RAINFALL PATTERNS ON THE KAWEKA RANGE

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ABSTRACT

Rainfall patterns are based on records from 17 storage rain gauges in the rangeland area, and from daily rain-gauge stations surrounding the Kaweka Range. Correlations between storage and daily reference stations, using rainfall amounts for corresponding periods, determined the affinities of the storage stations and indicated that three distinct directional influences exist. In relation to the Kaweka Range these are recognized as the N, SW, and SE regimes or sectors.

Normal annual rainfalls were derived for storage-gauge stations and the values were approximately related to altitude and distance from the divide by a general equation. Annual rainfalls attain about 150 in. in the highest part of the range. For a given altitude rainfall totals are lower in the northern area than on the southern Kaweka Range.

Annual rainfall variability is discussed, the SW sector being the least variable — about 10 percent. An appendix lists for each sector the approximate percentage of the normal rainfall for each year since 1932.

The seasonal and monthly patterns of rainfall are presented as percentages of annual norms, and it is shown how approximate seasonal or monthly values may be derived for any rangeland area. Variability of monthly rainfalls is referred to, and extremes are given for each range sector.

Annual and seasonal raindays are mentioned, as is snow. High-intensity storms have occurred, and details of one recorded in 1965 at 3,200 ft are given.

Reference is also made to long-term variations of annual rainfall, storminess and drought that must apply to the Kaweka Range.

INTRODUCTION

Before 1957 no rainfall measurements had been made on the Kaweka Range. Since November 1957 a total of 17 storage rain gauges has been installed at altitudes up to 5,620 ft. Of these, seven were octapent gauges (Meteorological Office, 1956) supplied by the N.Z. Meteorological Service and the remainder were type-C gauges designed locally (Grant, 1960). Installations were organized by the hydrological staff of the Hawke's Bay Catchment Board in collaboration with staff of the N.Z. Forest Service, and subsequent rainfall readings have been carried out by Forest Service personnel, trampers, and others. In May 1966, the Napier Hydrological Survey, Ministry of Works, assumed responsibility for all storage rain-gauge installations.

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In February 1964, a Casella 95-day automatic rain gauge, supplied by the N.Z. Meteorological Service, was installed at Makahu Saddle (3,200 ft). A field station was established by the N.Z. Forest Service at Makahu Saddle in 1959 for ". . . study of reforestation techniques, mountain climates, and rates and patterns of erosion". (Cunningham, 1963.)

This paper presents a first look at some spatial and temporal patterns of rainfall on the Kaweka Range — rainfall being one of the more powerful independent or nonmanageable variables that rangeland management has to contend with.

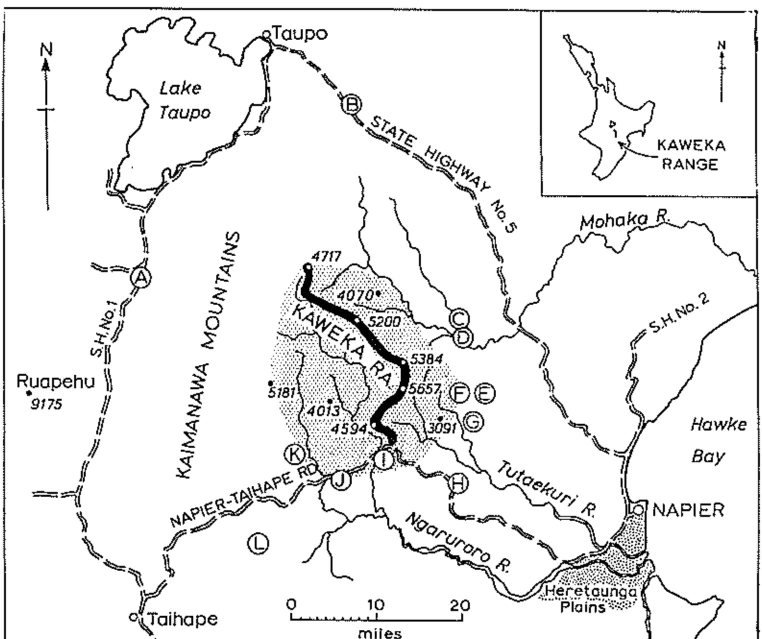


FIG. 1 — Location of Kaweka Range. Rangeland area discussed is stippled area in centre of map. Daily rain-gauge stations are shown by letters inside circles and refer to Table 2.

KAWEKA RANGE

The Kaweka Range lies 30 to 40 miles WNW of Napier. It extends for approximately 30 miles northward from Kuripapango on the Napier-Taihape Road. The southern portion of the range, about 12 miles, trends NNE; the northern 18 miles trend NW. The highest point is 5,657 ft (Figs. 1, 2 and 3).

The range consists largely of alternating greywacke and argillite (Grindley, 1960) which has been blanketed by pumice ash. Elder

(1959) further described its structure and physiography, and outlined the vegetation. Vegetation types and erosion surfaces of the southern Kaweka Range were detailed by Cunningham (1968).

