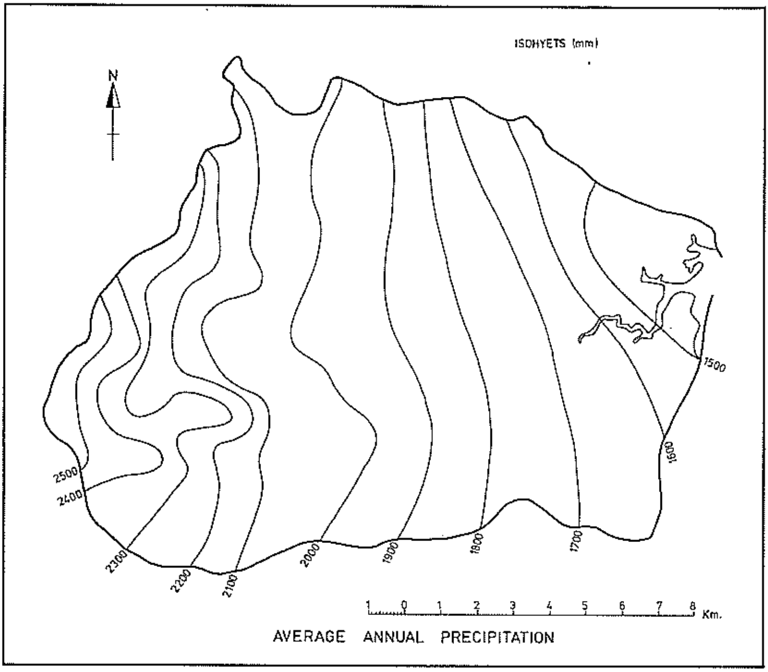

FIG. 3—Average precipitation of the Kerikeri region.

where P is average annual precipitation, E is average annual evapotranspiration and Q is average annual runoff. Evapotranspiration data (calculated by the Thornthwaite method) provided by the NZMS for the Kerikeri and other Northland stations were plotted against altitude. Using the derived relationship between annual evapotranspiration and altitude a map of evapotranspiration was constructed for the Kerikeri region. After overlaying the rainfall and evapotranspiration maps, differences between the two were calculated on a 20 mm grid at a scale of 1:63360. Points at each grid intersection were interpolated and isohyds plotted using standard isohyd values (Morrissey, 1972a).

STREAMFLOW

1. Maungaparerua Regional Station

The Maungaparerua catchment was selected as the representative basin of the Kerikeri region as defined by Toebes and Palmer (1969). The catchment is 11.14 km² in area with an altitudinal range from 183 m to 305 m and is a tributary of the Kerikeri River. Recordings of stream flow commenced in late 1967 at a 90 degree V-notch weir with 1:5 sloping wing walls. Table 1 summarises annual stream flow data.

Long term mean annual flow was estimated using rainfall records to extend flow data. Using rainfall normals (1941-1970) published by the NZMS and the method outlined by Morrissey (1972a), the long term

