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# THE CLIMATE AND WEATHER OF THE BAY OF PLENTY REGION

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# THE CLIMATE AND WEATHER OF THE BAY OF PLENTY REGION

A.M.QUAYLE

ABSTRACT

The weather experienced in the Bay of Plenty, as in other parts of New Zealand, is influenced by the eastward movement of weather systems and by the bold topography of New Zealand. The Bay of Plenty has a sunny climate, with less wind than most other parts of the country and with considerable rainfall and temperature variability.

## 1. INTRODUCTION

### 1.1 Geography

For the purposes of this publication the Bay of Plenty region, as defined by the Local Government Commission (1978), comprises the counties of Rotorua and Whakatane and the Tauranga and Opotiki Districts. The region is bounded by the Kaimai and Mamaku Ranges in the west, the Huiarau and Raukumara Ranges in the east and by the Pacific Ocean to the north. The southern boundary of the region forms an irregular line from the Atiamuri Power Station on the Waikato River to Minginui on the western fringe of the Urewera Country.

Geographically the Bay of Plenty is a diverse region. Volcanic landscapes dominate the area from Rotorua south towards Taupo, and heavily forested ranges cover a vast area in the Urewera National Park and Raukumara Ranges. These areas are a marked contrast to the coastal lowlands, extending from Waihi Beach in the northwest to Opotiki in the east.

Large parts of the volcanic plateau are now covered by exotic pine plantations. The coastal strip supports a large dairying industry but much of this area is best known for its kiwifruit and citrus orchards. The volcanic resources of the region have also been exploited - tourists provide a significant part of New Zealand's income while steam bores at Wairakei and Broadlands are utilised in the production of electric power. The port of Tauranga provides a means of export for much of the region's produce and the seas off the Bay of Plenty support important commercial and recreational fisheries.

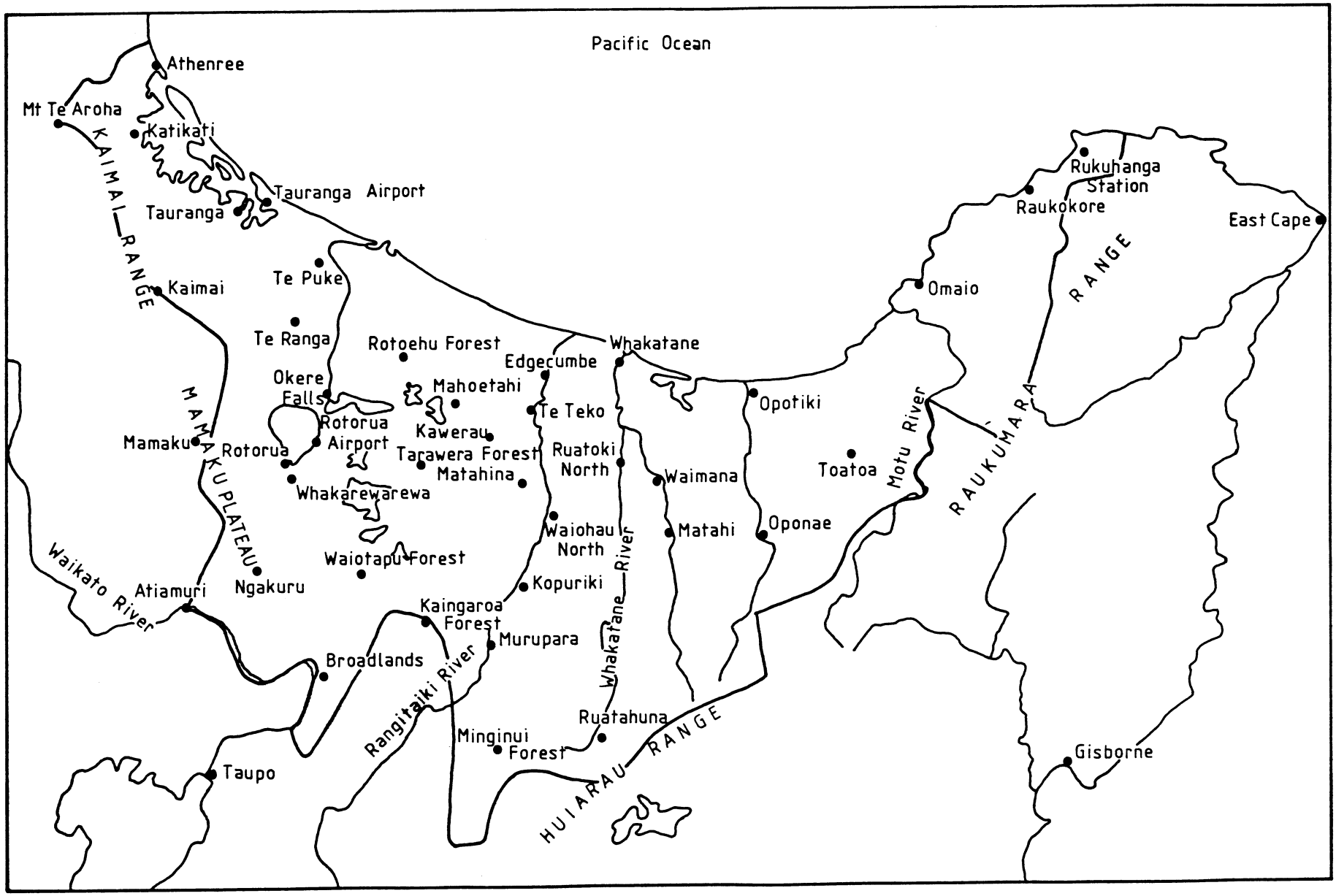


Fig. 1: The Bay of Plenty region showing locations of places referred to in the text.

## 1.2 Weather Patterns in New Zealand

New Zealand's weather is largely determined by the general eastward progression of anticyclones and troughs. However, the bold topography of the country results in large rainfall and temperature variations between the east and west coasts. The Bay of Plenty is sheltered from the prevailing winds by the high country of the North Island and hence has a sunny climate with comparatively frequent dry spells. However, the region is exposed to northerly and northeasterly airstreams, and as these are often very humid heavy rainfalls are not uncommon.

## 1.3 Meteorological Data

The New Zealand Meteorological Service maintains an extensive network of rainfall and climatological stations throughout the country. Archived and analysed data from these stations have been the primary source of information for this publication.

The locations of places referred to in the text are shown in Fig. 1.

# 2. TYPICAL WEATHER SITUATIONS

Because the Bay of Plenty is sheltered by high country to the west, south and east, day to day variations of the weather are largely determined by the direction of the wind. While high country areas may receive rain with airstreams from any direction, most of the area receives a large part of its annual rainfall during periods of onshore north to northeast winds.

The following sections describe the effects of various meteorological situations on the weather of the Bay of Plenty region.

## 2.1 North to Northeast Airstreams

Airstreams from the north and northeast frequently have long trajectories over the warm ocean to the north of New Zealand and, as a result, the air flowing onto the Bay of Plenty under these conditions is very humid. As the whole region is exposed to the north, these airstreams often produce widespread and heavy rain when the moist air is forced to ascend over the rising ground of the North Island. Such flows are normally associated with one of two types of situation. Firstly, when a cold front, oriented north-south, is approaching from the west, the northerly winds ahead of the front spread over the region, bringing widespread rain until the passage of the front when there is usually a clearance. The second type occurs when depressions cross the northern half of the North Island. These lows often move only slowly east, and the north to northeast flows on the eastern side of the centre may bring prolonged rain to the region.

An example of this type of situation occurred on July 28th and 29th, 1982. A large depression had developed near Lord Howe Island and on the 28th moved into the area northwest of Cape Reinga. A moist northeasterly airstream, extending from just south of Fiji, spread onto the North Island ahead of the cold front associated with the low (see Fig. 2.). The north-easterlies brought some light rain to the Bay of Plenty on the 27th but widespread heavy rain developed during the 28th. Heavy rain continued to fall throughout the 29th, with 40 to 50mm of rain falling over much of the region.

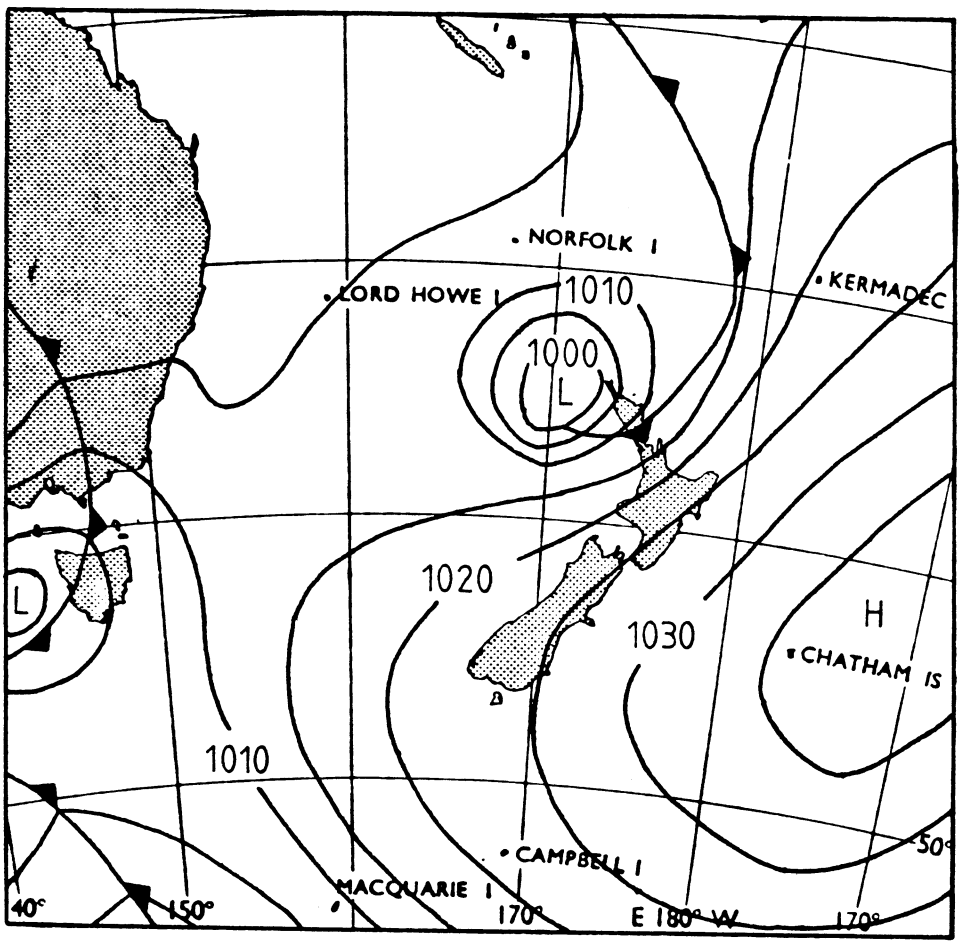


Fig. 2: Sea level analysis for 0000 NZST 29th July 1982.