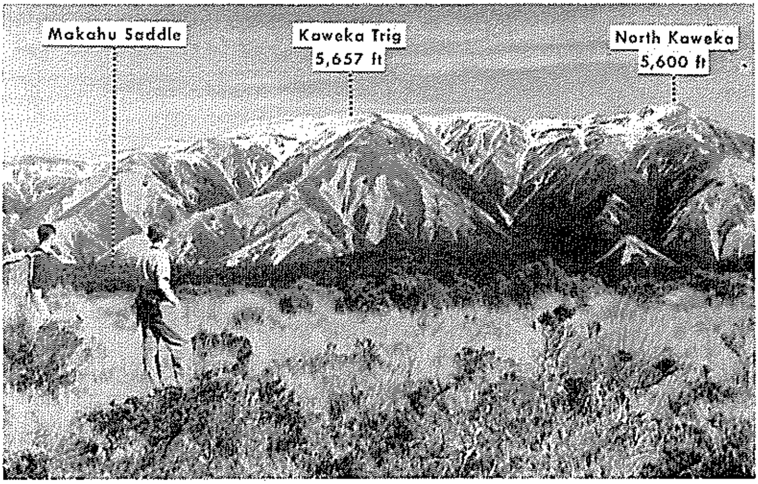


FIG. 2 — Part of the southern Kaweka Range, looking west from near Black Birch storage rain gauge, [10] on Fig. 6.
Photo: N.Z. Forest Service (A. Cunningham)

FIG. 3 — Part of the northern Kaweka Range, looking east across the Ngaruroro River from Tapuiomaruahine (4,367 ft) near Boyds storage rain gauge, [2] on Fig. 6.
Photo: N.Z. Forest Service (B. J. Osborne)

Three large rivers, the Mohaka, Ngaruroro and Tutaekuri, which flow eastward to Hawke Bay, originate on the Kaweka Range. Grant (1965a) determined that the Ngaruroro River is the major recharge source for the economically valuable ground-water system of the Heretaunga Plains (Fig. 1), and demonstrated that in summer the Kaweka Range is the greatest water-contributing area in the Ngaruroro catchment.

RAINFALL SAMPLING

To obtain more frequent maintenance, 13 of the 17 storage rain gauges were sited at huts, the other four being sited on main traverse routes. Some gauges have been read at fairly regular and short intervals — monthly, weekly or twice weekly; since mid 1968 Makahu Saddle rain gauge has been read daily by Forest Service staff. However, gauges in the more remote northern area have been read at various intervals up to seven months. For such long periods evaporation losses from octapent gauges (Fig. 4) are unknown, but it was determined that the oil film used in the type-C gauges (Fig. 5) completely inhibits evaporation.

It is inevitable, on steep high rugged terrain, that the standard of sampling sites will vary greatly, and accordingly the accuracy of rainfall catches will vary. Detailed comparisons (Grant, 1964) of

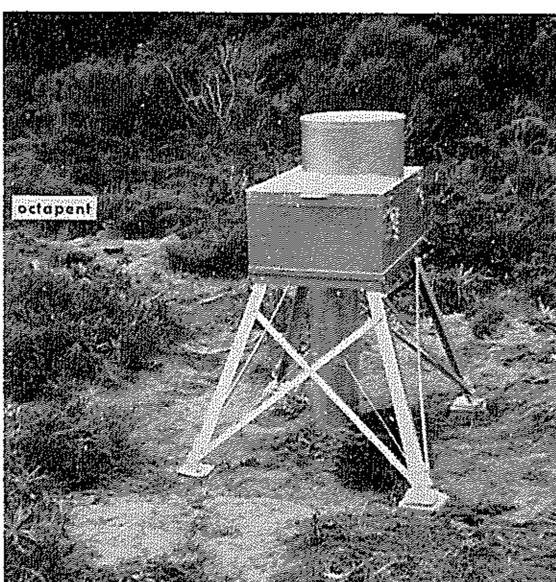


FIG. 4 — Casella 95-day automatic rain gauge and 27-inch octapent storage rain gauge at Makahu Saddle (3,200 ft).

FIG. 5 — Type-C storage rain gauge and weatherproof stationery cabinet at Kaweka Trig (5,620 ft).

records from Dominie at 4,800 ft on a steep east-west spur, and Makahu Saddle at 3,200 ft on a good site at the foot of the spur (Fig. 4) revealed that in each cold season Dominie gauge caught less (9–18%), and in each warm season it caught more (3–6%) than Makahu Saddle. For about the same period the six cooler months (May–October) are shown to have been more windy, by about 34%, than the warmer months (Cunningham and Gannaway, 1968). In one warm period (September–November 1964) known to have been exceptionally windy, Dominie caught 5% less than Makahu Saddle. Overall, Dominie gauge appears to undercatch by at least 20%, this probably being due to atmospheric turbulence. In the cool season the catch deficiency is accentuated because of the larger snowfall amounts. At four stations recorded values are considered to be too low because of bad exposure.

All rain gauges were installed in a vertical position and all gauge orifices were unshielded.