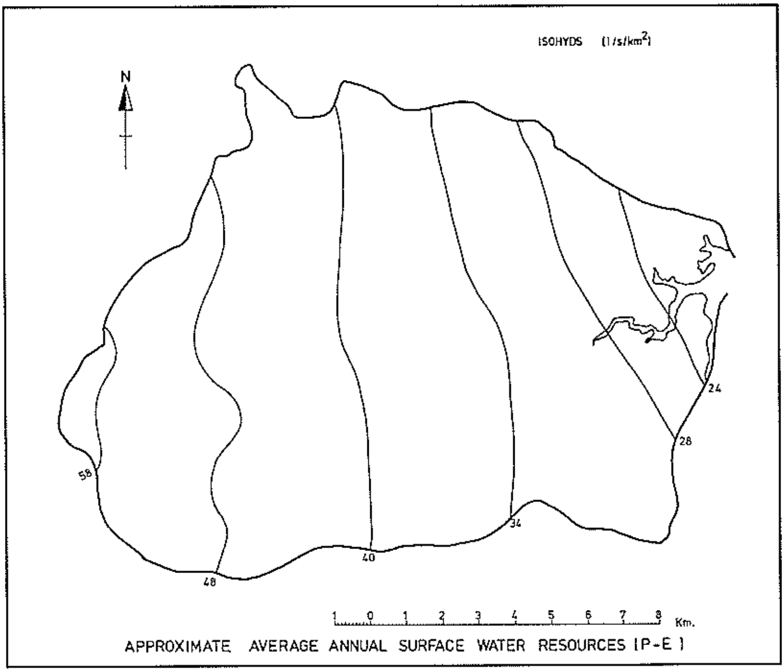

FIG. 4—Estimated average annual runoff (P-E).

TABLE 1—Annual mean and minimum flows for Maungaparerua Stream at Tyrees Ford.

Year	Annual mean flow (*l*/s)	k value	$t_{\frac{1}{2}}$ (days)	Minimum flow (*l*/s)
1968	658.8	0.967	22	25.5
1969	516.4	0.964	19	45.5
1970	335.2	0.962	18	15.5
1971	773.3			
1972	440.5			
1973	341.6			
1974	398.1			
1975	517.9			
1976	445.8			
Average Annual Flow	491.9			
Coeff. of Variation (%)	29.5			

mean annual rainfall and flow were estimated for Maungaparerua Stream. Mean annual rainfall is 2106 mm and mean annual flow is 1362 mm (481.4 *l*/s) for the period 1941-1970. These estimates are derived from nine years of records during which the mean annual rainfall was 2152 mm and the mean annual runoff, 1392 mm. The rainfall-runoff regression equation for the nine years of data (Fig. 5) is:

$$\text{Runoff} = 0.934\ \text{Rainfall} - 618 \quad (r^2 = 0.916, \text{SE} = 112\ \text{mm})$$

Characteristics of base flow recession along with the recurrence interval of minimum flows are important in planning water allocation when streamflow is the source of water. Base flow recession data for Maungaparerua stream are presented in Table 1 for years of lowest annual minimum flow (1970), highest annual minimum flow (1969) and that year's minimum flow (1968) which was closest to the median for the period of record (1968–76). The k value is derived from the simple exponential equation $q_t = q_o k^t$ where q_t is the discharge of the stream at time t, q_o is the initial discharge, t is the time lapse in days between q_o and q_t, and k is a constant defining the rate of recession. Martin (1973) proposed another form of characterisation of baseflow recessions; $t_{\frac{1}{2}}$—the time for flow to decrease by 50 per cent. The figures shown in Table 1 are indicative of the types of summer flows occurring in the Kerikeri region. Lowest flows occur during February and March except in 1972 when the lowest flow occurred in December. The recurrence intervals of the recorded low flows were determined using the Weibull formula

$$R = (N + 1)/M$$

where R = recurrence interval in years, N = number of years of record and M = the rank number of the event. The 5 year minimum flow for the Maungaparerua River at Tyrees Ford is 19.8 *l*/s and the 10 year minimum flow is 15.6 *l*/s, such flows being recorded in 1974 and 1970 respectively.

Flow duration curves for the Maungaparerua River at Tyrees Ford (Fig. 6) indicate the variability in the annual hydrologic regime of the river. The flow duration curve for the full period of record (1968-1976) indicates average conditions. The three annual curves are for the year

