MAPPING AVERAGE ANNUAL SURFACE WATER RESOURCES OF THE HYDROLOGICAL REGIONS OF NELSON, NEW ZEALAND

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ABSTRACT

A method for mapping average annual water resources is presented. Research is based on the hydrological region concept. River gauging data from temporary sites are correlated with concurrent data from representative basins or other long-term recording sites. A comparison is made between results obtained using a simple water balance approach and those obtained by gauging and correlation. Use of the correlation equations for evaluating other flow characteristics such as minimum flow and flow duration for previously ungauged sites is discussed briefly. The average annual pattern of surface water resources for the Nelson district is presented using this method.

INTRODUCTION

Maps are an excellent means of summarizing and presenting the vast amounts of hydrological information now becoming available. Furthermore, they are valuable if not essential in planning and co-ordinating future water resources programmes. The UNESCO Co-ordinating Council for the IHD, recognizing the attributes of hydrological mapping, created a working group to collate and summarize existing mapping procedures and to recommend standard procedures (Canadian National Committee for the IHD, 1969).

This paper describes a method for mapping average annual surface water resources of a district. Hydrological staff of the Ministry of Works will eventually complete similar maps for other districts with the ultimate objective of producing national water resources maps. For this project, research was conducted on a hydrological region basis, correlating gauging data from temporary sites with concurrent data from representative or other long-term recording sites.

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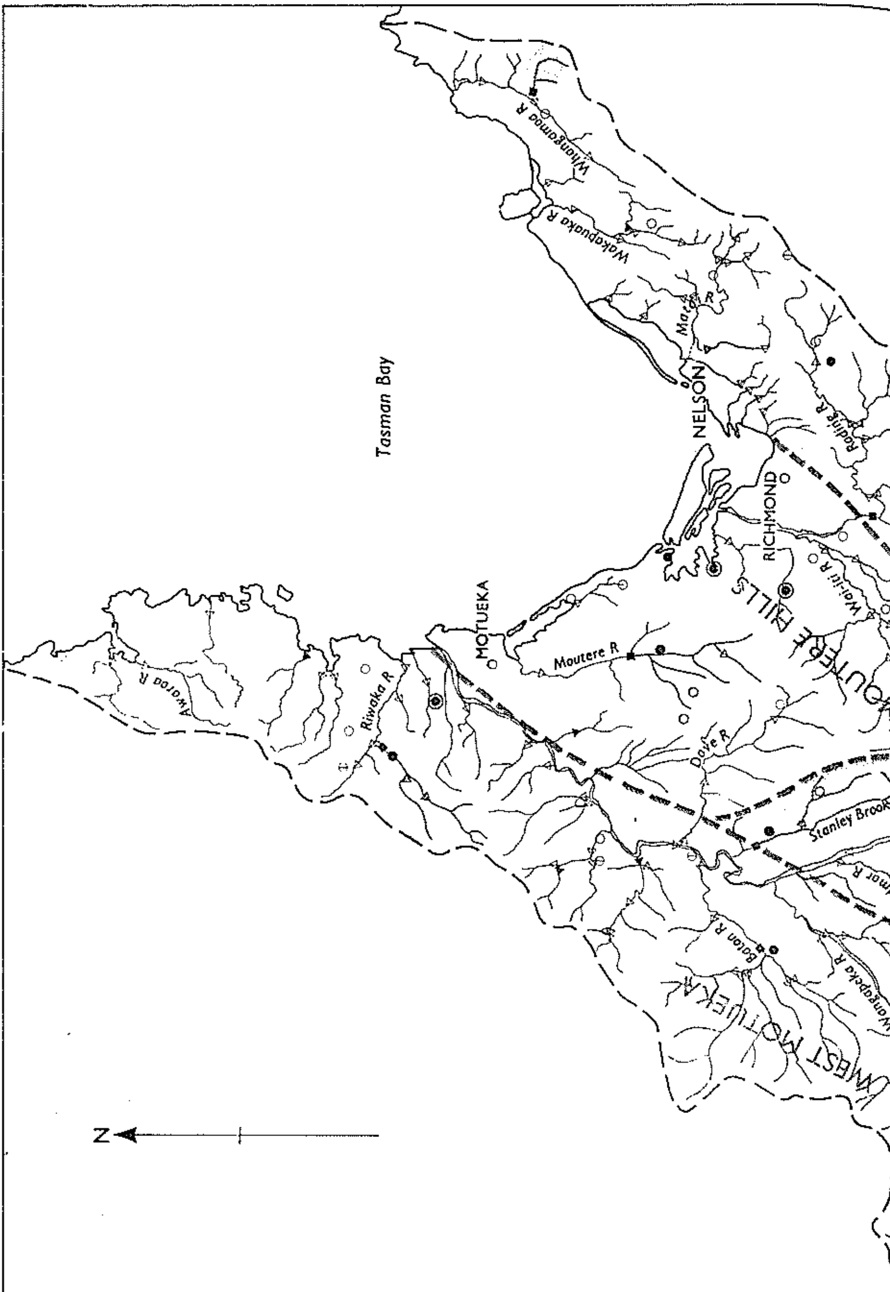


Tasman Bay
NELSON
RICHMOND
MOTUEKA
Whangamoa R
Wakapuaka R
Maitai R
Roding R
Wai-iti R
Moutere R
Riwaka R
Awaroa R
Dove R
Stanley Brook
Tadmor R
Baton R
Wangapeka R
MOUTERE HILLS
WEST MOTUEKA
N

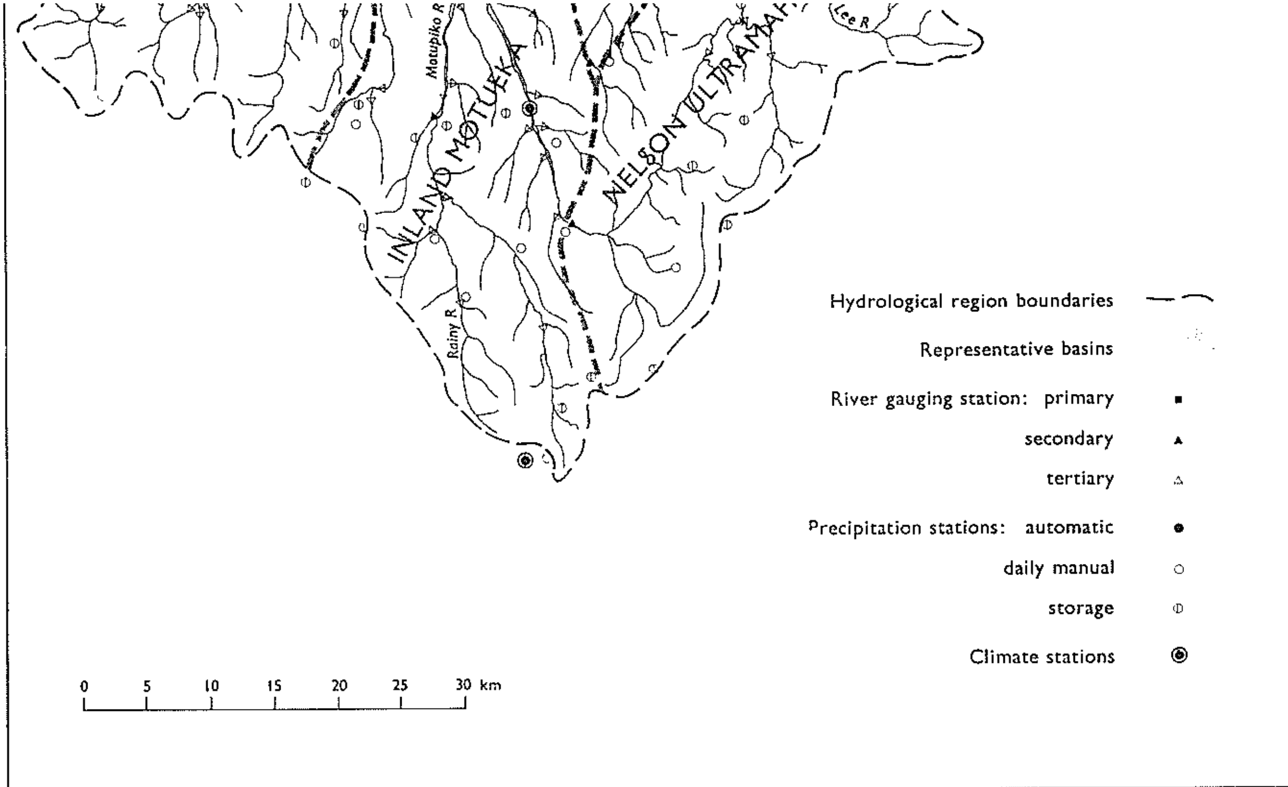


FIG. 1 — Nelson district, showing hydrological regions, representative basins, and hydrological sites.