The front and northeasterly airstream moved off to the east on the 30th and the rain cleared. The satellite image* (Fig. 3) shows a broad cloud band, associated with the front and moist northeasterly flow over the region.

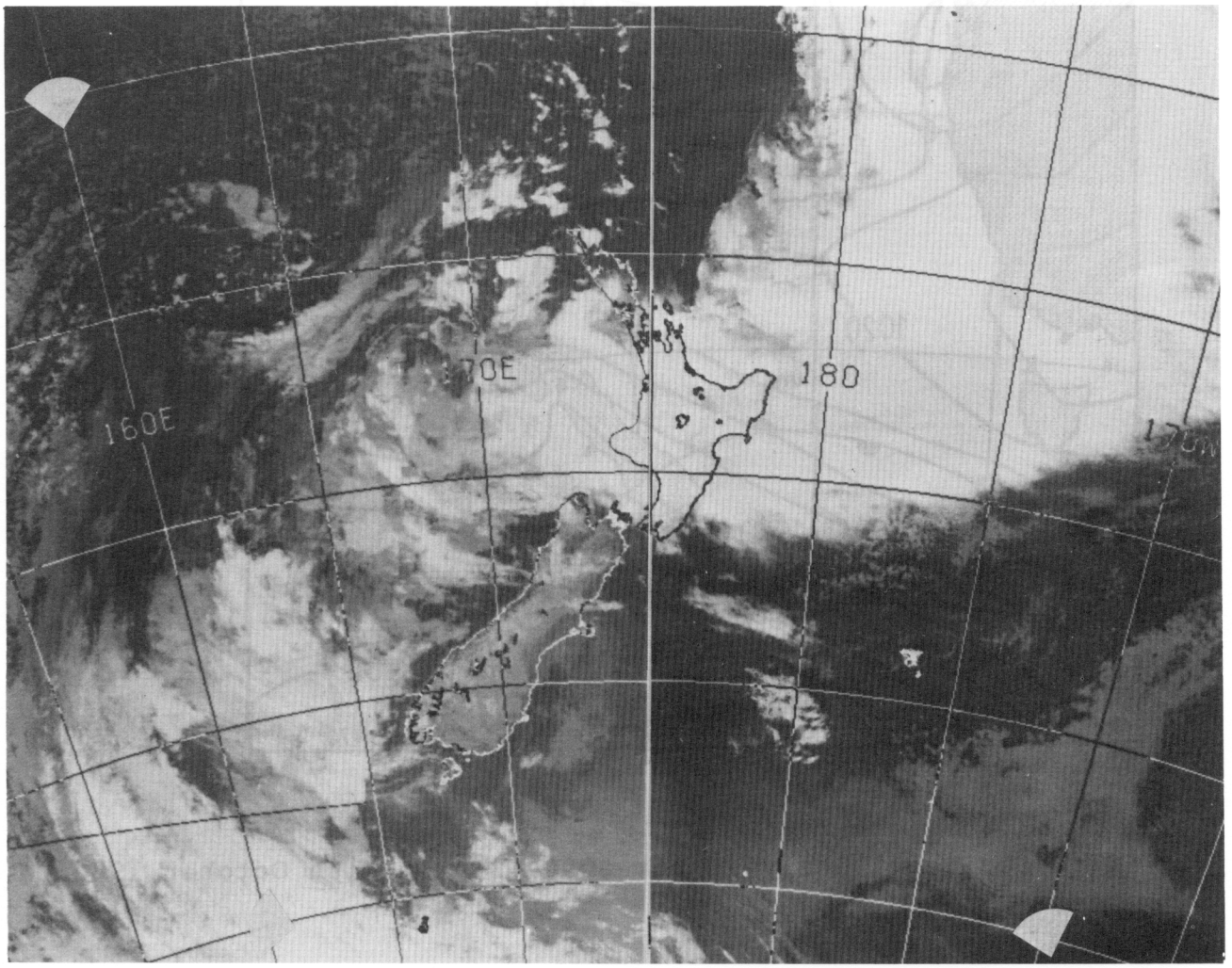


Fig. 3: Infrared satellite image at 1400 NZST 28th July 1982

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* Satellite imagery is available in two main forms, firstly as visible photographs and secondly as infrared images. Infrared imagery shows variations in temperature, with cold areas (such as high cloud tops) appearing white and warm areas (such as the land or sea) appearing dark grey.

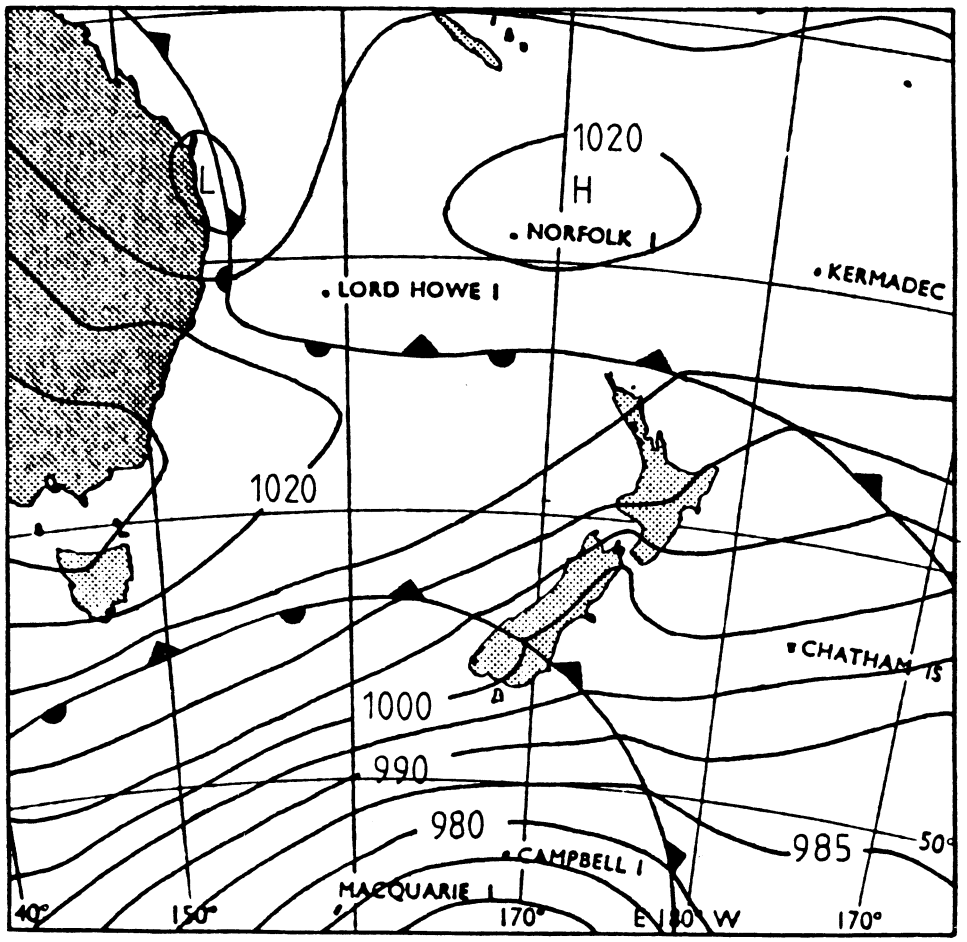


Fig. 4: Sea level analysis for 0000 NZST on 11th October 1982.

## 2.2 Disturbed West to Southwest Flows

This is a common situation in the New Zealand area, occurring most frequently during the spring months. Cold fronts move quickly eastnortheast across the country, giving showers, chiefly to western areas. The Bay of Plenty, however, is sheltered by high ground to the south and west and, as a result, only a few showers are experienced in most cases.

For example, a strong southwesterly airstream spread onto the North Island behind a cold front during 10th October 1982. The initial front, and subsequent disturbances (see Fig. 4) in

the southwesterlies gave brief light showers to the Bay of Plenty region but rainfall amounts were very small (less than 1mm).

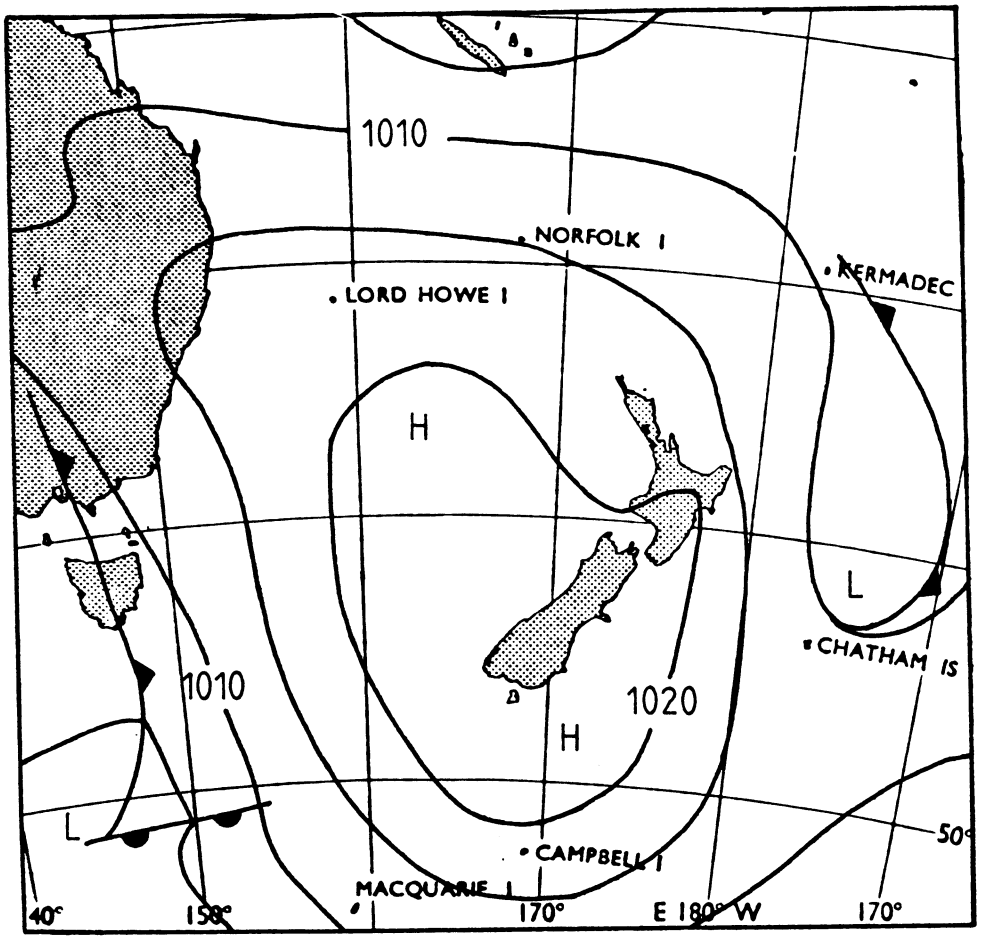


Fig. 5: Sea level analysis for 0000 NZDT on 21st February 1984.