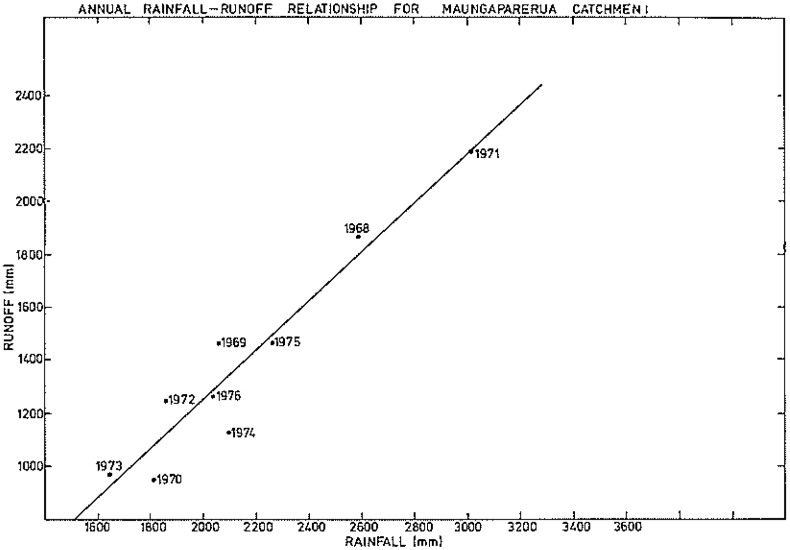

FIG. 5—Annual rainfall—runoff relationship for the Maungaparerua catchment.

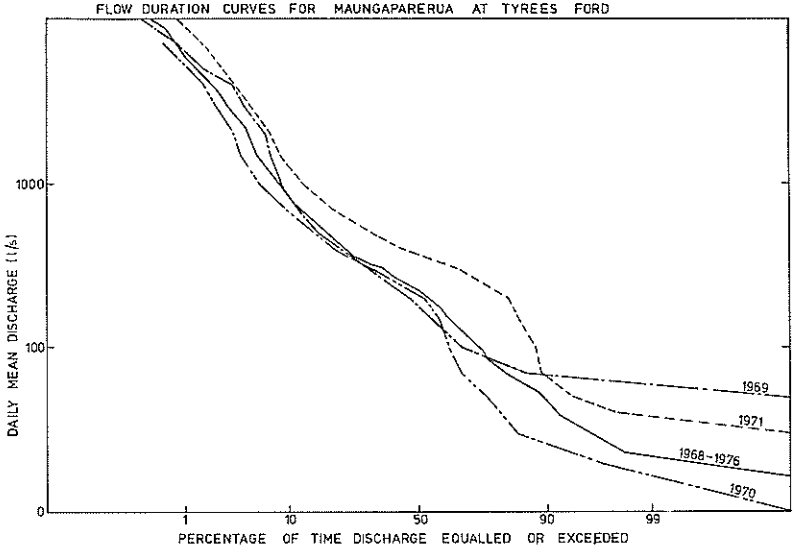

FIG. 6—Flow duration curves for Maungaparerua at Tyrees Ford.

of highest mean flow (1971), lowest mean flow (1970) and the year with a mean flow closest to the mean annual flow (1969). The greatest variation is in low flow where spring and summer rainfall patterns have a marked effect. Variations are less for higher discharges and do not reflect rainfall variability except for 1971 (the wettest year) when the moisture excess available for runoff influenced all but the lowest flows.

2. Other Recorder Stations

In addition to the Maungaparerua regional station, there are three other continuous recorders on streams in the region (Fig. 1), used primarily for irrigation investigations. The field gauging programme began a number of years prior to the establishment of these recorder stations and consequently they were not used because of their short period of record, most of which was not concurrent with other gauging. In addition the operation of these recorders has been fraught with difficulties and the data collected are insufficient for estimating most flow statistics. However recession flow duration data have been analysed for periods of concurrent operation with the Maungaparerua recorder.

The summer of 1977 was the only low flow period for which concurrent data were available and minimum flows and recession characteristics for this period are given in Table 2. Minimum specific discharge was highest in the Puketotara catchment and well sustained, but in the Kerikeri catchment where minimum specific discharge was next highest the flow was not so well sustained. The Maungaparerua River, while having a lower minimum specific discharge, had a more sustained flow than the Kerikeri River. The Waipapa Stream had a relatively low minimum specific discharge and streamflow was poorly sustained. The flow duration curves for the period June 1976 to March 1977 (Fig. 7), indicate that as daily mean discharge increases the runoff tends to become more uniform between catchments.

TABLE 2—Recession analysis for river stations in the Kerikeri Region.