The concept of mapping water resources in terms of lines of equal specific discharge, termed isohyds*, is comparatively new. This procedure permits the accurate assessment of average annual discharge for any catchment within the study boundaries.

In the process of preparing an average annual water resources map for the Nelson district, much information on other hydrological characteristics, notably minimum flows and flow duration, has also accrued. The methods described have wide application for evaluating flow characteristics at previously ungauged sites. It is intended that the water resources map given here, together with subsequent maps detailing other hydrological characteristics, will provide a basis for future overall water resources planning.

The exercise was designed also to test the validity of the representative basin concept: that is, that such a basin is representative in time and space of a much larger region. With some reservations, results from these studies confirm the findings of Waugh (1970a, b), demonstrating clearly that the transfer of data to other basins with similar geological characteristics is possible.

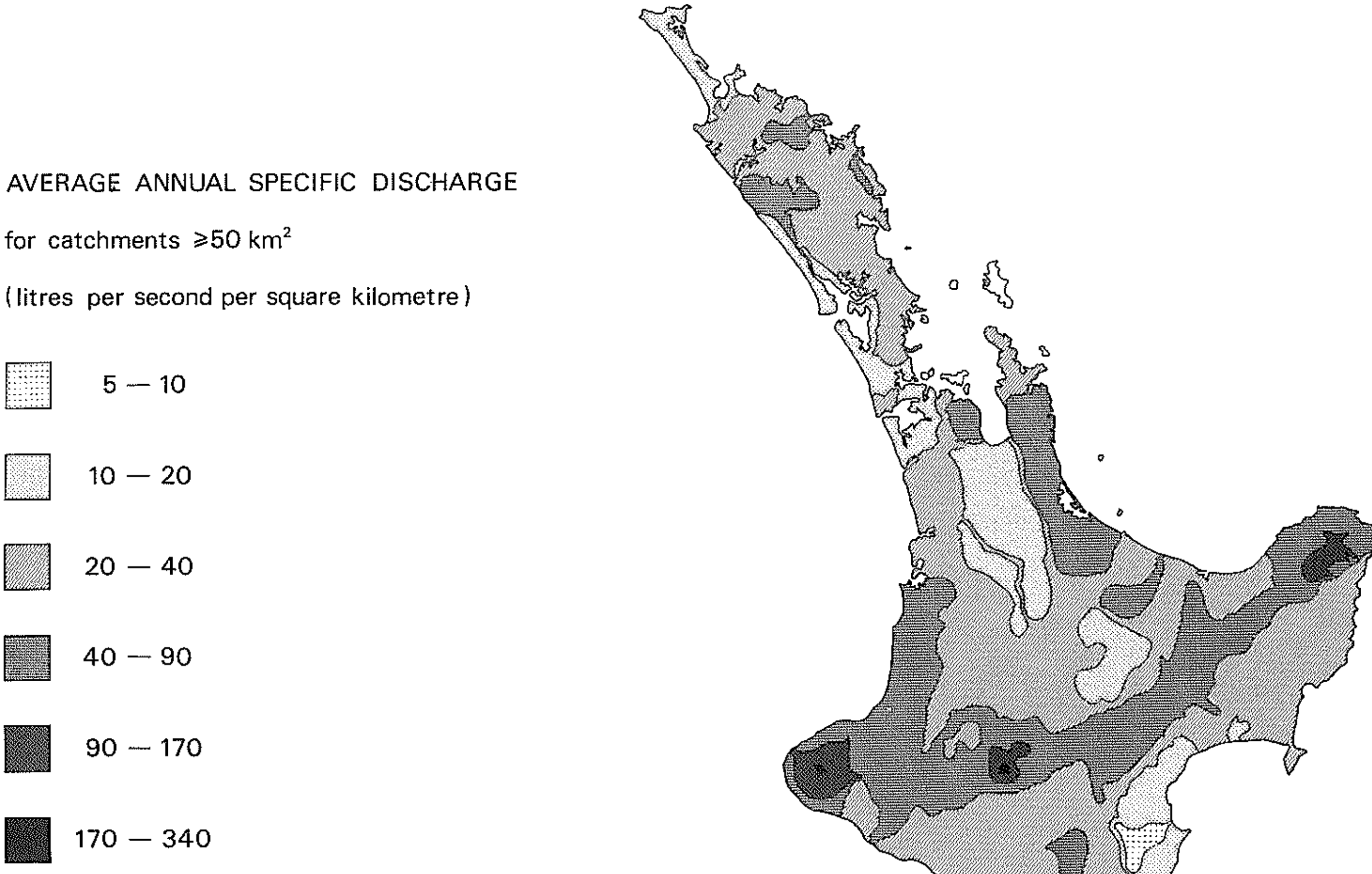
DESCRIPTION OF NELSON DISTRICT

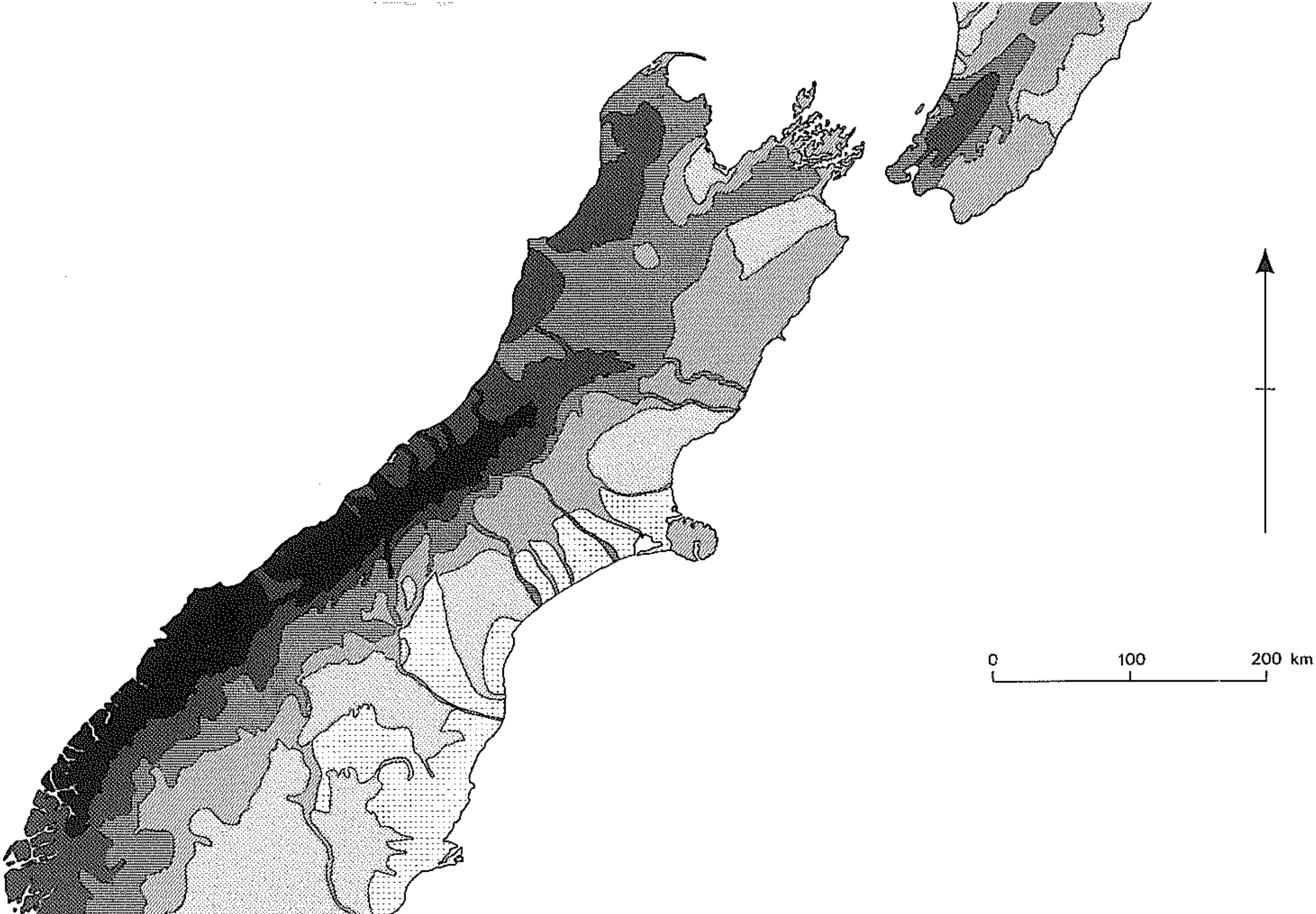
The Nelson district, with an area of some 3780 km^2, is bounded to the north by Tasman Bay, to the east by the Bryant Range, to the south by the Hope Saddle and Owen Range, and to the west by the Mt Arthur Range and Pikikiruna Ridge.