## 2.3 South to Southeast Airstreams

The area to the east and south of the Bay of Plenty comprises the central high country of the North Island. South to southeast airstreams will normally have released much moisture as rain on the ranges and usually produce fine, dry weather over the region. Such flows are normally associated with low pressures to the east or northeast of the North Island.

During the 20th and 21st of February 1984 a southerly airstream (see Fig. 5) over the North Island was giving showers to areas about and east of the ranges from East Cape to Hawkes Bay, while the Bay of Plenty experienced fine, sunny weather. The satellite photograph (Fig. 6) clearly shows the extensive cloud east of the ranges and clear skies over the Bay of Plenty.

Flows from the south and southeast are subject to foehn warming as they traverse the high country and, as a result, temperatures in the Bay of Plenty are often notably warmer than on the windward side of the ranges. Temperatures on 20 February 1984 were some 3 to 4°C warmer in the Bay of Plenty than on the eastern side of the ranges, as a result of this effect.

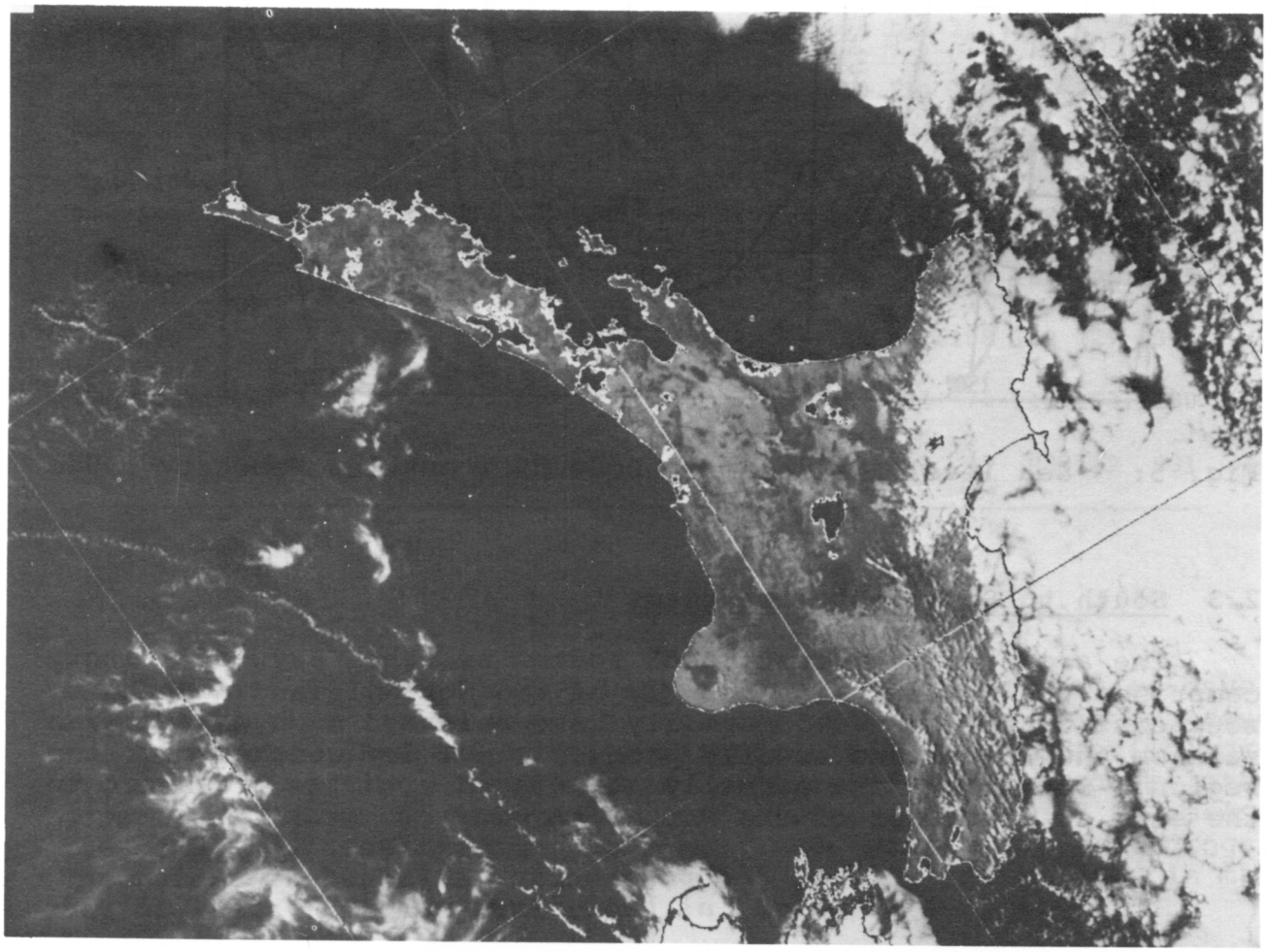

Fig. 6: High resolution satellite photograph at 1700 NZDT 20th February 1984.

## 2.4 West to Northwest Flows

The Coromandel, Kaimai and Mamaku Ranges provide sheltering to much of the Bay of Plenty in west to northwest situations, although the area from Cape Runaway to Whakatane and Murupara is open to flows from the northwest. Because of the sheltering, much of the rain that falls in the western Bay of Plenty with this type of situation occurs with the passage of fronts, rather than as a result of orographic effects on the northwesterly flow. Eastern areas, however, tend to experience rain both with fronts and with the northwesterlies ahead of fronts.

During the period 8th to 15th September 1983 a series of fronts moved eastsoutheast across the North Island in a predominantly northwesterly airstream. For much of the time the weather over the region was cloudy, with periods of rain occurring as fronts moved across the area. Daily rainfalls of up

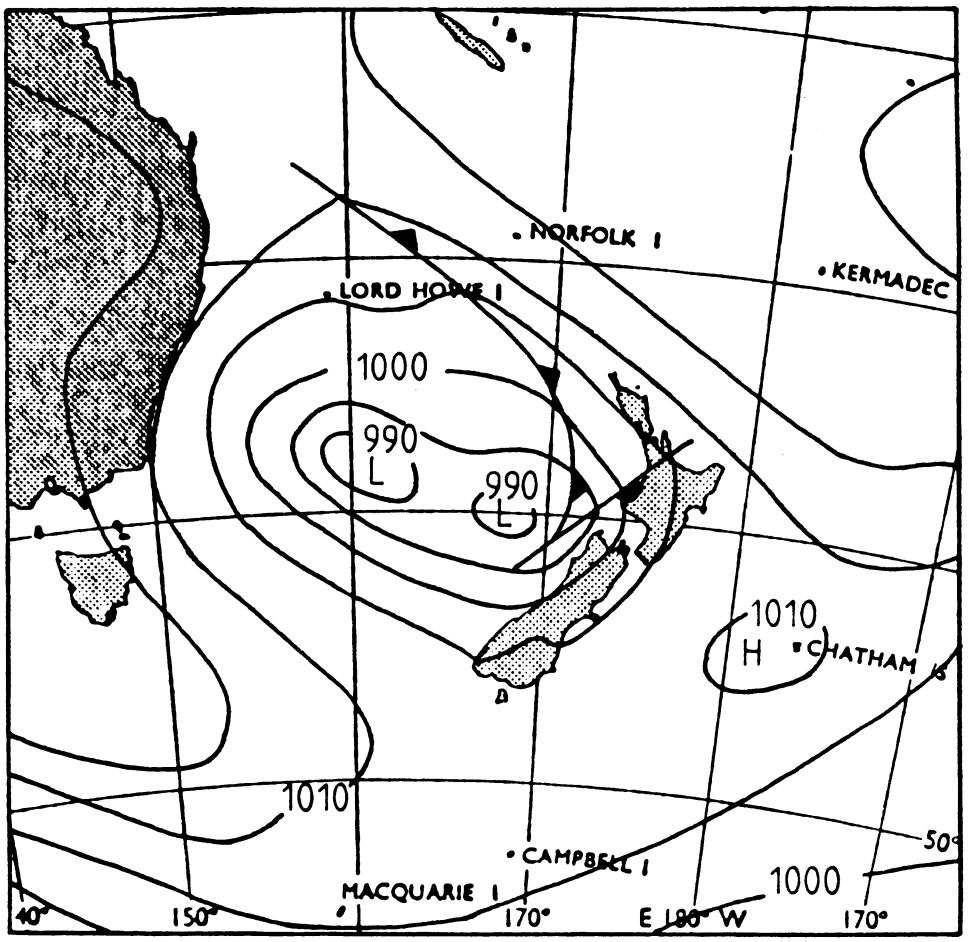


Fig. 7: Sea level analysis for 0000 NZST on 10th September 1983.

to 40mm were recorded on the days when fronts crossed the region but on the other days rainfalls were generally less than 5mm. The situation at midnight on 10th September 1983 is depicted in Fig. 7. The front west of Auckland moved quickly eastsoutheast across the North Island during the day.