River	Site	Minimum specific discharge (l s^{-1} km^{-2})	k	$t_{\frac{1}{2}}$ (days)
Maungeparerua	Tyrees	2.50	0.994	103
Kerikeri	Aish's	3.63	0.989	67
Puketotara	Backblocks	4.76	0.995	155
Waipapa	Pungaere Rd.	1.55	0.966	21

3. Regional Streamflow Gauging

A wide range of flows from minimum to above mean flow were measured. Gauging was undertaken only after three days of fine weather to allow streamflows to become relatively stable following storms. This proved difficult during winter months when there were often 25 raindays in a month. Consequently the collection of data at the higher stages was spread over six years. Gauging of minimum flows was simpler due to long periods of dry summer weather, but care was required to avoid the influence of streamflow abstractions. This latter problem meant that some sites were gauged up to 20 times to ensure that abstraction was not influencing the data.

Correlation and regression analysis were used to establish the relationship between each gauging site and the Maungaparerua Station (Fig. 8).

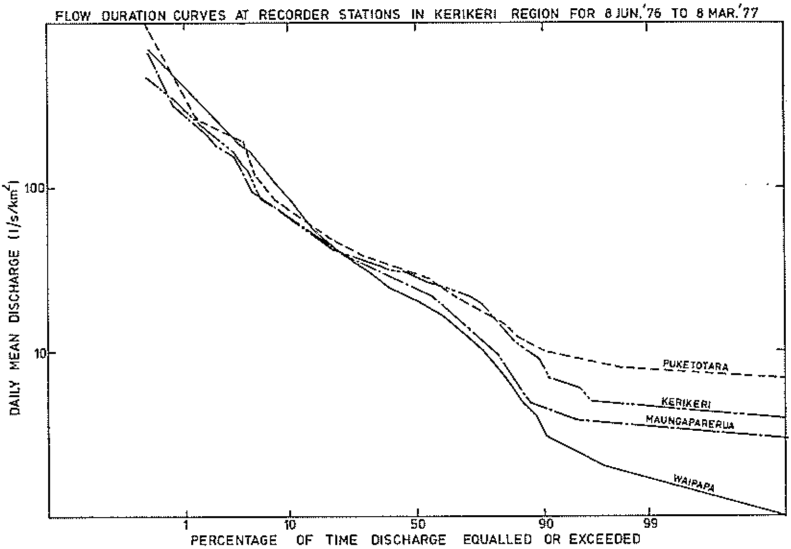

FIG. 7—Flow duration curves at recorder stations in the Kerikeri region for 8 June 1976 to 8 March 1977.

By using regression techniques it was possible to examine each gauging for influences from streamflow abstraction or rainfall. The variance explained by the regression was required to be 95 per cent, (i.e. $R^2 = \geqslant 0.95$) although this condition may be too rigorous considering the accuracy of current meter gaugings. Estimates of average annual flow and the five year minimum flow for all sites are given in Appendix 1.

4. Comparison of Measured and Calculated (P − E) Discharges

With the actual discharge known for a number of sites it is interesting to integrate the P − E map (Fig. 4) to estimate mean annual discharge for those same sites (Table 3). Measured and calculated discharges differ by 12 per cent. Considering the possible sources of error in the estimation of rainfall, evapotranspiration, streamflow, and the planimetering of the respective maps, this result is remarkably close. Within each catchment listed in Table 3 there is considerable variation between calculated and observed water yields, yet it would appear that the whole Kerikeri region is relatively "water tight" in view of the close balance between the observed and calculated yields.

5. Water Resources Mapping

The water resources of the region were mapped using the basic methods outlined by Scarf (1972) and Morrissey (1972a). Mean annual specific discharge values were calculated for each gauged site and for residual catchment areas. A residual catchment area is defined as that area remaining after the catchment areas of all upstream sites have been deducted. Similarly the corresponding discharge for calculating specific discharges of a residual catchment is obtained by deducting