Average annual total sunshine is 2370 hours – amongst the highest recorded in New Zealand. Except for the late summer months, rainfall is fairly evenly distributed throughout the year. In late summer it is not uncommon to receive little or no rainfall for periods of up to one month, during which time a heavy demand is made on surface water resources for irrigation. During winter, snow accumulates at altitudes greater than 1000 m, and severe frosts (– 11°C) occur in inland areas.

Included in the district are four hydrological regions: Nelson Ultramafic, Moutere Hills, Inland Motueka and West Motueka (Fig. 1). For delineating hydrological boundaries, Toebes and Palmer (1969) adopted geological characteristics and rainfall as dominant criteria. The Nelson Ultramafic region is not a hydrological region as defined by Toebes and Palmer (1969) but was constituted, before these studies, as a result of known differences in

* Ischyds are defined as lines of equal specific potential discharge in litres per second per square kilometre ($l\ s^{-1}\ km^{-2}$).


AVERAGE ANNUAL SPECIFIC DISCHARGE
for catchments ≥50 km²
(litres per second per square kilometre)
5 — 10
10 — 20
20 — 40
40 — 90
90 — 170
170 — 340



SURFACE WATER RESOURCES

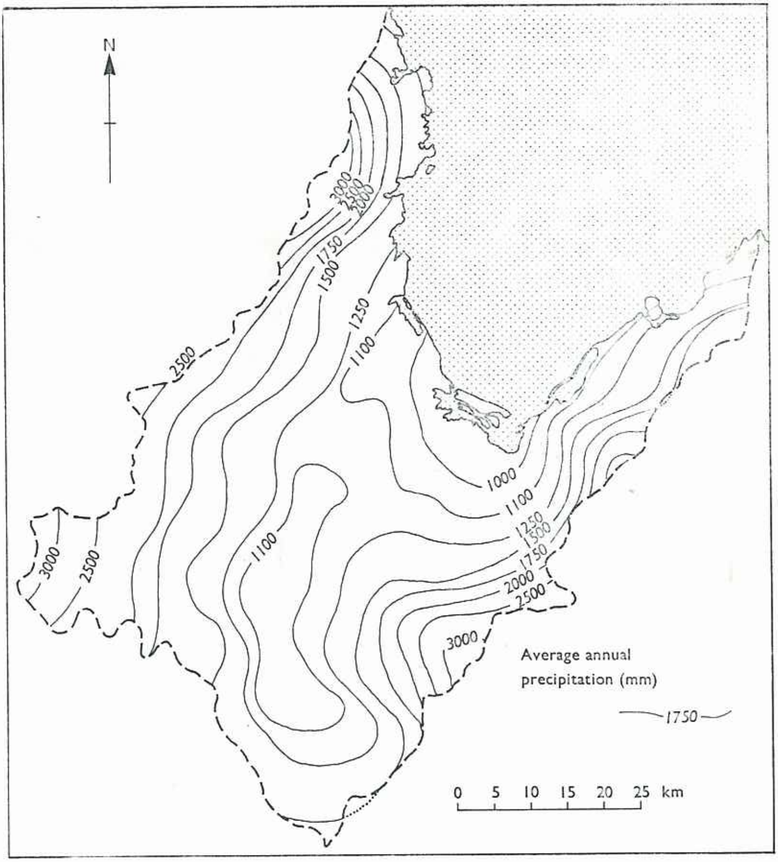


FIG. 2 — Average annual precipitation of the Nelson district.

geological and hydrological characteristics when compared with adjacent regions. Brief descriptions of hydrological regions are given in Appendix 1.

METHODS

Simple Water Balance

Linsley *et al.* (1958) suggest that an estimate of mean annual water resources for a region can be evaluated using the simple water balance equation:

$$Q = P - E \pm \Delta S$$

where Q, P and E are mean annual runoff, precipitation and potential evapotranspiration respectively. For evaluating long-term average water resources when changes to surface and subsurface

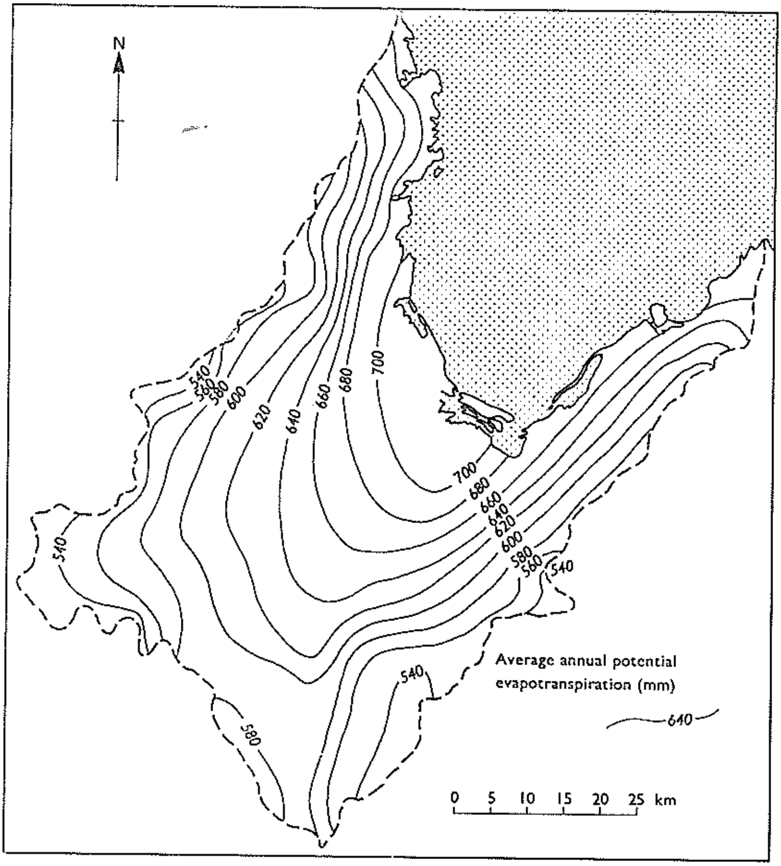


FIG. 3 — Average annual potential evapotranspiration for the Nelson district.

storages, ΔS, are small and randomly distributed, the equation approximates to:

$$Q = P - E$$

As a first approximation towards evaluation of the average annual water resources for this district a procedure similar to the approach of Linsley *et al.* was adopted.

Precipitation: All records from precipitation stations within and surrounding the Nelson district were collated. Records from short-term sites (mainly local farmer observers) were correlated with records from the nearest long-term station to estimate the normals for these sites. All results were then plotted to construct the isohyetal map of average annual precipitation shown in Fig. 2.