## 2.5 Tropical Cyclones

Occasionally, during the months November to April, cyclones originating in the tropics move onto northern New Zealand. Because of their origin over very warm tropical oceans, these depressions normally contain very moist air. Although the structure of tropical cyclones is much modified as they move into higher latitudes they may still produce very strong winds and heavy rain.

Tropical cyclone "Bernie" developed near the Solomon Islands on 1st April 1982 and during the following six days moved

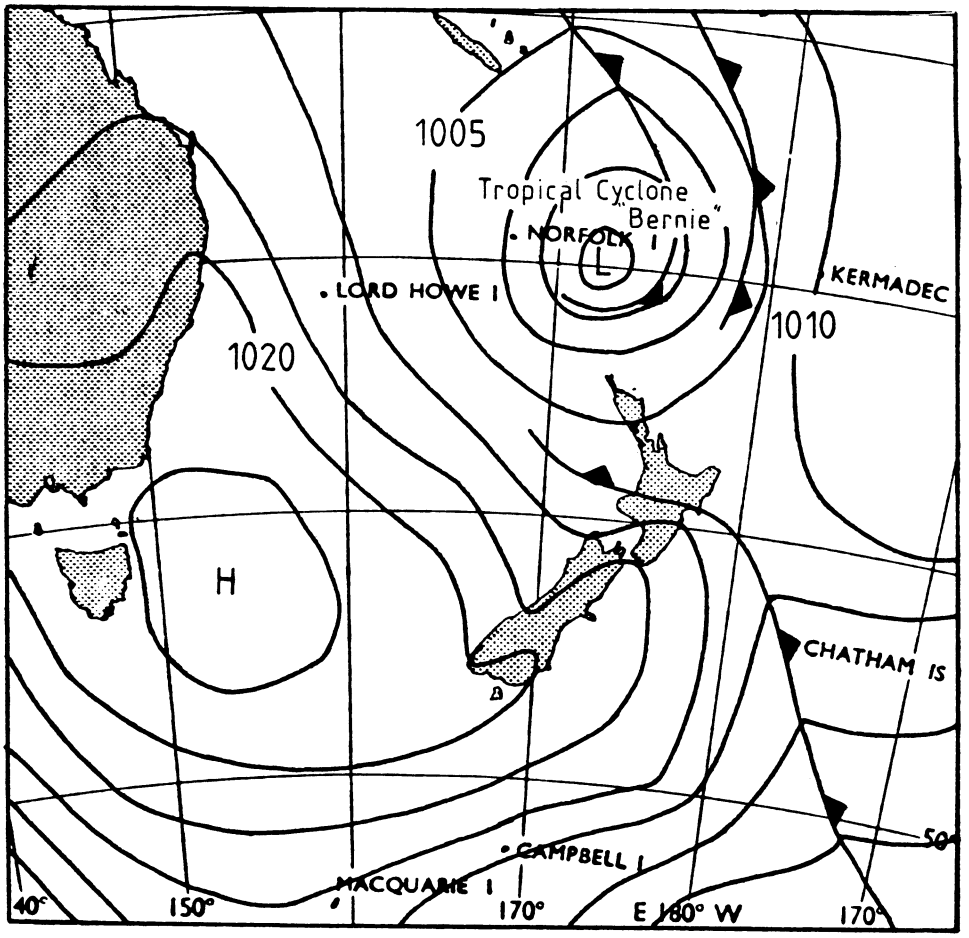


Fig. 8: Sea level analysis for 0000 NZST on 9th April 1982.

south into the area just west of New Caledonia, before turning southeast towards northern New Zealand. During the 9th Bernie moved fairly quickly southeast from near Norfolk Island to near East Cape (see Fig. 8). The very moist easterlies on the southern side of the cyclone gave continuous rain to the region throughout that day (up to about 25mm). On the 10th there was a rapid clearance when the flow turned southerly over the North Island as Bernie moved away. Very strong winds were experienced in the Bay of Plenty region during the 9th, causing severe damage to crops such as kiwifruit and apples and to trees in the Kaingaroa Forest. Rotorua Airport recorded its highest ever wind gust of 61kt the same day. The extensive cloud sheet associated with the heavy rain is clearly visible in the satellite photograph (Fig. 9).

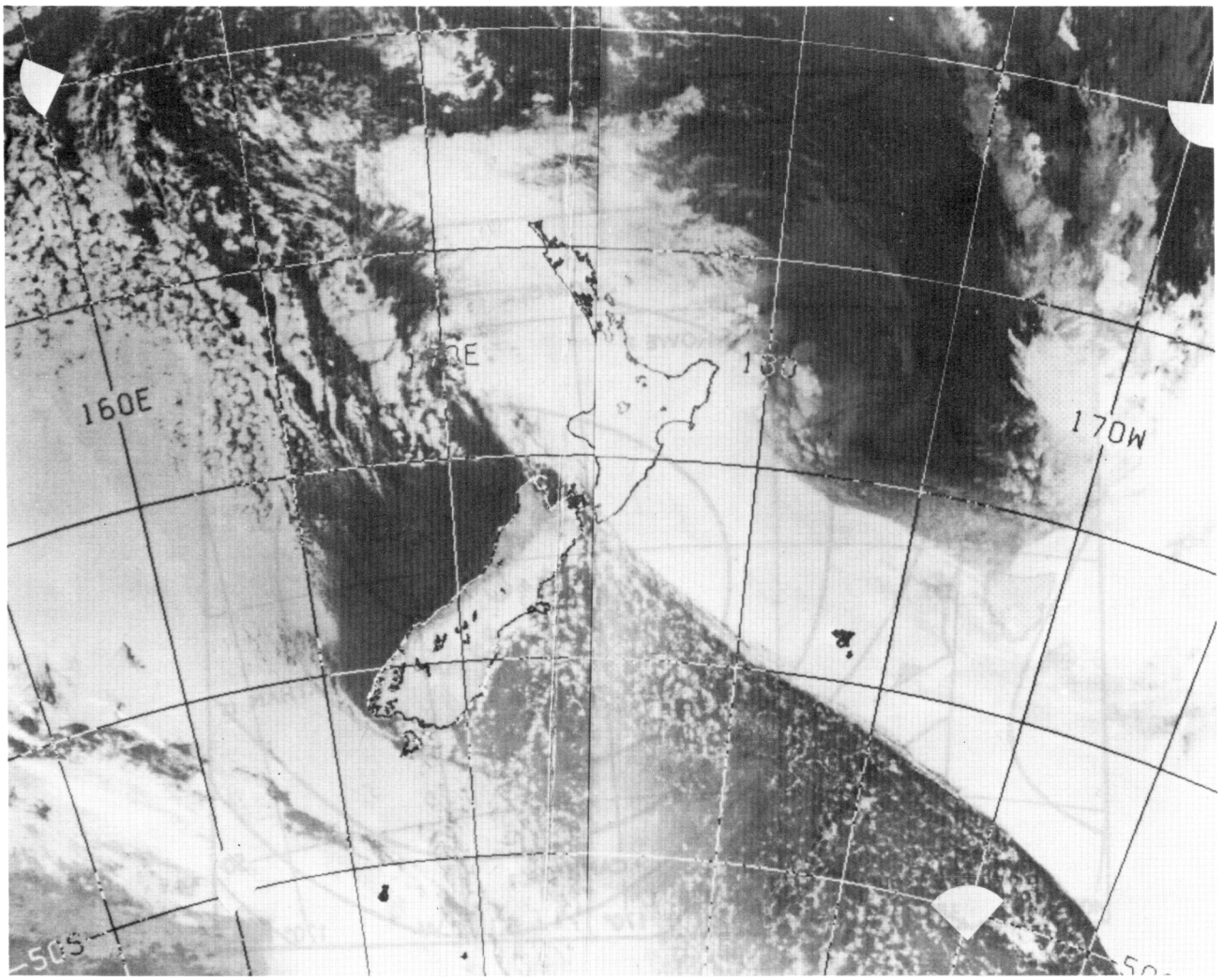


Fig. 9: Infrared satellite image at 0200 NZST on 10th April 1982.

Inset 2*

## 2.6 Dry Spells

As a result of the extensive sheltering provided by the high country surrounding three sides of the Bay of Plenty, the frequency of rain is rather less than in many other parts of the country and dry spells are relatively common. Quite frequently long periods occur when west to southwest flows persist over New Zealand without being interrupted by the north to northeast flows which give the Bay of Plenty most of its rain. The summer of 1982-3 was an excellent example and the Bay of Plenty, along with many other eastern areas of New Zealand, received very little rain.

During the 25-day period from 15th February to 11th March 1983 rain was recorded on only two days at Rotorua and 3 days at Tauranga, with the falls in each case amounting to only about 0.5mm. Figs. 10 and 11 show typical weather situations affecting the region during this period.

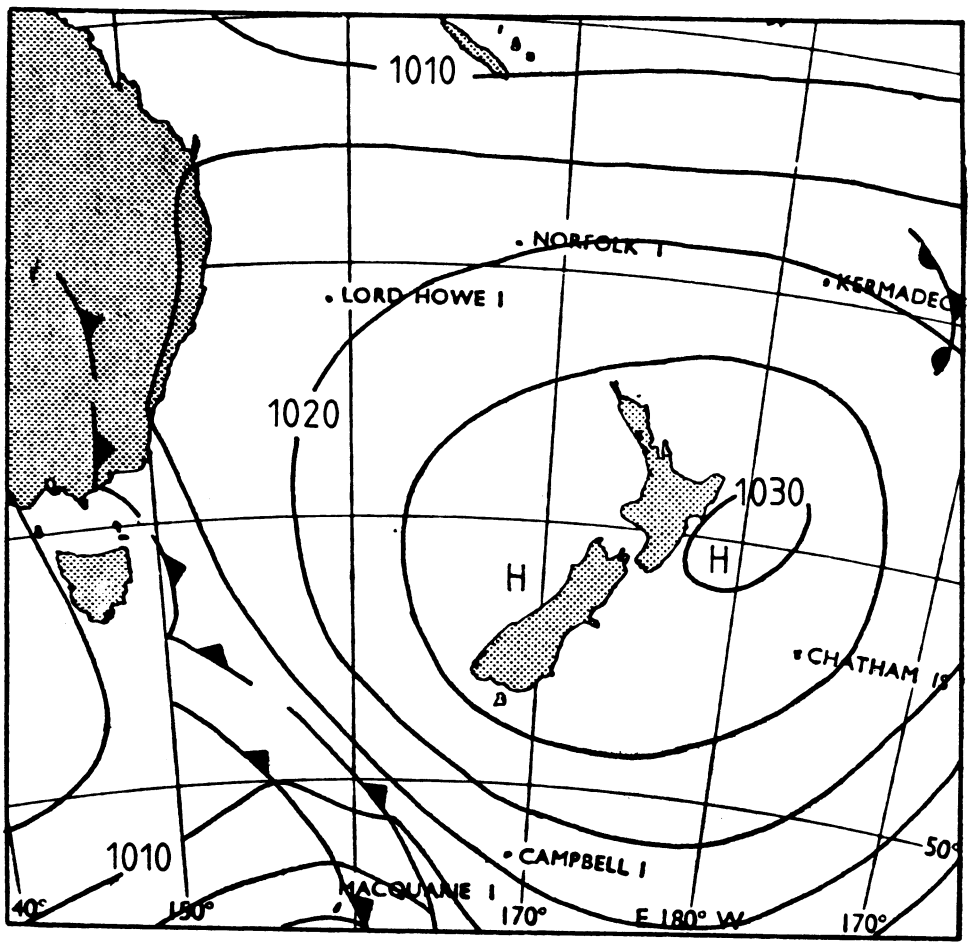


Fig. 10: Sea level analysis for 0000 NZDT 23rd February 1983.