On a few high but small areas the proportion of snowfall to rainfall amount may be relatively large for short periods, but overall — both spatially and temporally — the bulk of precipitation falls as rain. Consequently, although the storage gauges catch a certain amount of snow, it is convenient for subsequent discussion to refer only to rainfall.

RANGELAND AFFINITIES

Storage rain-gauge stations are listed in Table 1 and their locations are shown on Fig. 6. Because the periods of measurement are short, and readings at most gauges have been irregular, the recorded data on their own give a rather hazy picture. Use has therefore been made of records from daily rainfall stations surrounding the Kaweka Range (Fig. 1). These are listed in Table 2, and seven of them were selected as primary reference stations.

TABLE 1 — Storage rain-gauge stations.

No. on map	*Station*	*Gauge type**	*Date installed*	*Altitude (ft)*	*Range sector*	*Provisional annual norm (in.)*
1	Oamaru	O	Nov 1963	2,100	N	72
2	Boyds	O	Nov 1960	3,200	N	82
3	Harkness	C	Dec 1960	2,940	N	80
4	Mangaturuturu	C	Dec 1961	4.450	SE	115†
5	Middle Hill	C	Jan 1964	3,200	SE	90
6	Back Ridge	O	Nov 1957	4,300	SE	124
7	Kaweka Trig	C	Jan 1959	5,620	SE	150†
8	Dominie	O	Jun 1962	4,800	SE	130†
9	Makahu Saddle	O	Nov 1957	3,200	SE	113
10	Black Birch	C	Feb 1964	3,500	SE	90
11	Kaweka Hut	C	Jan 1962	3,000	SE	95
12	Lotkow	C	Jun 1960	2,200	SE	80
13	Kiwi Saddle	C	Jan 1962	3,900	SE	105†
14	Lawrence	C	Mar 1962	1,100	SE	62
15	Blowhard	O	Mar 1959	2,300	SE	69
16	Kiwi Mouth	C	Jun 1960	2,100	SE	70
17	Golden Hills	O	May 1960	3,240	SW	74

* C — Type-C rain gauge; O — Octapent rain gauge.
† Values estimated by equation.

TABLE 2 — Daily rain-gauge stations.

Symbol on map	*Station*	*Altitude (ft)*	*Range sector*	*Annual norm (in.)*	*Primary references*
A	Rangipo	1,700	N	83.2	+
B	Waimihia	2,400	N	61.8	+
C	Black Stump	2,500	SE	65.0 approx.	
D	Bairnsdale	1,550	SE	59.0 approx.	
E	Te Wairere	1,850	SE	74.0	+
F	Anawhenua	2,000	SE	80.0 approx.	
G	Hawkstone	1,200	SE	60.0 approx.	
H	Waiwhare	1,150	SE	52.7	+
I	Kuripapango	1,600	SE	64.0	+
J	Timahunga	2,200	SW	52.0 approx.	
K	Owhaoko	3,000	SW	43.0	+
L	Mangaohane	2,500	SW	39.9	+

Correlation analyses were done between storage rainfall stations and daily reference stations using rainfall amounts for corresponding periods. The Spearman rank correlation was used; this is

$$r = 1 - \frac{6\Sigma d^2}{N^3 - N}$$

where Σd^2 is the sum of the squares of the differences between the ranks of the paired rainfall amounts, and N is the number of ranked pairs — desirably $N \geqslant 20$. The results of more than 50 analyses indicated not only the dominant directional affinities of each storage station but also the daily reference station, or stations, that are most closely related. For each storage station highly significant measures of relation, from 72% ($r = 0.85$) to 98% ($r = 0.99$), were obtained with at least one reference station.

An examination of results on a spatial basis showed that three distinct directional influences exist. In relation to the Kaweka Range these broadly are the northerly, south-easterly, and south-westerly influences or regimes. Accordingly, three rangeland sectors were approximately defined (Fig. 6), being the N sector, SW sector, and SE sector. Clearly there are two dominant influences — the westerly and the easterly, the former being capable of subdivision into the north and south components. It follows that within the rangeland area there is a mixing of these three influences so that a transition from one influence to another, rather than abrupt change, is the natural order. The lines demarcating the three sectors (Fig. 6) are simply indicators of change; they must not be interpreted strictly.

ANNUAL RAINFALLS

On the foregoing basis provisional normal* values were calculated for each storage rainfall station. A simple proportional method was used:

$$N_s = (N_r / R) S$$

where N_s is storage-gauge annual normal,
N_r is reference-gauge annual normal,
R is reference-gauge amount } for a corresponding period.
S is storage-gauge amount }

The longer the corresponding period the more reliable is the result.

Only those daily rainfall stations marked as primary reference stations (Table 2) were used, and for each the normal annual rainfall was adopted (N.Z. Meteorological Service, 1967). Approximate normal values for the other daily stations were calculated.

* The term 'normal' in connection with the 'normal' 30-year period, 1921–50, is used because it is in common usage, but it is a misleading term because climate is constantly changing. Terms such as 'reference' period or 'datum' period are preferable.

Derived provisional normal annual values for the storage rain-gauge stations are shown in Table 1, excepting those values shown as having been estimated.