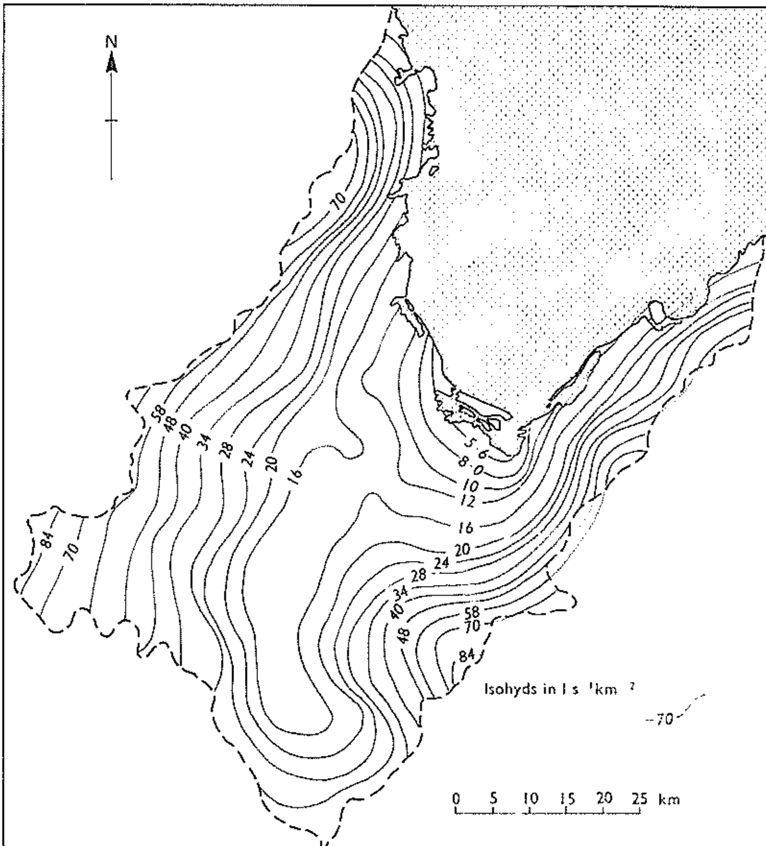


FIG. 4 — Approximate average annual surface water resources for the Nelson district, obtained by subtracting potential evapotranspiration from precipitation $(P-E)$.

Potential evapotranspiration: Temperature records from climate stations were used to calculate potential evapotranspiration using the Thornthwaite procedures (Toebes, 1968). To estimate potential evapotranspiration for altitudes above 600 m it was necessary to use observed data from stations outside the district, notably Black Birch (1400 m) and Molesworth (893 m) stations in southern Marlborough. Following adjustments for latitude, it was possible to construct a graph of altitude versus potential evapotranspiration. This graph, together with data from stations within the district boundary, was used to produce the average annual potential evapotranspiration map shown in Fig. 3.

Approximate average annual water resources: A 10-mm grid was placed over Figs. 2 and 3 in turn and the difference between precipitation and evapotranspiration interpolated at each grid intersection. These $P-E$ values were converted to $l\ s^{-1}km^{-2}$ and an approximate water resources map constructed (Fig. 4).

Gauging and Correlation

The district is fortunate in having a number of hydrological sites with long-term continuous records where the average annual flow and variance is known. Representative basins for the Nelson Ultramafic, Moutere Hills and West Motueka regions have been in operation since 1962, and for the Inland Motueka region since 1969. These long-term recording stations were designated primary sites. Study of their spatial arrangement, however, revealed large areas not truly represented by such sites. This necessitated the establishment of secondary sites within these areas. After careful selection to ensure that the proposed site had a natural rock control, a staff gauge was installed. Following a series of 12 to 15 concurrent gaugings on each secondary site and its two nearest primary sites, extending over a range of flows from minimum to above mean flow, standard correlation techniques were used to establish the average annual flow of the secondary site.

The aim in establishing secondary sites was to ensure an even spatial distribution of control sites (primary and secondary) throughout the hydrological region and thus maintain good overall control on later tertiary site gaugings.

Tertiary sites (temporary current-meter gauging stations) were selected on all other streams and rivers, mainly at tributary junctions. The geological complexity of the West Motueka and Nelson Ultramafic regions required that some sites be established at geological boundaries. Furthermore, because of the steep $P-E$ gradient indicated in Fig. 4, additional sites were selected in the Nelson Ultramafic region to the east of Nelson City.

Very few tertiary sites were endowed with good natural controls, and most tended to have a rough cross section with a variable stage discharge relationship. Considerable care was taken, however, to select (wherever possible) a rock-bound site with little or no depth of alluvium in the channel.

Fig. 1 shows the spatial arrangement of the 141 sites used for this study. The ratio of primary:secondary:tertiary sites was 1:1.7:21, distributed as shown in Table 1.

To establish the average annual flow at each tertiary site, the following stream gauging programme was adopted. Two to three days after widespread rain, three or four gauging parties would gauge all sites within a hydrological region over a 2- to 3-day period. This required that each party complete six to seven gaugings per day. Primary and secondary sites were gauged at the beginning and end of the programme to ensure correlation control. This programme was repeated six to eight times to extend over a wide range of flows from minimum to above mean flow.

Correlation of the data from these concurrent gaugings, assuming a relationship of the form

$$q_t = kq_c^n$$

where q_t is the flow at the tertiary site and q_c the flow at the nearest control site, leads to the evaluation of average annual flow at the tertiary sites. Fig. 5 demonstrates the technique used.

TABLE 1 — Distribution of primary, secondary and tertiary sites.

Region	Number of sites				Area	Average catchment
	Primary	*Secondary*	*Tertiary*	*Total*	*(km²)*	*area (km²)*
Nelson Ultramafic	2	4	39	45	1050	23.3
Moutere Hills	1	1	17	19	680	31.3
Inland Motueka	1	1	21	23	720	24.6
West Motueka	2	4	48	54	1330	26.8
Total:	6	10	125	141	3780	35.8

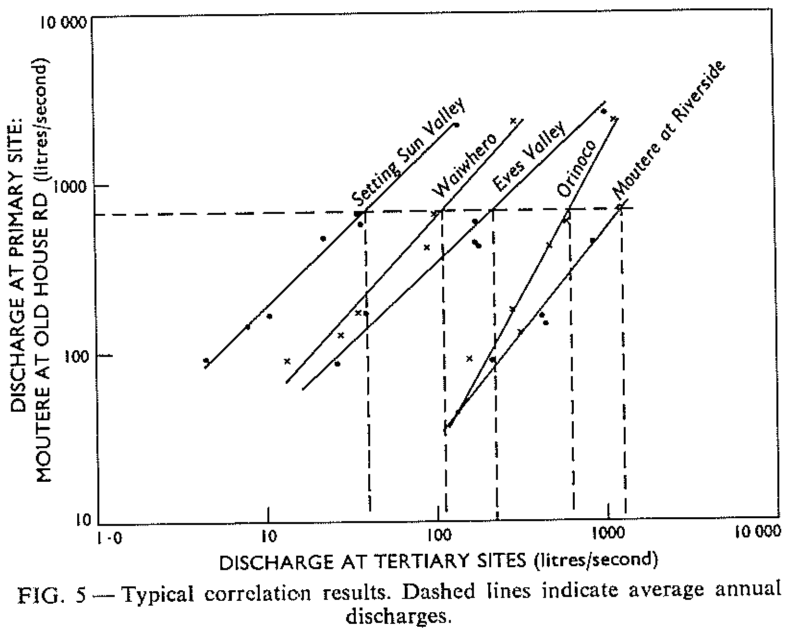


FIG. 5 — Typical correlation results. Dashed lines indicate average annual discharges.

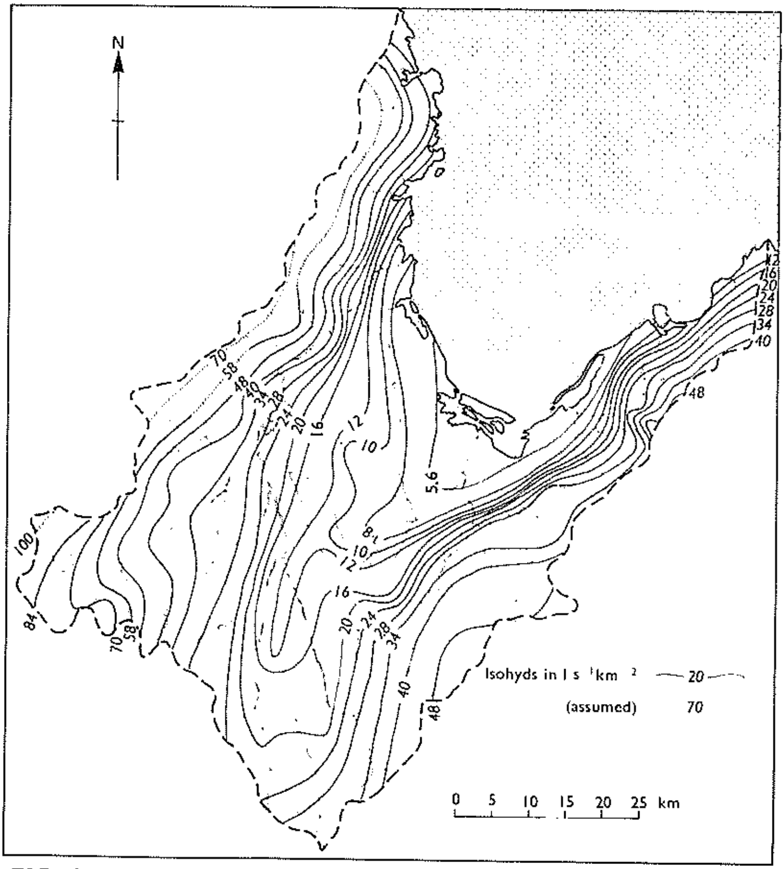


FIG. 6 — Average annual surface water resources for the Nelson district, obtained by gauging and correlation.