Pressures over New Zealand during the latter half of February were high and during the first eleven days of March a west to southwest airstream covered the country. The few fronts which crossed New Zealand were weak and at no stage did northeasterly winds affect the Bay of Plenty.

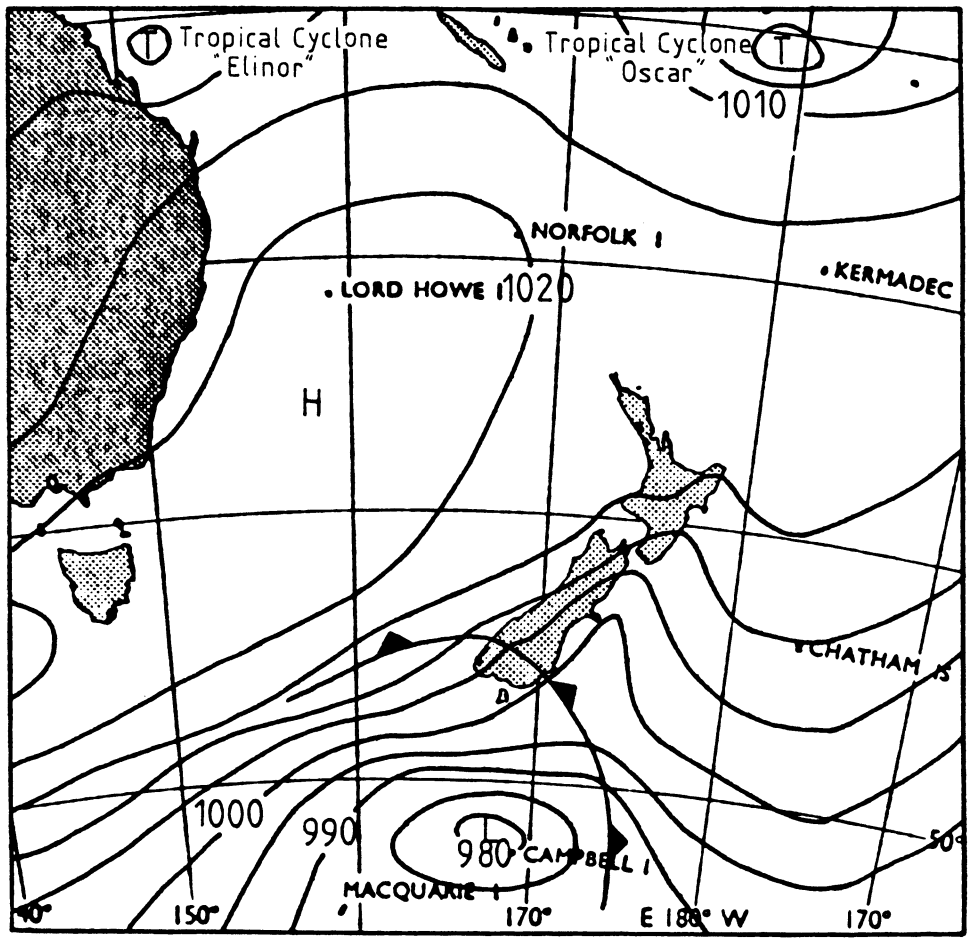


Fig. 11: Sea level analysis for 0000 NZDT 3rd March 1983.

## 2.7 Convection Showers

During the summer, on days when the air is unstable (i.e. there is a rapid decrease of temperature with height) surface heating will often cause the air to rise. This, in turn, leads to the formation of cumulus or cumulonimbus clouds and eventually, showers. Showers of this type are quite frequent in Bay of Plenty and normally occur on days which have begun fine. The showers are normally confined to inland areas, although on some occasions cumulonimbus clouds spread out and become very extensive, giving widespread showers and, occasionally, thunderstorms.

On 2nd January 1984 a ridge of high pressure covered the North Island and clear skies permitted rapid heating over the land. As a result of this heating the air began to ascend and this led to the formation of a "heat low" over the Bay of Plenty region in the afternoon (see Fig.12). The ascending air also led to a

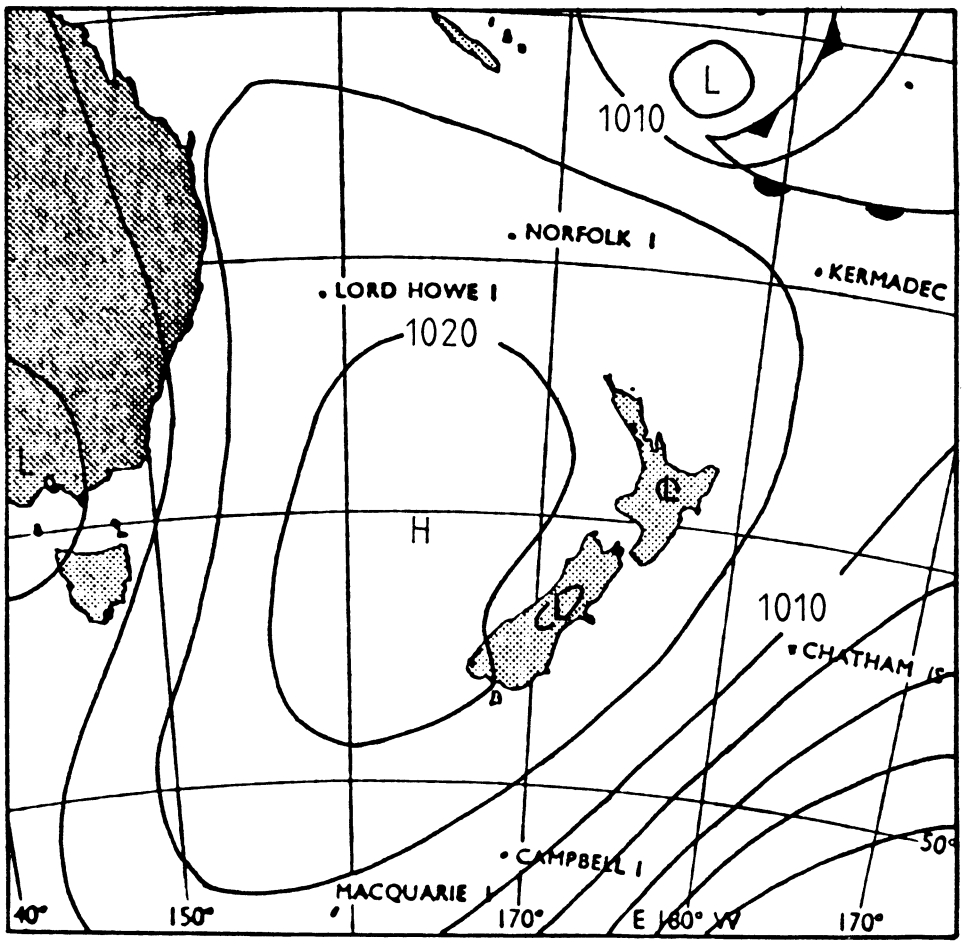


Fig. 12: Sea level analysis for 3pm 2nd January 1984

general increase in cloudiness during the day. By late afternoon "towering cumulus" clouds were developing in the Rotorua area and at about 7.30pm heavy showers developed. Showers were reported over a wide area around Rotorua but many other parts of the region recorded no rain at all. Between 7.30pm and midnight a total of 33mm of rain was recorded at Rotorua Airport. The showers then rapidly cleared and the cloud dispersed. The extensive area of high cumulonimbus cloud tops can be clearly seen in the satellite image (Fig.13).