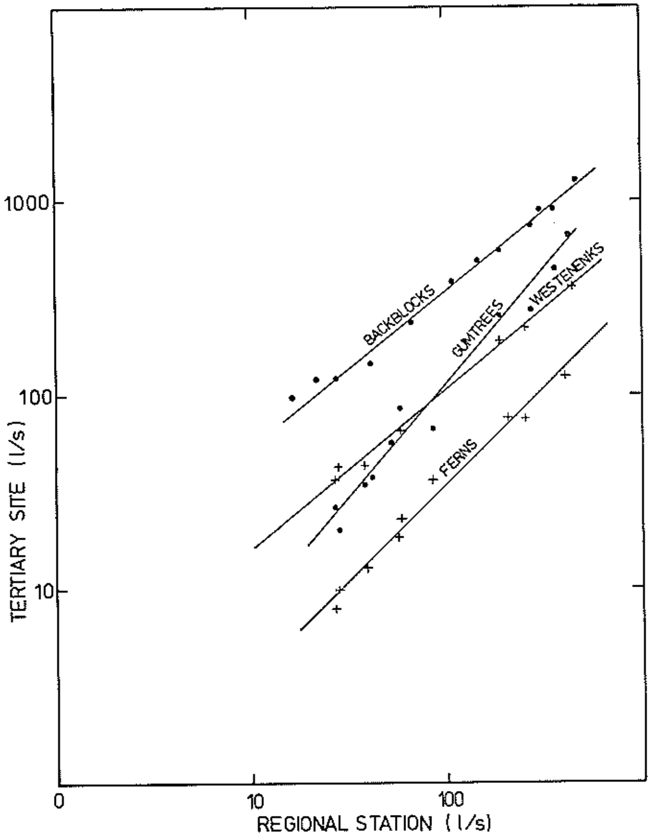

FIG. 8—Correlation between discharges at Maungaparerua station and at gauging sites.

average annual discharges of all upstream sites (Scarf, 1972). The three major catchments had at least six gauging sites and the Kapiro catchment had four. Average annual specific discharges, particularly for some residual catchments, are extremely high (over 200 $l\,s^{-1}\,km^{-2}$). Morrissey (1972a) suggests that the mean annual specific discharge should be plotted at the median elevation of the catchment on the assumption that there is a direct correlation between precipitation and evapotranspiration with altitude. This is not applicable for all catchments in the Kerikeri area due to the influence of flows from springs. By plotting the mean annual specific discharge at the centroid of the catchment a uniform distribution of runoff over the catchment is assumed although this is unlikely with the presence of spring flow. Scarf (1972) suggested that plotting error would be small either if the catchment area was small, or if the isohyd gradient was steep. In the Kerikeri

TABLE 3—Comparison of measured and calculated (P-E) discharges.

Catchment	Site	Measured discharge (*l*/s)	Calculated discharge (*l*/s)	Calculated discharge as a percentage of measured discharge
Kapiro	Stanners Rd	125.0	92.5	74.0
Kapiro	Hodders	184.2	139.5	75.7
Kapiro	Box Culvert	221.2	156.7	70.8
Kapiro	Long Pool*	761.0	451.1	59.3
Mangakohou	Ram	89.7	174.1	194.1
Pungaere	Totara Trees	337.5	424.4	125.7
Waipapa	Pungaere Rd	1023.0	786.9	76.9
Waipapa	Koglers	1047.0	849.3	81.1
Waipapa	Wedge	1200.0	1006.8	83.9
Waipapa	Pines	1636.0	1178.2	72.0
Waipapa	Lava falls*	2000.0	1266.4	63.3
Kerikeri	NE fork	207.0	59.6	28.8
Kerikeri	30 m below Jtn	704.4	181.8	25.8
Kerikeri	Aish's	1132.0	1286.8	118.6
Kerikeri	Wooden R	1300.0	1456.5	112.0
Kerikeri	SH Bridge*	1617.0	2226.8	137.7
Maungaparerua	Tyrees	481.4	471.3	97.9
Puketotara	Ferns	150.8	225.8	149.7
Puketotara	Westenenks	363.6	462.6	127.2
Puketotara	Backblocks	1104.0	1142.1	103.5
Puketotara	SH Bridge	1937.0	1653.4	85.3
Puketotara	Tangelo Grove*	2013.0	1734.6	86.6
Waiwhakanga-rongaro	Gum Trees	577.1	406.5	70.4
Wairoa	Cobham Rd*	355.0	308.7	86.9
TOTAL DISCHARGE		6746.0	5987.6	88.0

* Site added to give total discharge.