Rainfall and Physiography

A broad positive relation was apparent between altitude and normal annual rainfall amount, but some anomalies existed which could be related to the proximity of high land. To separate this proximity effect from altitudinal effect for each station, the approximate distance was measured in miles to the divide, where this exceeded 4,000 ft. Using the 13 more reliable storage stations, graphical plots were made of altitude versus rainfall and distance versus rainfall and, by combination, the following approximate relation was obtained:

$$R=34.0+0.021\,H-2.5\,D$$

where R is approximate normal annual rainfall (inches),
H is altitude of rainfall station (feet),
D is distance of station from the divide above 4,000 ft (miles).

Comparisons of measured and calculated values of annual rainfall suggested that this equation applies only at altitudes above approximately 2,000 ft. The standard error of estimate for the 12 more reliable stations above 2,000 ft was calculated: $s=9.0$. The data indicated that other physiographic factors also govern rainfall amount. Two of them appear to be: (i) the maximum elevation of the nearby divide; (ii) the elevation and proximity of local high areas.

The region is heterogeneous; three rainfall regimes have been recognized, therefore no one relation can be expected to apply strictly throughout. In addition, the shorter the time span considered the greater will be the discrepancies when sectors are compared. It should be recognized that in the general relation, $R=\pm x+yH-zD$, neither x, y nor z can be regarded as constants when specific periods are under review; they must vary according to frequencies of rains from different directions, storm types, and wind forces.

In relation to annual normal rainfalls, because there are insufficient stations for the determination of separate relations for each sector, the one generalized relation, $R=34.0+0.021\,H-2.5\,D$ (± 9.0), should be considered only as a useful approximation. Its first application was for a closer estimate of normal values for the four badly exposed storage rain gauges (Table 1).

Spatial Pattern

The 17 storage rain-gauge station values, plus those of daily rainfall stations in close proximity to the range, were used to produce the normal annual isohyetal pattern (Fig. 6) which was fortified locally by estimates using the relation $R = 34.0 + 0.021\,H - 2.5\,D$.

It is interesting that for a given altitude, annual rainfalls in the northern rangeland area are markedly lower than on the southern Kaweka Range.

Variability

Annual rainfall amounts vary from year to year. Seelye (1940) demonstrated that variability increases from west to east. For the short but only common period, 1958–65, the percentage variability of annual rainfalls is shown in Table 3 for selected stations. Percentage variability is the average departure of the annual totals from their mean expressed as a percentage of the latter (Seelye, 1940).

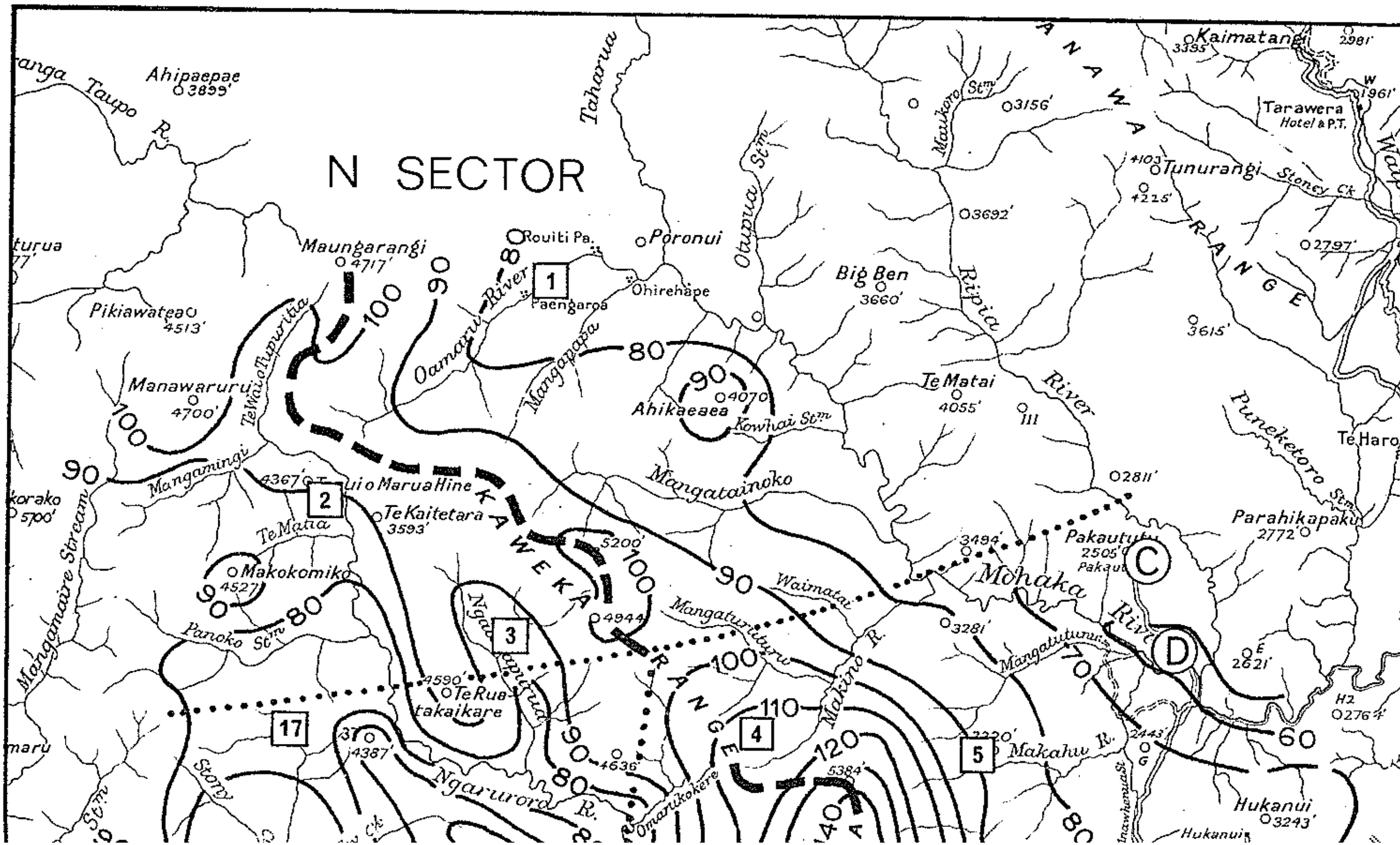
TABLE 3 — Variability of annual rainfalls during 1958–65.