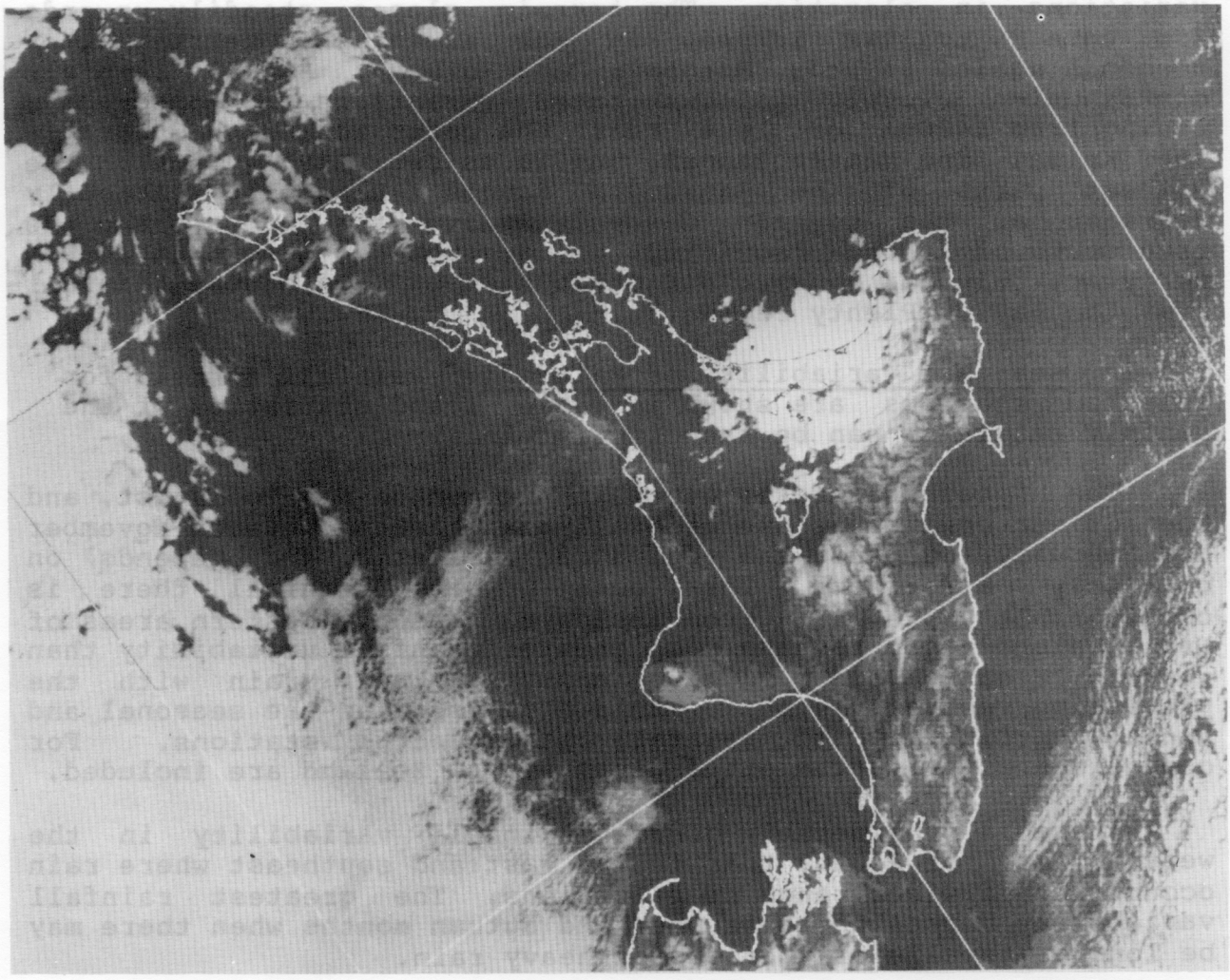

Fig. 13: Infrared satellite image for 9pm 2 January 1984

# 3. CLIMATIC ELEMENTS

## 3.1 Rainfall

3.1.1 Spatial Variability of Rainfall. The pattern of rainfall distribution over the Bay of Plenty largely reflects the region's exposure to the main rain-bearing northeasterly winds, and also variations in elevation. The terrain slopes steadily upwards for some 25 to 30km inland. In the south the terrain then descends again, towards Murupara and Rotorua. Annual rainfall distribution closely follows these variations in topography, rising from 1400mm or less near the coast to around 2500mm in the Kaimai and Mamaku Ranges, and to an estimated 4000mm on the highest parts of the Raukumara Ranges. Rainfalls steadily decrease as the terrain descends again, with Murupara and the area south of Rotorua receiving an average of less than 1400mm per year. Fig. 14 shows the distribution of mean annual rainfall over the Bay of Plenty region.

3.1.2 Seasonal Variability of Rainfall. Rainfall normals for selected stations are shown in Table 1 and statistics of the monthly rainfalls can be seen in Fig. 15.

The highest rainfalls occur in the months May to August, and the driest conditions are generally experienced between November and February. Because the region is sheltered and depends on northerly airstreams for much of its rainfall there is considerable variability from season to season. Eastern areas of New Zealand tend to have much greater rainfall variability than western areas, which receive most of their rain with the prevailing westerly winds. Table 2 illustrates the seasonal and annual variability of rainfall at selected stations. For comparison figures from other parts of New Zealand are included.

There is considerably greater rainfall variability in the western Bay of Plenty than in the east and southeast where rain occurs with a wider range of situations. The greatest rainfall variability occurs in the summer and autumn months when there may be long dry spells or periods of heavy rain.

3.1.3 Frequency of Rain. Rainfalls amounting to 1mm or more occur on an average of about 120 days per year in the Bay of Plenty region. Actual frequencies range from 110 days at Whakatane up to 133 days at the Minginui Forest; higher frequencies undoubtedly occur in the high country of the Raukumara Range and Urewera National Park. Monthly and annual frequencies of raindays (1mm or more of rain recorded) are included in the climatological summaries for individual stations (see Appendix).

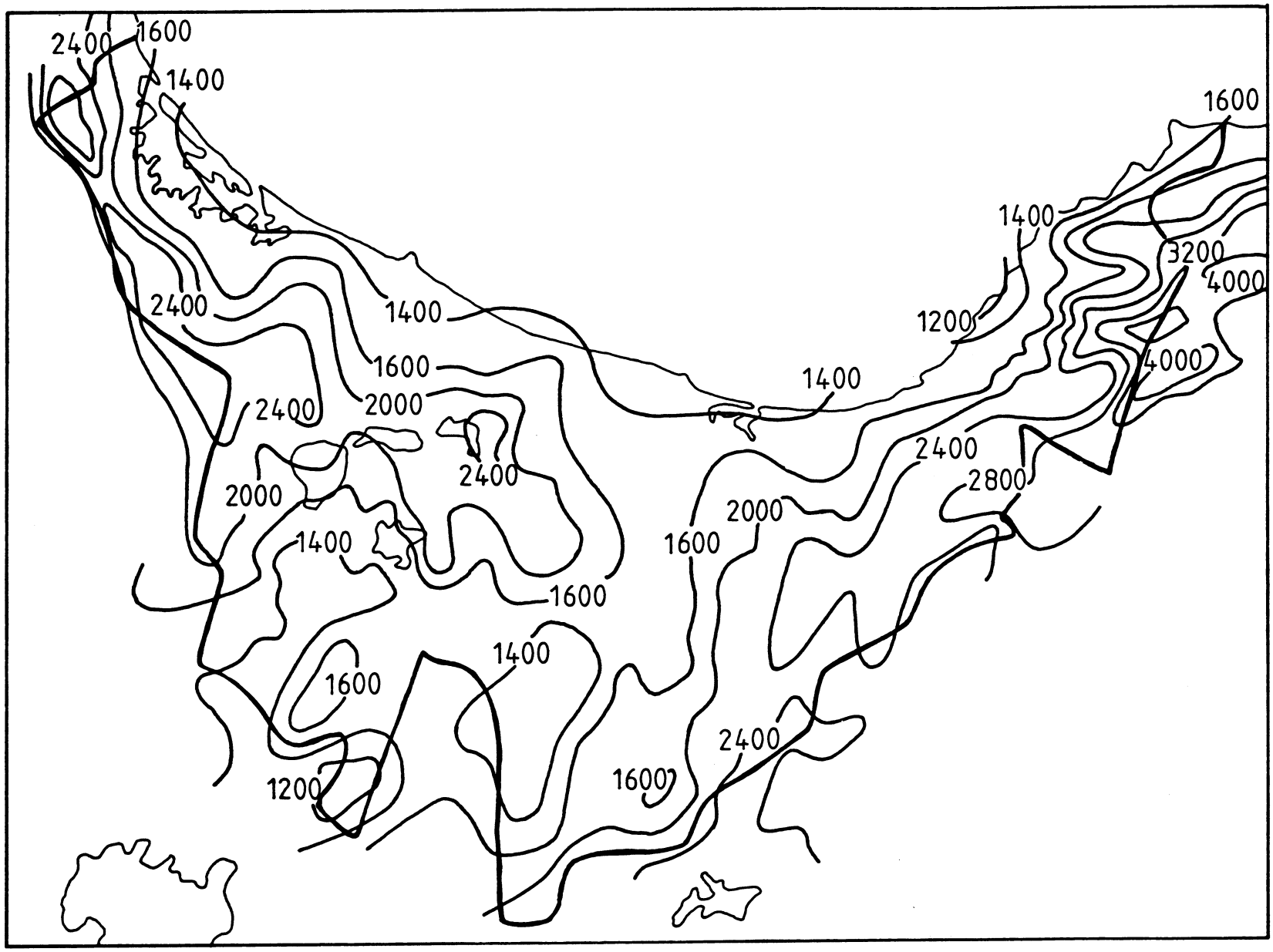


Fig. 14: Mean annual rainfall (mm).

TABLE 1: RAINFALL NORMALS 1951 - 1980 (a) AND MONTHLY RAINFALL AS A PERCENTAGE OF ANNUAL TOTAL (b).
(Stations are presented in approximate geographical order, from NW to SE).