(Total discharge is an addition of mean annual discharges or estimated discharge at the site for the greatest catchment area for each of the major subcatchments to the Inlet.)

area commonly both of these apply, and points were plotted at the centroid of the catchments.

The map of mean annual specific discharge was contoured by eye (Fig. 9). A 20 per cent increase in the interval between isohyds was used although this creates deceptive gradients. Uniform interval isohyds would be more appropriate but may introduce error when assessing discharge from the map.

When the map discharge value is checked with the known mean annual discharge for each gauging site, it is apparent that catchments are either yielding more or less water than expected. For example, in the upper Kerikeri catchment 704 *l*/s comes from 3.73 km^2 of catchment while

1132 *l*/s comes from 25.7 km². This means that the residual catchment area has a discharge of 19.5 $l\ s^{-1}\ km^{-2}$, yet it was established that over 40 $l\ s^{-1}\ km^{-2}$ occurred in the upper part of the residual catchment. Therefore, to balance the estimated and measured discharge, a loss zone is postulated in the lower portion of the residual catchment. Similar problems occurred with mapping runoff where Maungaparerua Stream joins the Kerikeri River, and near the junction of the Puketotara River and Waiwhakangarongaro Stream. While this is the most appropriate way to portray this data on a map, in practice the zones of gains and losses would be confined to stream channels. Whether these are point zones or spread over a length of channel would depend on the geological structure of the area.

Changes in the hydrological regime within the catchments can be noted by examining Table 3 and Figures 9 and 10. Streamflow is higher than the calculated flow in the Kapiro, Lower Waipapa, Upper Kerikeri and Lower Puketotara catchments. The high specific discharges and the isohyd gradients suggest that flows from springs occur in these areas. The flow in the Upper Waipapa comes from water stored in a large swamp. Only in the Kerikeri River do the headwater spring flows persist during low flows (Fig. 10b); for other streams, flow is depleted, changing the hydrological regime, particularly in the lower Waipapa and Puketotara Rivers.

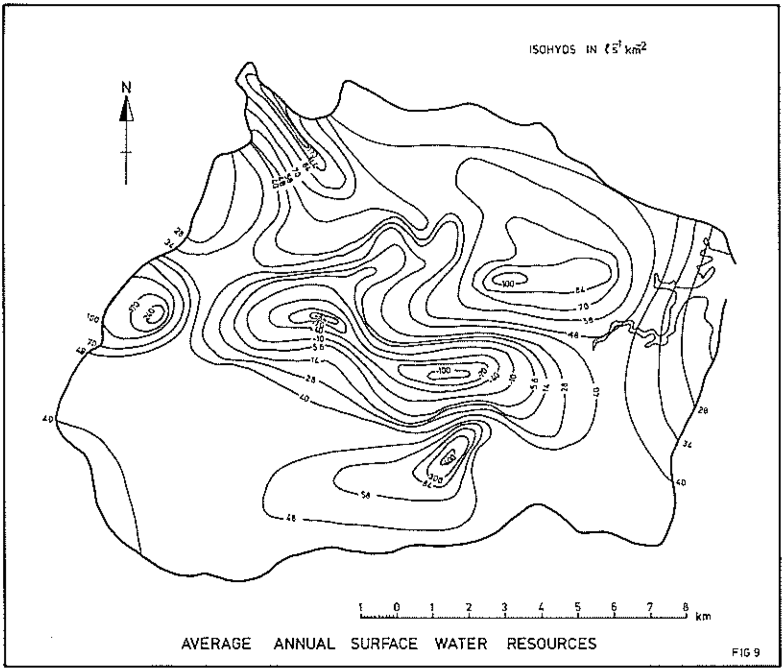

FIG. 9—Average annual runoff.