Station	*Range sector*	*Percentage variability*
Owhaoko	SW	10.0
Kuripapango	SE	10.5
Makahu Saddle	SE	13.2
Waiwhare	SE	14.0
Te Wairere	SE	18.7
Rangipo	N	18.1
Waimihia	N	17.4

Because the period is short the variability values cannot be interpreted too strictly. The values suggest that the N sector is more variable than the SE, but because N-sector reference stations are further from the range than those of the SE sector (Fig. 1) this state may not apply to the rangeland area. The main indication is that the SW sector has the least variable annual rainfall. Although Kuripapango has been placed in the SE sector, its low variability value of 10.5% must be a reflection of the influence of the westerly rains. At Makahu Saddle, further north and also further east from Kuripapango, notwithstanding its altitude of 3.200 ft and close proximity to the highest portion of the Kaweka Range, the variability was 13.2% — a certain indication of a decreased westerly and increased easterly influence.

For the 11-year period 1958–68 at Makahu Saddle the variability was 11.5%, with a maximum of +30% in 1960 and a minimum of −24% in 1964.

Appendix 1 lists for each sector the approximate percentage of the normal, derived from reference stations, for each year since 1932. In only 18 years (out of 34) does the SE sector agree with



N SECTOR
KAWEKA RANGE
Maungarangi 4717'
Rouiti Pa.
Poronui
Paengaroa
Ohirehape
Oamaru River
Mangapapa
Ahikaeaea
Kowhai Stm
Mangatainoko
Big Ben 3660'
Ripia River
Te Matai 4055'
Otupua Stm
Taharua
Ahipaepae 3899'
Taupo R.
Pikiawatea 4513'
Manawaruru 4700'
Te Wai o Tupuritia
Mangamingi
Mangamaire Stream
Tu i o MaruaHine
Te Kaitetara 3593'
Te Matia
Makokomiko 4527'
Panoko Stm
Ngaruroro R.
Te Rua-takaikare
Waimatai
Mangaturituru
Makino R.
Omarukokere
Mohaka River
Mangatutunui
Makahu R.
Pakautuku 2505'
Parahikapaku 2772'
Puneketoro Stm
Te Harot
Hukanui 3243'
Tunurangi
Stoney Ck
Tarawera Hotel & P.T.
Kaimatangi 3395'
Maukoro Stm
Waipunga
ANAWA RANGE
Stony