RESULTS

A tabulation of relevant statistical information for the primary sites is given in Appendix 2.

To test that the average annual discharge for the period of record was representative of the long-term average mean, annual runoff totals were correlated with the annual rainfall totals recorded at the nearest long-term precipitation station. This showed the average annual flow for the period of record to be within ±4 per-cent of the long-term average annual given by the correlation. Thus the values listed in Appendix 2 were used in all subsequent correlations of primary versus secondary or tertiary flow data.

Appendix 3 lists the sites, their classification, catchment area, average annual discharge and specific discharge.

Specific discharge values for residual catchment areas* were also calculated. These, together with the data tabulated in Appendix 3, were used to construct the isohydal map of average annual surface water resources shown in Fig. 6. The specific discharge value for each catchment or residual catchment was plotted in the centre of mass of that catchment area. Isohyds were constructed by linear interpolation between points.

Average annual surface water resources for each region and the district are shown in Table 2. Actual water resources obtained by integrating† Fig. 6 are compared with assessed resources obtained by integrating the $P-E$ map (Fig. 4).

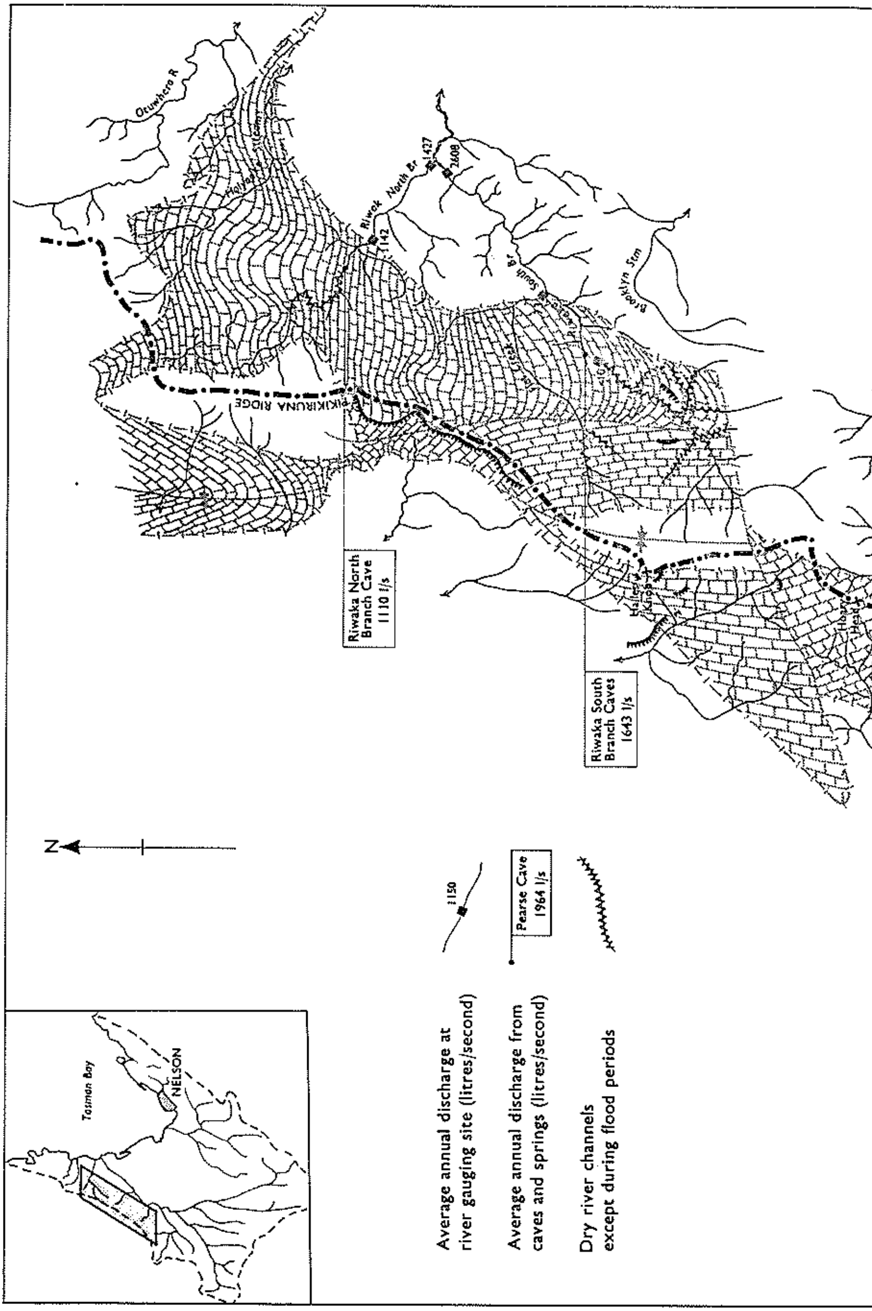
The Mt Arthur marble formations in the West Motueka region demanded special consideration. The hydrogeology of these formations is complex, with relief boundaries bearing little or no relationship to hydrological boundaries. Nearly all excess precipitation falling on these formations infiltrates directly through sinkholes to deep synclinal structures running almost due north-south on the eastern side of the Mt Arthur range (Fig. 7). Water is stored temporarily in extensive aquifers and is released through springs directly into the river channels. Spring flow rate is in direct sympathy with rainfall, indicating that aquifers take the form of extensive pipe structures.

By balancing potential water resources against measured resources it was possible to make certain inferences as to the source area of the waters contributed by each major spring.

With an average discharge of 1964 l/s, the Pearse Spring is the largest and receives water lost from the Eyles and Whisky catchments. Additionally, the Ellis catchment to the south has a low specific discharge ($29.7\ l\ s^{-1}\ km^{-2}$) when compared with adjacent catchments (approximately $60\ l\ s^{-1}\ km^{-2}$), indicating that some of the precipitation to the marble formations in the upper catchment contributes to the Pearse Spring.

* A residual catchment is defined as that area remaining after the catchment areas of all upstream sites have been deducted. Similarly, the corresponding discharge for calculating specific discharge of such a residual catchment is obtained by deducting average annual discharges of all upstream sites.

† Integrating involves planimetering the area between successive isohyds and multiplying by the mean of the bounding isohydal values, followed by summation of these contributing increments.