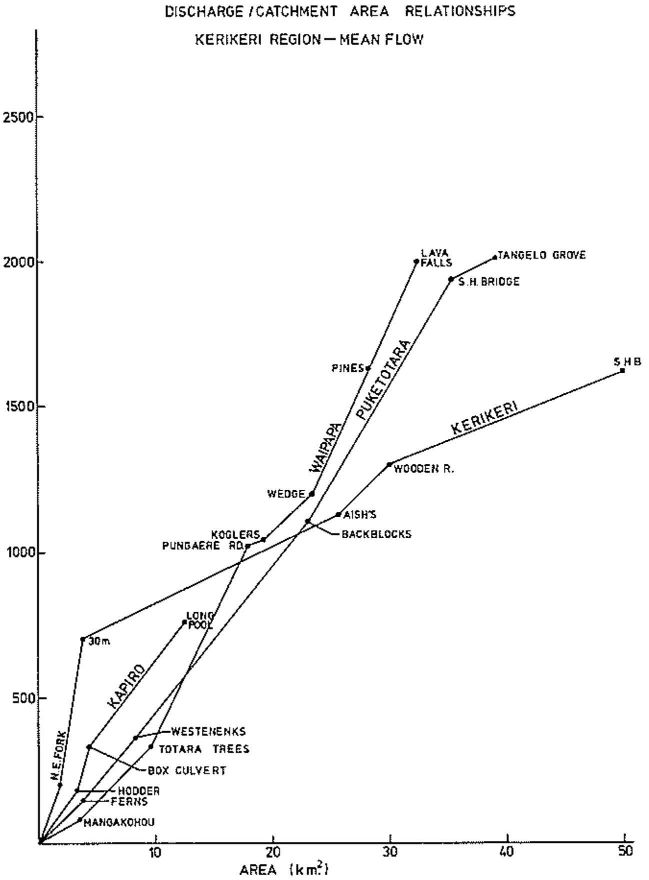

FIG. 10a—Relationship between discharge and catchment area at mean flow—Kerikeri region.

While the isohyd values appear to be extreme the pattern is realistic as the estimated runoff is in close agreement with total measured runoff, and specific discharges throughout the region form patterns which can be matched in adjacent catchments (Fig. 9). Map discrepancies can be explained by the hydrological effects of the bedrock geology. The spring zone in the upper Kerikeri is associated with outcrops of Wairakau andesite (Fig. 2), while the loss zones of the Kerikeri are associated with alluvial deposits and Parahaki volcanics. The underlying dissected greywacke terrain probably permits the movement of water from one catchment to another. In addition to the geological features, the relative levels of stream channels may also influence runoff patterns by allowing losses from a perched stream, through fractured basalt, to an adjacent incised channel.