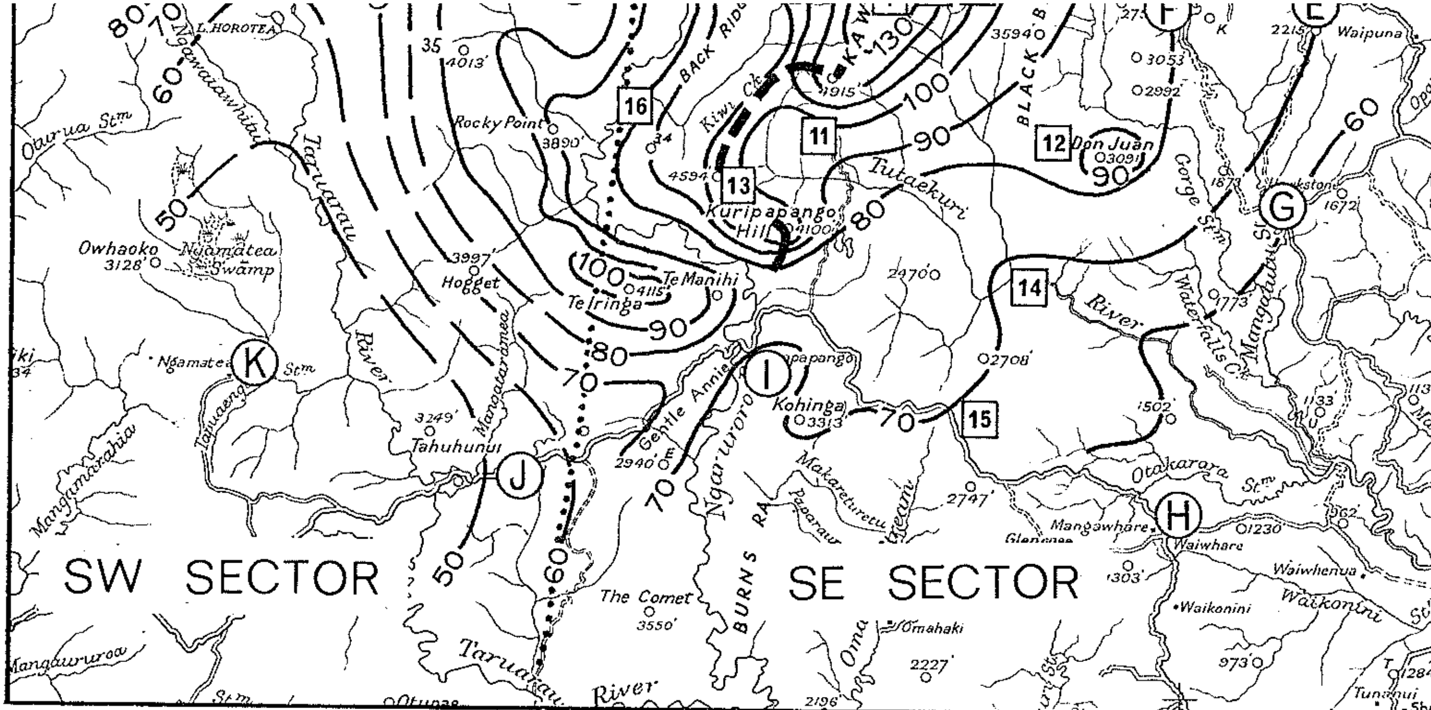


FIG. 6 — Provisional normal (1921–50) annual isohyetal pattern with values in inches. Storage rain-gauge stations are shown by numbers in boxes and refer to Table 1. Daily rain-gauge stations are shown by letters inside circles and refer to Table 2. Scale: 4 miles to 1 inch (1:253,440).

Base map: Lands and Survey Department

the SW in the direction of change — in 16 years when rainfall is below normal in one sector it is above normal in the other. In only 14 years does the SE sector agree with the N sector, whereas in 22 years there is agreement between the N and SW sectors — an indication of the common westerly influence.

It is worthwhile to note that since 1932 in the SE sector the driest years were 1934, 1942, 1945 and 1964; in the N sector they were 1932, 1937, 1939 and 1950; and in the SW sector they were 1932, 1939, 1963 and 1964.

Very wet years were 1938, 1940 and 1960 in the SE; 1935, 1956 and 1962 in the N; and 1936, 1938 and 1965 in the SW. The low level of agreement among sectors, in each case, emphasizes the reality of the divisions recognized.

In any year where there is disagreement among sectors (Appendix 1) — it is rarely that close agreement occurs as in 1933 — there must be transitions linking the sectors. It is reasonable to assume that from any position on the periphery joining Rangipo, Waimihia, Te Wairere, Waiwhare and Mangaohane (Fig. 1) transitions are more or less lineal with distance toward the opposite peripheral boundary. On this basis it is possible to synthesize an approximate annual rainfall pattern for any year by linearly adjusting the respective-percentage values appended and applying them to the normal isohyetal pattern of each rangeland sector (Fig. 6).

Annual Raindays

Average annual raindays (days with at least 0.005 in.) at reference stations for the only reliable common period, 1954–65, are tabulated.

TABLE 4 — Average annual rainday numbers for the period 1954–65.

Station	*Range sector*	*Raindays*
Rangipo	N	159
Waimihia	N	169
Owhaoko	SW	146
Kuripapango	SE	156
Waiwhare	SE	137

The values indicate that in the N sector raindays exceed 170 in number, in the SW they exceed 150, and in the SE they exceed 160.

Raindays during 1968 were: Rangipo — 147, Waimihia — 187, Kuripapango — 153, Waiwhare — 144, and Makahu Saddle — 197. In relation to the values of Table 4 the 1968 values suggest an average annual rainday number around 200 for Makahu Saddle.

SEASONAL PATTERNS

Rainfall Amounts

Using data from the primary reference daily rainfall stations, the normal seasonal patterns of rainfall for each rangeland sector have been defined as percentages of the normal annual values (Table 5).

TABLE 5 — Seasonal rainfall amounts as percentages of the annual norms.

Range sector	*Summer (Dec, Jan, Feb)*	*Autumn (Mar, Apr, May)*	*Winter (Jun, Jul, Aug)*	*Spring (Sep, Oct, Nov)*
N	23.1	23.1	28.7	25.1
SW	24.4	24.0	28.6	23.0
SE	24.9	25.5	28.2	21.4

In the N sector, rainfall contributions are lowest in summer and autumn; in both southerly sectors the minimum is in spring. Maximum contributions occur in winter in all sectors.