Otuwhero R
Riwaka North Br
1427
2608
1142
South Br
Brooklyn Stm
PIKIKIRUNA RIDGE
Riwaka North Branch Cave 1110 l/s
Riwaka South Branch Caves 1643 l/s
N
Tasman Bay
NELSON
1150
Pearse Cave 1964 l/s
Average annual discharge at river gauging site (litres/second)
Average annual discharge from caves and springs (litres/second)
Dry river channels except during flood periods

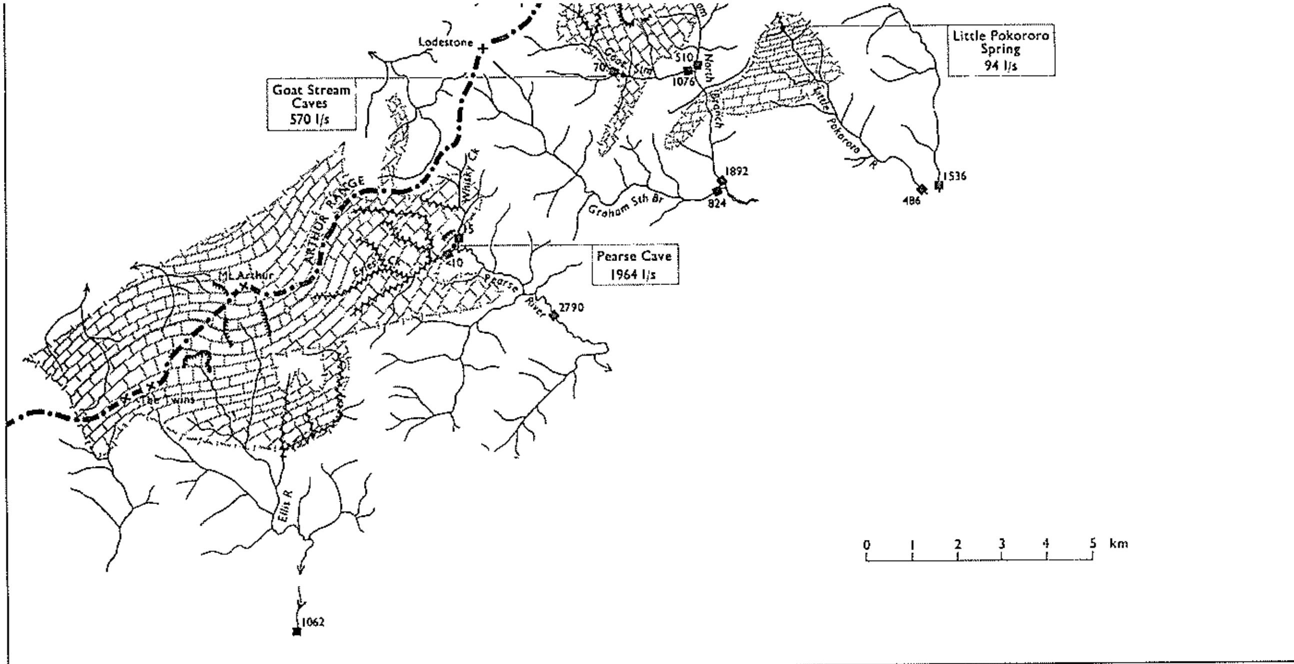


FIG. 7 — Average annual water resources of the Mt Arthur marble formations.

TABLE 2 — Summary of average annual water resources for the Nelson district.

Hydrological region	*Area (km^2)*	*Actual resources** ($l\ s^{-1}$)	*Actual resources** ($l\ s^{-1}\ km^{-2}$)	*Assessed resources†* ($l\ s^{-1}$)	*Assessed resources†* ($l\ s^{-1}\ km^{-2}$)	*Difference (%)*
Nelson Ultramafic	1050	31230	29.74	34400	32.76	—10.2
Moutere Hills	680	6900	10.15	9280	13.65	—34.5
Inland Motueka	720	14210	19.74	14230	19.76	—0.1
West Motueka	1330	64020	48.14	56830	42.73	+11.2
Total:	3780	116360	30.78	114740	30.35	+1.4

* Fig 6.
† Fig. 4.

Goat Stream, a tributary of the Graham North, has six spring outlets, all within a radius of 20 m, producing a total average annual discharge of 570 l/s. Inspection of the specific discharge data does not suggest that water to these springs is contributed by the adjacent Graham North or Graham South catchments. This leaves only the adjacent area above and to the north-west of the springs as the contributing zone.

The Riwaka South Spring has an average annual discharge of 1643 l/s. Above the spring outlet the river channel is dry except during flood periods. Flat Creek, an adjacent catchment, has a very low specific discharge ($4\ l\ s^{-1}\ km^{-2}$), indicating that almost all of the precipitation to this catchment flows directly to the Riwaka South Spring. The Riwaka North Spring, with an average annual discharge of 1110 l/s, receives its water from the upper Riwaka North and Holyoake catchments.

The only other major spring outlet is in Blue Creek, a tributary of the Rolling River in the upper Wangapeka area. With an average annual discharge of 1110 l/s – by coincidence the same as the Riwaka North – its contributing area appears confined to within the relief boundary.

DISCUSSION

Plotting of Specific Discharge Values

Plotting the specific discharge value at the centre of mass of the catchment is not essentially correct, since it assumes an even distribution of runoff throughout the catchment. However, providing the catchment area is small, then the error in plotting is also correspondingly small. This comment is particularly applicable to those areas where the isohyd gradient is steep. Morrissey (1972) suggests that the value should be plotted at the point of median elevation of the catchment. This assumes a direct correlation between contributing rainfall and elevation. Undoubtedly this assumption is reasonable for certain areas, but it is unlikely to apply for all catchments. The correct technique for plotting the specific discharge values lies somewhere between these two procedures.

Average Annual Surface Water Resources

Isohydal values ranged from 5.6 l s^{-1} km^{-2} in the lowland coastal region to 100 l s^{-1} km^{-2} in the mountainous catchments in the upper Wangapeka area.

It is interesting to compare the actual water resources measured by gauging and correlation with those assessed using the $P-E$ approach (Table 2). While the value for total water resources for the district agrees very well with the actual value, totals for the individual regions show marked differences.

In the case of the Nelson Ultramafic region, the difference (3170 l/s) is equivalent to -95 mm (3.02 l s^{-1} km^{-2}) throughout the whole region. Thus, either the interpretation of rainfall data is incorrect, or the Thornthwaite procedure has underestimated the true evapotranspiration. The latter is the probable cause, since the region has a north-westerly aspect and receives a high annual sunshine total.

For the Moutere Hills region the difference is equivalent to -110 mm (3.5 l s^{-1} km^{-2}). The Moutere gravel formations are essentially impermeable, but small groundwater reservoirs are present in the alluvial valleys. It is considered, however, that a major part of the difference is attributable to an underestimation of true evapotranspiration. The distribution of precipitation-recording sites throughout the region is sufficient to ensure an accurate isohyetal map.

The West Motueka region has a south-easterly aspect. The difference of $+170$ mm (5.4 l s^{-1} km^{-2}) is related to a lack of high-altitude precipitation data and an overestimation of true evapotranspiration because of aspect.

Catchments in the Nelson Ultramafic and West Motueka regions have the greatest potential to meet future water demands in this district. Future agricultural development of the Moutere Hills region could be restricted by inadequate water supplies. If this region is to realize its full agricultural potential, existing resources will need to be conserved to combat severe droughts, or alternatively be supplemented by resources from an adjacent region.

Application of Data

Within the boundaries shown in Fig. 6 the average annual surface water resources for any catchment or area can be estimated using the integration process.

From the average flow duration for the primary sites it is possible, using the correlation graphs (e.g. Fig. 5) or equations to construct approximate flow-duration graphs for other sites. Good reliability could be expected throughout the range of mean to low flows. Above mean flow, where rainfall intensities and times of concentration are dominant flood regime parameters, reliability is doubtful.

Provided sufficient low-flow data are available to complete minimum-flow frequency analyses for the primary site, the correlation equations could further be used to extend this information to other catchments and the whole region. Production of minimum water resources maps for allotted return periods is considered possible but has yet to be fully investigated.

Representativeness of Representative Basins

In testing the representativeness of basins within the hydrological regions of Northland, Waugh (1970a, b) concluded that geology was the most important parameter affecting low flow.

As part of the present studies, a low-flow survey was carried out during a reference period of 21 days without rainfall. Discharges at approximately 40 sites were measured at least three times during that period. Results confirmed the findings of Waugh (1970a, b) and Grant (1971), in that groups of catchments with similar geology displayed characteristic baseflow recession coefficients.

Furthermore, it was found that for those areas having uniform geology, notably the Moutere Hills and Inland Motueka regions, the relationship $q_t = kq_c$ between control and tertiary sites was almost linear, i.e. $n \cong 1$. If the catchment included any geological formation other than Moutere gravels then this was no longer true.

Perhaps, therefore, it is reasonable to suggest that geology should be the dominant criterion for delineating hydrological region boundaries.

CONCLUSIONS

1. Assessment by means of the *P–E* approach of Linsley *et al.* (1958) gives a reasonably accurate estimate of average annual water resources. This method is less reliable for regions of low rainfall and/or high evapotranspiration, and has little application for regions where surface resources are lost to deep aquifer storage.