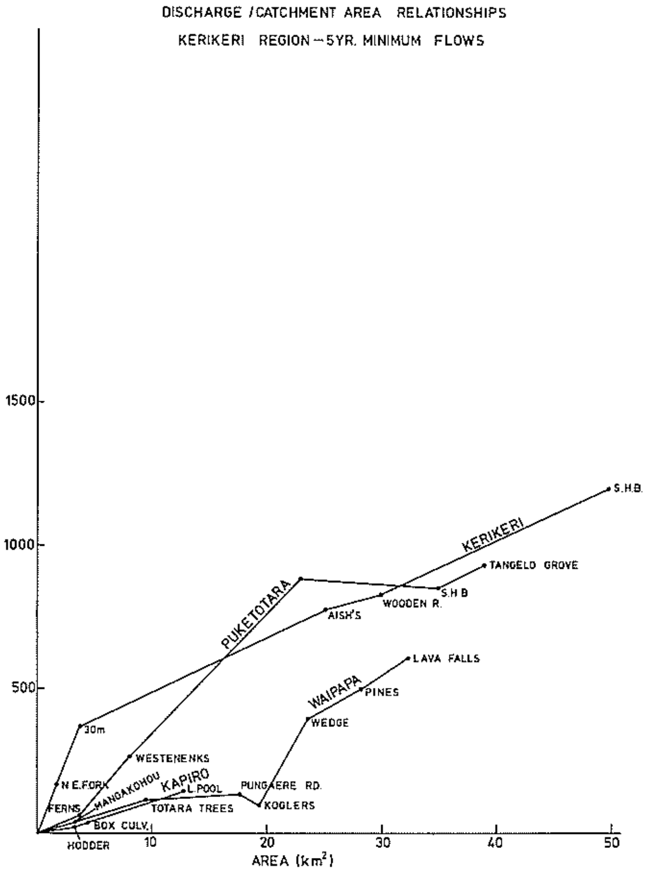

FIG. 10b—Relationship between discharge and catchment area at the five-year minimum flow—Kerikeri region.

CONCLUSION

Comparison between measured and calculated runoff indicates complex runoff patterns within the Kerikeri regional which are caused by geological structure and changes in lithology.

The Maungaparerua catchment has a runoff remarkably close to that estimated using the simple water balance, and yet other catchments show deviations of up to 94 per cent. The magnitude of specific discharges are exceptionally high in the Puketotara catchment and reflect the problems of using topographical rather than hydrological catchment boundaries. This problem, together with that of having to introduce negative isohyds (Fig. 9) to allow data to correspond with measured discharges within a catchment introduces error in mapping the available water.

The validity of using the isohyd mapping technique in such a complex area could be questioned. Yet in defence of its use, it should be noted that the total measured runoff from the region is in reasonably close agreement with that calculated by the simple water balance equation. Runoff regimes within the catchments can be logically accounted for by geological and topographical features. While the high isohyd values and the negative isohyd values indicate catchment runoff characteristics, the large gains or losses in streamflow are confined to the channel. For estimating discharge in the channel at any point on the stream the use of isohyds provides an adequate tool for water resource management.

ACKNOWLEDGEMENTS

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APPENDIX 1

River	Site	Map reference	Area (km^2)	Average annual flow (l/s)	Specific discharge (l s^{-1} km^{-2})	Five year minimum flow (l/s)
Kapiro	Stanners Rd	N11:424626	2.46	125.0	50.8	5.00
Kapiro	Hodders	N11:412617	3.30	184.2	55.8	2.56
Kapiro	Box Culvert	N11:417612	4.33	221.2	51.1	3.30
Kapiro	Long Pool	N11:448614	12.70	761.0	59.9	14.65
Mangakohou	Ram	N11:361628	3.37	89.7	26.6	3.96
Pungaere	Totara Trees	N11:382619	9.56	337.5	35.3	11.44
Waipapa	Pungaere Rd	N11:392604	17.70	1023.0	57.8	13.26
Waipapa	Koglers	N11:405610	19.30	1047.0	54.2	9.94
Waipapa	Wedge	N11:418598	23.5	1200.0	51.1	39.84
Waipapa	Pines	N11:443601	28.3	1636.0	57.8	49.50
Waipapa	Lava Falls	N11:468597	32.2	2000.0	62.1	61.00
Kerikeri	NE Fork	N11:329594	1.92	207.0	107.8	17.39
Kerikeri	30 m below Junction	N11:331593	3.73	704.4	188.8	37.12
Kerikeri	Aish's	N11:385595	25.70	1132.0	44.0	77.43
Kerikeri	Wooden R	N11:416587	30.00	1300.0	43.3	82.28
Kerikeri	SH Bridge	N11:427575	50.25	1617.0	32.2	119.8
Maungaparerua	Tyrees	N11:391555	11.14	481.4	43.2	19.83
Puketotara	Ferns	N11:325539	3.81	150.8	39.6	6.70
Puketotara	Westenenks	N11:339539	8.26	363.6	44.0	26.99
Puketotara	Backblocks	N11:395545	23.05	1104.0	47.9	88.67
Puketotara	SH Bridge	N11:423564	35.85	1937.0	54.0	85.23
Puketotara	Tangelo Grove	N11:438559	39.06	2013.0	51.5	93.07
Waiwhakangarongaro	Gum Trees	N11:423555	11.19	577.1	51.6	16.54
Wairoa	Cobham Rd	N11:462569	7.25	355	48.9	22.5