Raindays

Seasonal rainday numbers for the period 1954–65, expressed as percentages of the annual averages at daily reference stations, are given in Table 6. On the average all sectors experience maximum rainday numbers in winter and minimum numbers in summer.

TABLE 6 — Seasonal rainday numbers expressed as percentages of the 1954–65 annual averages, and an indication of actual rainday numbers.

Range sector	*Summer*	*Autumn*	*Winter*	*Spring*	*Annual raindays*
N	21	24	29	26	>170
SW	17	24	35	24	>150
SE	22	25	30	23	>160

MONTHLY PATTERNS

The normal monthly patterns of rainfall contribution, expressed as percentages of the annual normal rainfall, are shown for each sector (Fig. 7). Napier is included to illustrate the extreme variability of the far-easterly monthly pattern and the close relation to it of the pattern of the SE sector.

These patterns may be used with care, making allowances for transitions, in conjunction with the normal annual pattern (Fig. 6) to derive approximate monthly norms for any rangeland area. For any year storage rain-gauge amounts may be reduced to approximate monthly amounts by the judicious application of monthly percentages of the annual total at primary reference stations.

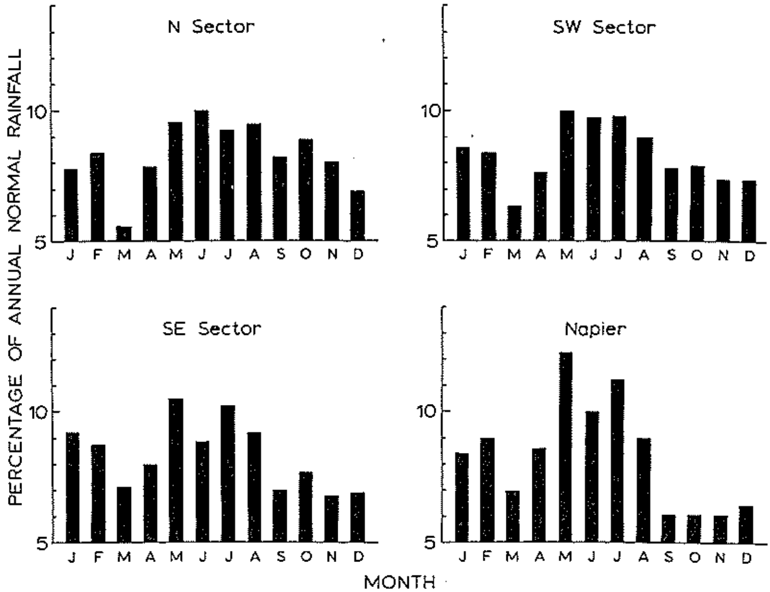


FIG. 7 — Normal monthly patterns of rainfall contribution.

Variability

Seelye (1946) illustrated that variability for every month increases from west to east, and showed that for the North Island February has the most variable rainfall. Daily reference stations indicated that in each range sector February has the greatest negative deviation from normal for the period 1932–65 (Table 7).

TABLE 7 — Monthly rainfall extremes, 1932–65, expressed as percentages of normal values.

Range sector	*Extreme*	*Month*											
		J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
SE	Low	6	1	15	19	16	15	18	15	9	28	9	13
	High	395	346	356	883	243	259	348	324	315	288	482	380
N	Low	12	9	15	14	31	27	23	30	31	13	31	28
	High	275	287	305	258	223	225	272	214	234	223	223	384
SW	Low	2	0	13	19	13	9	26	42	16	21	7	29
	High	186	323	550	288	215	221	178	224	191	230	306	263

About the Kaweka Range mean variability of monthly rainfall, for 1911–40, was shown by Seelye (1946) to be:

30–40% for June, July, August and September;

40–50% for October, November, December, April and May;

50–60% for January, February and March.

Table 7 gives for each sector the approximate monthly extremes. Following the derivation of approximate normal monthly values for a rangeland location, some idea of monthly extreme values may be obtained by using the values of Table 7 and adjusting them for transitions.

SNOW

Even a preliminary study of precipitation patterns, such as this, warrants some mention of snow.

The incidence of snow is related to altitude. For the years 1963 to 1968 the average number of days per month with snow lying on the southern Kaweka Range at 3,000 ft and 5,000 ft was as follows:

	Apr	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*
3,000 ft:	1	3	5	14	11	4	1	1
5,000 ft:	3	7	13	29	30	29	17	4

Snow depth is influenced by altitude, physiography and aspect. The greatest depth of snow recorded at Makahu Saddle, 3,200 ft, is 24 in. About 5,000 ft, average depths of 30 in. have been recorded.