2. A catchment can be hydrologically representative only if its geology is characteristic of the geology of the hydrological region it is intended to represent.

3. The methods described have wide application for evaluating the average annual surface water resources of a district. From the map (Fig. 6) it is possible to estimate the average annual discharge of a river or its tributaries at any point along its channel. The method also allows the estimation of other flow characteristics, in particular minimum flows and flow duration.

ACKNOWLEDGMENTS

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APPENDIX 1 — Descriptions of hydrological regions.

1. *Nelson Ultramafic* (1050 km^2)

The region has a north-westerly aspect and receives an annual average precipitation of about 1600 mm. Relief is classified as steep to mountainous, rising from sea level to 1790 m.

Geologically the region is relatively complex, with a mixture of old greywacke formations interbedded with Dun Mountain ultramafics and some limestones. Old basalt formations north of Nelson City are also included.

In the past much of the region was used for sheep farming but this is now being planted in exotic forest (mainly *Pinus radiata*). Native forest (mainly *Nothofagus* spp.) occurs in the headwaters of the Roding, Lee, Wairoa, Wai-iti and Motueka Rivers. Grazing of sheep and cattle is confined mainly to the valley floors.

2. *Moutere Hills* (680 km^2)

Dissected and tilted gravel formations, sands and clays from Pliocene–early-Pleistocene glacial periods dominate geologically. Outwash material has formed extensive flood plains along river channels, especially at the mouths of the Motueka, Moutere and Waimea Rivers.

Average annual precipitation is about 1000 mm, and elevation ranges to 500 m with a flat to gently rolling relief. Exotic forestry (mainly *Pinus radiata* and *Pseudosugo menziesii*) is the predominant land use to the south, while in the northern coastal lowlands, orchards and cropping predominate.

3. *Inland Motueka* (720 km^2)

This region has moderately steep relief from 500 to 1500 m, with an annual precipitation of about 1250 mm.

Geology is similar to that described for the Moutere Hills region, with a lesser incidence of recent alluvial gravel formations. Soils are typical yellow-brown earths with weakly developed horizons.

Much of the region is covered by forest; indigenous (mainly *Nothofagus* spp.) in the headwaters of the Motupiko, Rainey and Tadmor Rivers and exotic on the less steep hill country around Golden Downs. Sheep and cattle grazing and some berry cropping are confined to the valley floors.

4. *West Motueka* (1330 km^2)

Geologically this region is extremely complex, comprising Cambrian volcanics, Ordovician marbles, quartzites and argillitic shales, quartz and hornblende schists of Devonian age and Carboniferous (?) granites. Interbedding, faulting and folding add further to the geological complexity. The Mt Arthur marble formations are highly permeable, and almost all of the precipitation to these areas goes directly to groundwater storage through sinkholes and vertical fissures. The water reappears in major spring outflows in the river channels.

Soils are mainly brown granular clays and loams. Elevation ranges from sea level to 1800 m the region has a south-easterly aspect and receives an average annual precipitation of approximately 1800 mm.

Native forest (*Podocarpus* and *Nothofagus* spp.) above 600 m grades into scrub, pasture and areas of cultivated land in the valley floors. Land use closely follows relief, with sheep farming and mixed cropping to intensive cultivation of tobacco on the coastal areas and along the river terraces of the Riwaka and Motueka Rivers.

APPENDIX 2 — Average annual flow data for primary sites.

River: *Site.*	Collins* Drop Str.	Wairoa Gorge	Moutere* Old House	Stanley Bk* Barker's	Riwaka* Moss Bush	Baton Faulkner's
Annual mean discharge (l/s):						
1956	–	23810	–	–	–	–
1957	–	18260	–	–	–	–
1958	–	12320	–	–	–	–
1959	–	12490	–	–	–	–
1960	–	16310	–	–	–	–
1961	–	12520	–	–	–	–
1962	1100	25150	1270	–	3415	–
1963	483	15010	701	–	2356	–
1964	515	18180	588	–	2339	–
1965	471	13880	343	–	2053	–
1966	678	17160	516	–	2721	–
1967	753	18010	564	–	2710	–
1968	743	16930	631	–	2790	9937
1969	428	15040	–	–	2430	6640
1970	891	21210	780	1336	2610	7286
1971	–	–	–	–	–	8673
Average annual discharge (l/s):	674	17085	674	1147†	2603	8135
Coefficient of variation (%):	31.4	22.2	37.9	–	13.9	15.7
k max:	1.63	1.47	1.88	–	1.31	1.22
k min:	0.64	0.72	0.51	–	0.79	0.82

* Representative basin.
† Average annual flow approximated in proportion to data from Moutere at Old House Road.
k max = (maximum mean annual) ÷ (average annual).
k min = (minimum mean annual) ÷ (average annual).

APPENDIX 3 — Average annual flow of rivers and streams in the Nelson district.

River	*Site*	*Map reference*	*Class*	*Area (km^2)*	*Average annual flow ($l\ s^{-1}$)*	*Specific discharge ($l\ s^{-1} km^{-2}$)*
Nelson Ultramafic						
Collins	Drop Structure	S15:863430	P	17.6	674	38.3
Whangamoa	Kokorua	S15:876471	T	77.7	2265	29.2
Whangamoa	Picnic Ground	S15:858425	T	42.0	1416	33.7
Whangamoa	Mt Duppa	S15:810382	T	22.3	779	34.9
Maori Pa	Delaware Bay	S14:787412	T	4.35	56.6	13.0
Wakapuaka	Drumduan	S14:763395	T	61.6	1784	29.0
Lud	Hira	S14:738359	T	9.82	261	26.6
Teal	Fantail Reach	S14:739343	T	15.3	496	32.4
Teal	Saddle Hill	S20:733298	T	4.30	190	44.2
Slaters	Whangamoa	S14:738345	S	15.3	566	37.0
Todds	S.H.B.	S14:683365	T	5.02	29.2	5.82

River	*Site*	*Map reference*	*Class*	*Area (km²)*	*Average annual flow ($l\ s^{-1}$)*	*Specific discharge ($l\ s^{-1} km^{-2}$)*
Oldham	Atawhai Cres.	S14:667358	T	4.97	29.7	5.98
Maitai	Bridge Street	S20:642295	T	88.6	1642	18.5
Sharland	Packer Confl.	S20:681295	T	7.46	93.4	12.5
Packer	Sharland Confl.	S20:681293	T	7.33	119	16.2
Maitai Nth	Ford	S20:712269	T	13.3	453	34.1
Maitai Nth	Powerlines	S20:728252	T	5.02	167	33.3
Maitai Sth	N.C.C. Intake	S20:712257	T	18.3	524	28.6
Beauchamps	Waterfall	S20:722242	T	2.38	85.0	35.7
Brook	Central Sch.	S20:640288	T	16.7	173	10.4
Brook	Old Dam	S20:640241	T	8.39	105	12.5
Jenkins	Enner Glyn	S20:607255	T	3.70	28.3	7.65
Orphanage	Suffolk Rd	S20:584234	T	7.46	53.8	7.21
Saxtons	Weir	S20:574217	S	1.63	11.3	6.93
Wairoa	Gorge	S20:493141	P	448	17085	38.1
Roding	Above Lee Confl.	S20:509144	T	127	3681	29.0
Roding	Above Hackett	S20:570157	T	57.2	1671	29.2
Roding	Above Reservoir	S20:623187	T	38.0	1133	29.8
Hackett-Miner	Rapids	S20:570153	T	38.7	1133	29.3
Serpentine	Ford	S20:561147	T	16.3	481	29.5
Lee	Above Roding	S20:509136	T	111	4701	42.4
Lee	Quarry	S20:511090	T	94.1	4191	44.5
Lee	Waterfall Ck	S20:519048	T	64.5	3087	47.9
Wairoa Left	Poplars	S20:445037	T	98.2	4871	49.6
Wairoa Left	Gibbs Ck	S20:467002	T	81.8	4134	50.5
Wairoa Right	Sandfly Spit	S20:441035	T	58.8	2152	36.6
Wairoa Right	Cedar Ford	S20:411004	T	42.0	1557	37.1
Pig Valley	Wairoa Confl.	S20:449078	T	13.2	368	27.9
88 Valley	Highfield	S20:366056	T	8.24	130	15.8
Quail	88 Valley Rd	S19:335017	T	8.29	232	28.0
Wai-iti	Hiwipango	S19:306003	S	30.9	736	23.8
Gordans	Golden Downs	S26:266948	T	15.3	275	18.0
Motueka	Gorge	S26:288864	S	163	5890	36.1
Blue Glen	Forestry Camp	S26:276871	T	20.8	425	20.4
Inland Motueka						
Stanley Bk	Barkers	S19:209249	P	81.6	1147	14.1
Forsythes	Stanley Bk Confl.	S19:226210	T	22.7	297	13.1
Stanley Brook	Moulders Ford	S19:241163	T	31.0	340	11.0
Norris Gully	Highway Bridge	S19:265044	T	11.3	193	17.0
Reays Stm	Golden Downs	S26:258976	T	9.04	157	17.4
Long Gully	Kings Camp	S26:265916	T	13.5	221	16.4
Rough'ns	Forestry Bridge	S26:257947	T	20.0	359	18.0
Motupiko	Quinneys Bush	S19:201074	T	328	6830	20.8
Long Gully	Motupiko	S19:197057	T	16.8	193	11.5
Brewertons	Beech Grove	S26:189986	T	12.5	142	11.3
Motupiko	Korere	S26:183979	T	272	5873	21.6
Motupiko	Atapo Forks	S26:183889	T	108	2529	23.4
Motupiko	1½ mile Ck	S26:262778	T	41.3	1206	29.2
Rainy	Nichols	S26:174865	T	105	2234	21.3
Rainy	Nestor Gully	S26:191800	T	56.8	1246	21.9