| Station | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Athenree | a | 110 | 163 | 147 | 163 | 175 | 140 | 205 | 165 | 142 | 115 | 109 | 156 | 1790 |
| | b | 6 | 9 | 8 | 9 | 10 | 8 | 11 | 9 | 8 | 6 | 6 | 9 | |
| Katikati | a | 90 | 124 | 145 | 141 | 169 | 182 | 165 | 175 | 146 | 131 | 108 | 139 | 1715 |
| | b | 5 | 7 | 8 | 8 | 10 | 11 | 10 | 10 | 9 | 8 | 6 | 8 | |
| Kaimai School | a | 154 | 150 | 210 | 190 | 266 | 234 | 244 | 253 | 238 | 208 | 185 | 195 | 2527 |
| | b | 6 | 6 | 8 | 8 | 11 | 9 | 10 | 10 | 9 | 8 | 7 | 8 | |
| Tauranga Airport | a | 79 | 90 | 133 | 107 | 130 | 130 | 137 | 134 | 116 | 106 | 85 | 116 | 1363 |
| | b | 6 | 7 | 10 | 8 | 10 | 10 | 10 | 10 | 9 | 8 | 6 | 9 | |
| Te Puke | a | 94 | 108 | 167 | 124 | 163 | 159 | 168 | 166 | 144 | 131 | 110 | 148 | 1682 |
| | b | 6 | 6 | 10 | 7 | 10 | 9 | 10 | 10 | 9 | 8 | 7 | 9 | |
| Te Ranga | a | 128 | 160 | 237 | 180 | 231 | 213 | 239 | 240 | 209 | 188 | 148 | 195 | 2368 |
| | b | 5 | 7 | 10 | 8 | 10 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | |
| Rotoehu Forest | a | 95 | 125 | 150 | 128 | 159 | 144 | 164 | 169 | 134 | 134 | 106 | 146 | 1654 |
| | b | 6 | 8 | 9 | 8 | 10 | 9 | 10 | 10 | 8 | 8 | 6 | 9 | |
| Whakatane | a | 82 | 103 | 125 | 96 | 119 | 127 | 132 | 105 | 132 | 104 | 86 | 110 | 1321 |
| | b | 6 | 8 | 9 | 7 | 9 | 10 | 10 | 8 | 10 | 8 | 7 | 8 | |
| Raukokore | a | 81 | 98 | 94 | 113 | 143 | 137 | 126 | 149 | 111 | 118 | 95 | 95 | 1360 |
| | b | 6 | 7 | 7 | 8 | 11 | 10 | 9 | 11 | 8 | 9 | 7 | 7 | |
| Rukuhanga Station | a | 85 | 98 | 121 | 141 | 151 | 155 | 164 | 174 | 128 | 123 | 97 | 100 | 1537 |
| | b | 6 | 6 | 8 | 9 | 10 | 10 | 11 | 11 | 8 | 8 | 6 | 7 | |
| Mamaku | a | 122 | 136 | 170 | 163 | 199 | 213 | 221 | 203 | 178 | 174 | 168 | 181 | 2128 |
| | b | 6 | 6 | 8 | 8 | 9 | 10 | 10 | 10 | 8 | 8 | 8 | 9 | |
| Okere Falls | a | 125 | 167 | 176 | 159 | 170 | 185 | 177 | 203 | 177 | 158 | 118 | 221 | 2036 |
| | b | 6 | 8 | 9 | 8 | 8 | 9 | 9 | 10 | 9 | 8 | 6 | 11 | |
| Mahoetahi | a | 148 | 189 | 233 | 205 | 201 | 247 | 265 | 259 | 205 | 185 | 163 | 175 | 2475 |
| | b | 6 | 8 | 9 | 8 | 8 | 10 | 10 | 10 | 8 | 7 | 7 | 7 | |
| Kawerau | a | 116 | 142 | 160 | 131 | 174 | 163 | 177 | 178 | 143 | 138 | 107 | 151 | 1780 |
| | b | 7 | 8 | 9 | 7 | 10 | 9 | 10 | 10 | 8 | 8 | 6 | 8 | |
| Te Teko | a | 97 | 129 | 145 | 124 | 154 | 139 | 153 | 158 | 130 | 121 | 101 | 135 | 1586 |
| | b | 6 | 8 | 9 | 8 | 10 | 9 | 10 | 10 | 8 | 8 | 6 | 9 | |

Table 1 (cont)

| Station | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whaka- | a | 97 | 115 | 124 | 119 | 139 | 140 | 146 | 136 | 123 | 117 | 108 | 145 | 1509 |
| rewarewa | b | 6 | 8 | 8 | 8 | 9 | 9 | 10 | 9 | 8 | 8 | 7 | 10 | |
| Matahina | a | 132 | 160 | 175 | 156 | 195 | 169 | 200 | 202 | 161 | 167 | 147 | 164 | 2028 |
| | b | 7 | 8 | 9 | 8 | 10 | 8 | 10 | 10 | 8 | 8 | 7 | 8 | |
| Waiohau | a | 117 | 126 | 175 | 152 | 199 | 146 | 192 | 182 | 171 | 156 | 139 | 142 | 1897 |
| North | b | 6 | 7 | 9 | 8 | 10 | 8 | 10 | 10 | 9 | 8 | 7 | 7 | |
| Ngakuru | a | 91 | 94 | 97 | 107 | 107 | 131 | 129 | 120 | 107 | 110 | 107 | 121 | 1321 |
| | b | 7 | 7 | 7 | 8 | 8 | 10 | 10 | 9 | 8 | 8 | 8 | 9 | |
| Waiotapu | a | 88 | 108 | 118 | 118 | 129 | 138 | 138 | 134 | 123 | 113 | 106 | 126 | 1439 |
| Forest | b | 6 | 8 | 8 | 8 | 9 | 10 | 10 | 9 | 9 | 8 | 7 | 9 | |
| Kopuriki | a | 97 | 114 | 112 | 105 | 136 | 122 | 136 | 129 | 118 | 116 | 101 | 128 | 1414 |
| | b | 7 | 8 | 8 | 7 | 10 | 9 | 10 | 9 | 8 | 8 | 7 | 9 | |
| Kaingaroa | a | 103 | 122 | 123 | 125 | 140 | 142 | 143 | 148 | 134 | 124 | 115 | 143 | 1562 |
| Forest | b | 7 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 | 8 | 7 | 9 | |
| Murupara | a | 97 | 117 | 97 | 101 | 120 | 117 | 123 | 118 | 111 | 103 | 97 | 137 | 1338 |
| | b | 7 | 9 | 7 | 8 | 9 | 9 | 9 | 9 | 8 | 8 | 7 | 10 | |
| Broadlands | a | 82 | 84 | 78 | 96 | 95 | 102 | 104 | 91 | 80 | 97 | 80 | 106 | 1095 |
| | b | 7 | 8 | 7 | 9 | 9 | 9 | 9 | 8 | 7 | 9 | 7 | 10 | |
| Minginui | a | 112 | 119 | 96 | 114 | 133 | 132 | 143 | 144 | 128 | 128 | 129 | 145 | 1523 |
| Forest | b | 7 | 8 | 6 | 7 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 10 | |
| Ruatahuna | a | 95 | 99 | 101 | 127 | 136 | 147 | 165 | 158 | 126 | 137 | 118 | 136 | 1545 |
| | b | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 10 | 8 | 9 | 8 | 9 | |
| Opotiki | a | 82 | 102 | 132 | 115 | 130 | 127 | 129 | 136 | 113 | 113 | 95 | 121 | 1395 |
| | b | 6 | 7 | 9 | 8 | 9 | 9 | 9 | 10 | 8 | 8 | 7 | 9 | |
| Ruatoki | a | 90 | 112 | 134 | 120 | 151 | 145 | 139 | 138 | 123 | 127 | 93 | 116 | 1488 |
| North | b | 6 | 8 | 9 | 8 | 10 | 10 | 9 | 9 | 8 | 9 | 6 | 8 | |
| Toa Toa | a | 139 | 133 | 189 | 201 | 206 | 274 | 200 | 206 | 190 | 234 | 196 | 219 | 2387 |
| | b | 6 | 6 | 8 | 8 | 9 | 11 | 8 | 9 | 8 | 10 | 8 | 9 | |
| Matahi | a | 145 | 159 | 186 | 152 | 202 | 197 | 186 | 198 | 181 | 195 | 170 | 200 | 2171 |
| | b | 7 | 7 | 9 | 7 | 9 | 9 | 9 | 9 | 8 | 9 | 8 | 9 | |
| Oponae | a | 162 | 137 | 137 | 228 | 225 | 230 | 246 | 238 | 234 | 213 | 202 | 224 | 2476 |
| | b | 7 | 6 | 6 | 9 | 9 | 9 | 10 | 10 | 9 | 9 | 8 | 9 | |

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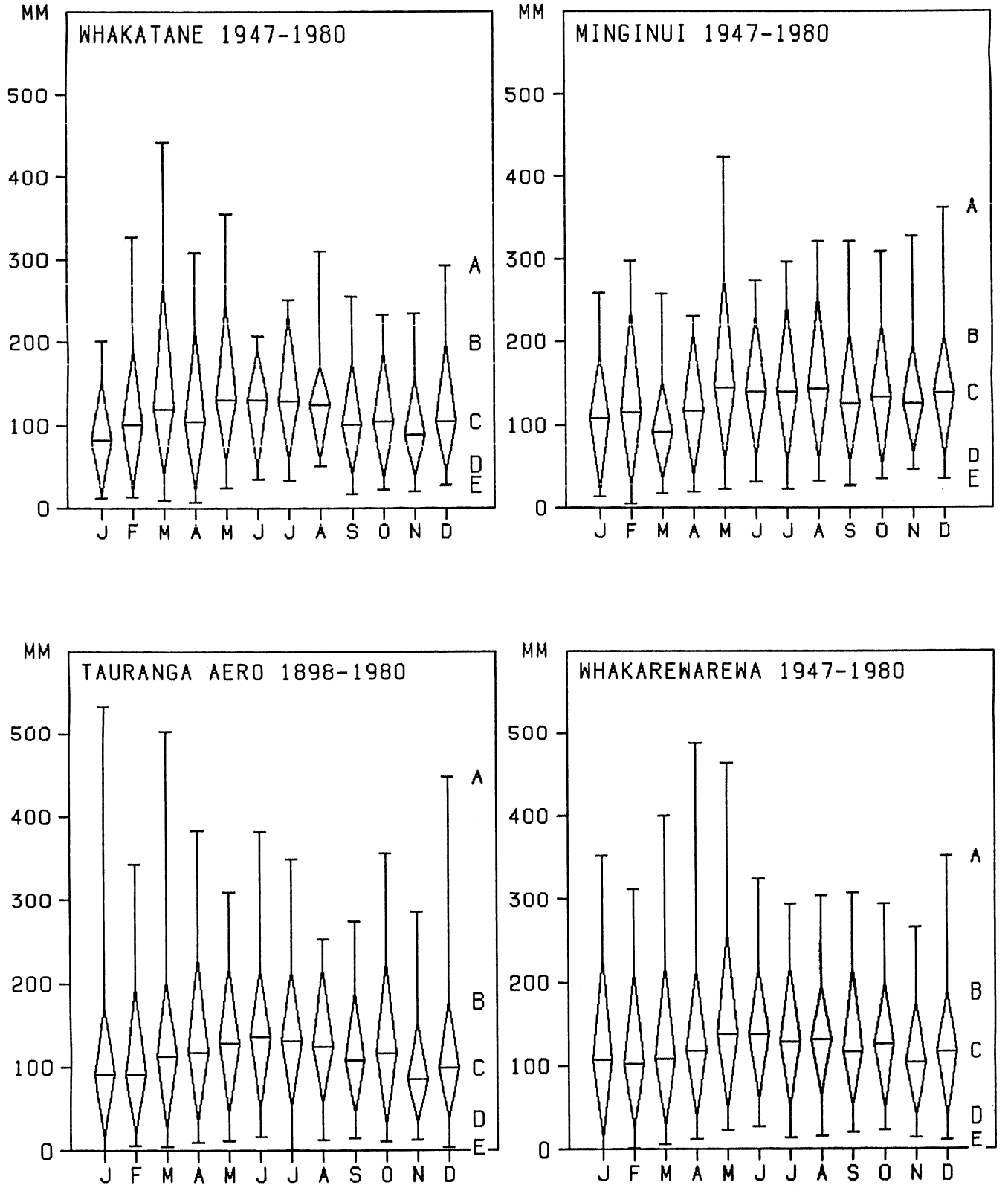