STORM PATTERNS

Severe flood-producing storms on the range are usually associated with depressions. Judged by the magnitude of flood levels and the large quantities of transported rock detritus in streams draining the SE Kaweka slopes, the storm of 17–18 March 1965, was the most intense in the area for many years. Storage rain-gauge records show that the storm affected most of the SE sector of the range but there was little more than an inch of rain at the time in the N sector. Intensities were recorded at Makahu Saddle by the Casella 95-day rain gauge (Fig. 4). Maximum rainfalls recorded for various durations are:

Duration	20	30	60 min	2	6	12	24	48	72 hrs
Rainfall (*in.*)	0.7	0.9	1.6	2.4	3.7	6.8	10.1	13.0	13.9

The storm pattern with time at Makahu Saddle is shown in Fig. 8. The very intense and sustained rain towards the end of the storm, when 2.20 in. fell in 90 minutes, probably was largely responsible for the transport, both into and along the channels, of the large rock debris loads observed after the event.

A storm on 21 June 1968 produced 5.24 in. in 12 hours at Makahu Saddle.

The cyclonic storm of 9–10 March 1964 severely eroded numerous stream channels of the N sector (Mr P. Cook, N.Z. Forest Service, pers. comm.), while over the southern portion of the range only very small non-flood-producing rainfalls occurred.

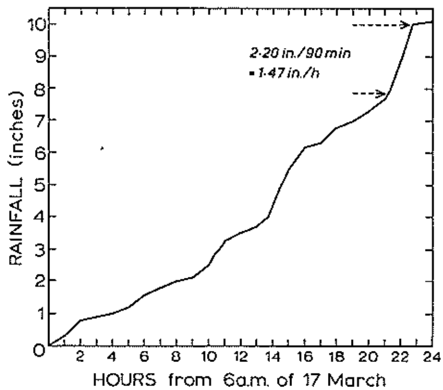


FIG. 8 — Cumulative rainfall pattern for the storm of 17–18 March 1965 at Makahu Saddle (3,200 ft).

This event demonstrated that the N sector is also subject to high-intensity storms; however, it is likely that their return period is longer than for the SE sector.

Of all historical storms it is probable that the one of 16–17 April 1897 was the greatest in the rangeland area. Lasting evidence of the magnitude of this storm in the southern area exists at Kuripapango in the form of large outwash debris fans from very small catchments. The origin of these fans was obtained from the late Mr M. Robson, N.Z. Forest Service, Kuripapango.

LONG-TERM PATTERNS

The spatial annual rainfall patterns presented, while varying from year to year in an apparently haphazard way, must nevertheless conform with patterns of longer-period variation demonstrated for the North Island by de Lisle (1961).

The SE sector is positively related to extreme easterly influences, therefore the findings of Grant (1966) for Eastern Hawke's Bay may be qualitatively applied to the SE sector — possibly also to the remainder of the range. These concern marked variations in the seasonal frequencies of the larger daily rains since 1890, and periods of greater storminess. In the latter respect it was earlier suggested by the author (Grant, 1965b) for part of the Ruahine Range, farther south, that small-area rainstorms have increased in intensity in the last 20–30 years.

Drought has affected the Kaweka Range, as evidenced by the observations of Elder (1956) for the northern rangeland area. Drought patterns for the East Coast were presented by Grant (1968) and it is certain that they can be applied qualitatively to the Kaweka Range.

ACKNOWLEDGMENTS

This study would not have been possible without the assistance of those who made rainfall measurements, often in inclement weather, at the storage gauges. Readings have been made by visitors from far and near but the majority of records came from staff of the N.Z. Forest Service and from members of clubs such as the Heretaunga Tramping Club.

Thanks are due to staff of the Hawke's Bay Catchment Board for assistance in the early stages of type-C gauge design and manufacture, and to N.Z. Forest Service personnel for co-operation and assistance from the time storage-gauge installations were proposed.

Grateful acknowledgment is made to Mr J. Finkelstein, N.Z. Meteorological Service, for assistance with data for daily rainfall stations. To Mr A. Cunningham, N.Z. Forest Service, the author is indebted for the photographs for Figures 2 and 3, for the information on snow, and for helpful comments on the script; his staff have assisted greatly in the field.

Permission to publish this paper was given by the Commissioner of Works.

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APPENDIX 1

Approximate Mean Annual Rainfall Indices
(Percentages of Annual Norms)

	*SE Sector	N Sector	SW Sector
1932	104	78	74
1933	89	87	88
1934	61	86	82
1935	119	131	117
1936	91	103	120
1937	109	74	80
1938	260	107	122
1939	137	81	70
1940	177	88	113
1941	102	106	114
1942	77	119	98
1943	91	101	108
1944	111	104	108
1945	62	117	101
1946	75	105	88
1947	91	93	102
1948	83	105	90
1949	91	103	97
1950	98	81	102
1951	94	105	104
1952	95	118	116
1953	79	112	96
1954	111	85	93
1955	104	107	88
1956	121	128	114
1957	84	94	102
1958	83	117	102
1959	101	96	98
1960	136	94	93
1961	95	85	95
1962	95	157	96
1963	88	89	77
1964	64	124	78
1965	107	111	121
1966	85	124	–
1967	87	107	–

* For 1932–53 the indices are based on only Te Wairere; for 1966–7 the indices are based on Makahu Saddle.