River	*Site*	*Map reference*	*Class*	*Area (km²)*	*Average annual flow (l s⁻¹)*	*Specific discharge (l s⁻¹km⁻²)*
Big Gully	Rainy Ford	S26:173864	T	27.2	566	20.8
Clark	State Highway	S26:174955	S	21.5	411	19.1
Tadmor	Glen Rae	S19:194181	T	119	3194	26.8
Tadmor	Tadmor	S19:144103	T	90.7	2425	26.8
Tadmor	Tui	S26:132985	T	53.7	1451	27.0
Donald	Tui	S26:121975	T	12.1	311	25.7
Glen Rae	Glen Rae	S19:181209	T	13.7	334	24.4
Motueka	Woodstock	S13:212320	S	1750	56860	32.5
Moutere Hills						
Wai-iti	Brightwater	S20:465185	T	285	3681	12.9
Pitfure	Spring Grove	S20:454158	T	23.8	246	10.4
88 Valley	Totaradale	S20:400129	T	35.4	508	14.4
Quail	Mill Bridge	S19:341078	T	26.4	501	19.0
Wai-iti	Belgrove	S19:331077	S	64.2	1331	20.7
Pretty Bridge	Belgrove	S19:335088	T	24.4	198	8.11
Trass	Farm Ford	S20:362018	T	17.4	142	8.16
Hoult Valley	Farm Bridge	S20:372131	T	7.46	52.4	7.02
Pigeon Valley	Russians	S20:406146	T	37.8	340	9.00
Eves Valley	Coast Road	S20:472264	T	43.2	223	5.15
Tasman	Tasman	S14:425399	T	9.53	54.7	5.73
Moutere	Riverside	S14:371434	T	137	1283	9.36
Moutere	Old House Rd	S14:377347	P	62.4	667	10.7
Setting Sun	Hyatts	S20:377269	T	3.88	40.0	10.3
Waiwhero	Gaudions	S13:312405	T	8.31	114	13.7
Orinoco	Ngatimoti	S13:274388	T	35.4	629	17.8
Dove	Woodstock	S13:213314	T	103	1303	12.6
Dove	Thorpe	S19:261293	T	82.9	898	10.8
Dove	Hodgens	S19:320231	T	26.6	236	8.88
West Motueka						
Wangapeka	Blue Rock	S19:133189	S	447	23230	52.0
Sherry	Blue Rock	S19:132172	T	78.4	2447	31.2
Sherry	Painkiller	S19:100058	T	26.9	861	35.7
Slippery	Woolshed	S19:114075	T	9.63	263	27.3
Coal	Wangapeka	S19:129196	T	8.91	320	35.9
Dart	Devils Thumb	S19:046113	T	80.6	3222	40.0
Chummie	Wangapeka	S19:005115	T	18.3	923	50.4
Rolling	Swingbridge	S19:987097	T	65.2	3902	59.8
Granity	Courthouse Flat	S19:975067	T	16.7	895	53.6
Blue	Goldfields	S19:973064	T	15.0	1198	79.9
Blue	Caves	S19:970044	T	13.3	1110	83.0
Nuggety	Goldfields	S19:972065	T	24.2	1416	58.5
Wangapeka	Rolling Jntn	S19:987098	T	142	10590	74.6
Kiwi	Kiwi Flat	S19:905091	T	13.2	1133	85.8
Wangapeka Nth	Kings Hut	S18:890068	T	28.5	2492	87.4
Wangapeka Sth	Kings Hut	S18:891067	T	55.0	4389	79.8
Baton	Motueka Confl.	S19:195297	T	215	9815	45.7
Stoney	Baton Run	S19:150287	T	11.0	513	46.6
Baton	Faulkner's	S19:120246	P	174	8135	46.8
Clarke	Hayshed	S19:097230	T	24.2	923	38.1

River	*Site*	*Map reference*	*Class*	*Area (km^2)*	*Average annual flow ($l\ s^{-1}$)*	*Specific discharge ($l\ s^{-1}km^{-2}$)*
Fowler	Hayshed	S19:095230	T	16.4	640	39.0
Skeet	Baton Jntn	S19:100260	T	38.2	2180	57.1
Baton	Gold Diggings	S19:101266	T	44.3	2761	62.3
Ellis	Rock	S19:103267	T	35.8	1062	29.7†
Pearse	Limeworks	S13:203352	S	48.7	3769	77.4*
Granity	Mailboxes	S13:195349	T	7.30	243	33.3
Pearse	Poplars	S13:161362	T	26.1	2790	106.9*
Pearse	Cave	S13:136379	T	0.00	1964	∞
Eyles	Pearse Cave	S13:136378	T	8.34	0.0	0.0†
Whisky	Pearse Cave	S13:137380	T	3.00	45.3	15.1†
Graham Sth	Ford	S13:201393	T	13.6	824	60.6
Graham Nth	South Junction	S13:204394	T	21.3	1892	88.8*
Graham Nth	Woolshed	S13:197423	T	7.46	510	68.4
Goat	Woolshed	S13:195422	T	9.35	1076	115.1*
Little Pokororo	Bridge	S13:253392	T	8.68	486	56.0
Pokororo	Bridge	S13:255393	T	24.7	1536	62.2
Herring	Bridge	S13:284423	T	6.35	300	47.2
Rocky	Bridge	S13:304443	T	12.2	405	33.2
Shaggery	Bridge	S13:331492	T	7.77	271	34.9
Brooklyn	Tobacco Res.	S13:350515	T	16.3	756	46.4
Little Sydney	Fry's	S14:361528	T	6.22	238	38.3
Riwaka	Highway Bridge	S14:365551	T	93.4	4788	51.3
Jordan	Farm Bridge	S13:345554	T	4.97	171	34.4
Riwaka Sth	Moss Bush	S13:307571	P	48.7	2608	53.6
Flat	Flat Hut Flat	S13:276545	T	18.2	72.8	4.00†
Riwaka Sth	Cave Gorge	S13:264536	T	19.0	1643	86.5*
Riwaka Nth	Moss Bush	S13:306574	T	25.0	1427	57.1*
Riwaka Nth	Picnic Ground	S13:289588	T	17.7	1142	64.5*
Holyoake	Cross Roads	S 9:363614	T	17.7	614	34.7†
Otuwhero	Sandy Bay	S 9:368617	T	22.0	1176	53.5
Marahau	Tobacco Kiln	S 9:382635	S	24.4	1664	68.2
Falls	Sandfly Bay	S 9:421719	T	19.9	1246	62.6
Awaroa	Black Jacks	S 9:374773	T	31.6	1982	62.7
Awapoto	Awaroa Inlet	S 9:382804	T	19.6	850	43.4

* Gaining water from an adjacent catchment.
† Losing water to an adjacent catchment.