KEY
A: HIGHEST RECORDED
B: 90 PERCENTILE
C: MEAN
D: 10 PERCENTILE
E: LOWEST RECORDED

**Fig. 15: Monthly rainfall statistics.**

TABLE 2: VARIABILITY (%) OF SEASONAL AND ANNUAL RAINFALL.*

| STATION | SUMMER | AUTUMN | WINTER | SPRING | YEAR |
|---|---|---|---|---|---|
| Tauranga Airport | 48 | 33 | 28 | 34 | 18 |
| Rotoehu Forest | 44 | 42 | 24 | 31 | 20 |
| Whakatane | 36 | 42 | 27 | 32 | 19 |
| Whakarewarewa | 43 | 40 | 26 | 28 | 19 |
| Waiotapu Forest | 40 | 38 | 28 | 28 | 19 |
| Matahina | 37 | 38 | 31 | 32 | 20 |
| Kaingaroa Forest | 38 | 40 | 26 | 30 | 19 |
| Minginui Forest | 37 | 35 | 26 | 27 | 14 |
| Opotiki | 39 | 42 | 30 | 32 | 20 |
| New Plymouth | 38 | 31 | 25 | 25 | 16 |
| Auckland | 46 | 37 | 27 | 28 | 19 |
| Gisborne | 37 | 39 | 33 | 45 | 20 |
| Wellington | 40 | 30 | 27 | 27 | 17 |
| Christchurch | 41 | 44 | 41 | 42 | 22 |
| Greymouth | 31 | 26 | 23 | 22 | 13 |

* The figures shown are the percentage values of the coefficient of variation, i.e. the standard deviation divided by the mean. Large figures indicate greater variability.

TABLE 3: RAINFALL DEPTH-DURATION-FREQUENCY RELATIONS.
(Units - mm.)

Tauranga

| Duration | | 10min | 20min | 30min | 1hr | 2hr | 6hr | 12hr | 24hr | 48hr | 72hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Return Period (years) | 2 | 12 | 19 | 23 | 32 | 44 | 70 | 90 | 108 | 125 | 137 |
| | 5 | 18 | 28 | 36 | 51 | 71 | 104 | 124 | 143 | 167 | 181 |
| | 10 | 22 | 35 | 45 | 64 | 88 | 126 | 147 | 166 | 195 | 210 |
| | 20 | 26 | 41 | 53 | 77 | 105 | 148 | 169 | 188 | 222 | 238 |
| | 50 | 31 | 49 | 64 | 93 | 127 | 176 | 198 | 217 | 257 | 275 |

Whakatane

| Duration | | 10min | 20min | 30min | 1hr | 2hr | 6hr | 12hr | 24hr | 48hr | 72hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Return Period (years) | 2 | 11 | 15 | 19 | 27 | 36 | 55 | 71 | 89 | 112 | 127 |
| | 5 | 13 | 20 | 25 | 38 | 55 | 78 | 95 | 114 | 150 | 170 |
| | 10 | 15 | 23 | 28 | 45 | 68 | 93 | 111 | 132 | 174 | 199 |
| | 20 | 17 | 25 | 32 | 52 | 80 | 108 | 127 | 148 | 198 | 226 |
| | 50 | 19 | 29 | 37 | 61 | 96 | 127 | 147 | 169 | 229 | 262 |

Whakarewarewa

| Duration | | 10min | 20min | 30min | 1hr | 2hr | 6hr | 12hr | 24hr | 48hr | 72hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Return Period (years) | 2 | 11 | 16 | 20 | 28 | 38 | 60 | 78 | 105 | 131 | 142 |
| | 5 | 14 | 21 | 27 | 38 | 52 | 85 | 108 | 146 | 173 | 187 |
| | 10 | 16 | 25 | 31 | 45 | 62 | 102 | 128 | 173 | 201 | 217 |
| | 20 | 18 | 28 | 36 | 52 | 72 | 118 | 147 | 199 | 228 | 246 |
| | 50 | 20 | 32 | 41 | 61 | 84 | 138 | 172 | 232 | 263 | 283 |

Table 3 (cont)

| Opotiki Duration | | 10min | 20min | 30min | 1hr | 2hr | 6hr | 12hr | 24hr | 48hr | 72hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Return Period (years) | 2 | 11 | 16 | 19 | 26 | 36 | 57 | 73 | 95 | 115 | 126 |
| | 5 | 16 | 24 | 27 | 38 | 53 | 81 | 102 | 132 | 160 | 179 |
| | 10 | 19 | 29 | 33 | 45 | 64 | 97 | 121 | 156 | 190 | 214 |
| | 20 | 22 | 34 | 39 | 52 | 75 | 112 | 139 | 180 | 219 | 248 |
| | 50 | 26 | 40 | 46 | 62 | 89 | 132 | 162 | 210 | 256 | 292 |

3.1.4 Extreme Short-Period Rainfalls. Coulter and Hessell (1980), using the theory of extreme values, have calculated depth-duration-frequency tables for a number of rainfall stations throughout New Zealand. Tabulations of these values for a selection of Bay of Plenty stations are reproduced in Table 3.

The intensity of rainfalls over various durations (10 minutes to 72 hrs) is given for return periods from 2 to 50 years. For example, at Tauranga, a 10-minute rainfall of 26mm can be expected, on average, once every twenty years, a 6-hr rainfall of 70mm once every two years and a 72-hr rainfall of 275mm can be expected once every 50 years.

Maximum 3-day rainfalls at various Bay of Plenty stations can be seen in Table 4.

TABLE 4: MAXIMUM 3-DAY RAINFALLS.

| | | |
|---|---|---|
| Katikati | 387mm | June 1946 |
| Kaimai School | 340mm | December 1928 |
| Tauranga Airport | 296mm | March 1979 |
| Te Puke | 363mm | March 1979 |
| Rotoehu Forest | 331mm | April 1974 |
| Whakatane | 235mm | April 1948 |
| Omaio Stores | 230mm | June 1970 |
| Rukuhanga Station | 304mm | March 1979 |
| Te Teko | 305mm | August 1970 |
| Whakarewarewa | 238mm | April 1974 |
| Kaingaroa Forest | 347mm | February 1944 |
| Minginui Forest | 192mm | January 1972 |
| Matahina | 295mm | July 1981 |
| Opotiki | 279mm | December 1974 |
| Oponae | 326mm | August 1967 |

3.1.5 Droughts and Dry Spells. Droughts can be defined as periods of 15 days or more with no rain, and dry spells as periods of 15 days or more with less than 1mm of rain on any day.

Both droughts and dry spells are common in the Bay of Plenty, with an average of 1 drought and 2 dry spells each year at most stations. These frequencies are similar to those recorded in other eastern parts of New Zealand, while droughts and dry spells in the Bay of Plenty are about twice as frequent as they are at Auckland.

The meteorological situation associated with the prolonged dry spell during February and March 1983 is described in Section 2.6.

3.2 Thunder, Hail and Tornadoes. Table 5 shows the frequency of thunder and hail at stations in the Bay of Plenty, and in other parts of New Zealand for comparison.

While both of these phenomena may occur in any month, thunderstorms are most frequent during summer and hail is more likely during winter. Thunder and hail both occur more frequently in and near the high country than in other parts of the region.

Occasionally (probably once every two or three years) severe hailstorms occur in the Bay of Plenty. Severe hailstorms are defined as storms where hailstones with a long-axis length of at least 0.5cm are reported. Neale (1977) has documented 16 reports of severe hail in the Bay of Plenty region since 1967. Severe hail has been reported from most parts of the region but storms may easily pass undetected in sparsely populated areas.

Tomlinson and Nicol (1976) collated reports of tornadoes around New Zealand between 1961 and 1975. Of 236 reported tornadoes, 21 (9%) occurred in the Bay of Plenty. New Zealand tornadoes, which are generally much smaller than those occurring in the USA, typically have a damage path 10 to 30 metres wide and one to five kilometres long.

On 31st March 1984 a tornado struck the Tauranga suburb of Otumoetai damaging some 40 homes. Roofs were torn off, windows smashed and trees uprooted.

TABLE 5: FREQUENCY OF (a) HAIL AND (b) THUNDER (number of days).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tauranga Airport | | | | | | | | | | | | | |
| a | 0.7 | 0.3 | 0.4 | 0.3 | 0.8 | 0 | 0.3 | 0.3 | 0.3 | 0.5 | 0.4 | 0.5 | 4.8 |
| b | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0 | 0.2 | 0 | 0.2 | 0.2 | 0.1 | 0.9 |
| Te Puke | | | | | | | | | | | | | |
| a | 1.8 | 0.6 | 0.1 | 0.6 | 1.0 | 0.5 | 0.8 | 1.0 | 1.0 | 1.3 | 0.9 | 1.9 | 11.5 |
| b | 0 | 0 | 0 | 0.1 | 0.1 | 0 | 0.6 | 0.5 | 0.3 | 0.4 | 0.1 | 0.4 | 2.5 |
| Rotoehu Forest | | | | | | | | | | | | | |
| a | 0 | 0 | 0 | 0 | 0.1 | 0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.9 |
| b | 0.3 | 0 | 0.2 | 0.1 | 0.2 | 0 | 0.1 | 0.2 | 0.3 | 0.2 | 0.3 | 0.1 | 2.0 |
| Whakatane Airport | | | | | | | | | | | | | |
| a | 1.3 | 1.0 | 0.8 | 0.7 | 0.7 | 0.2 | 0.2 | 0.8 | 1.3 | 0.3 | 0.8 | 1.6 | 9.7 |
| b | 0 | 0 | 0 | 0.2 | 0.2 | 0 | 0 | 0 | 0.7 | 0 | 0.2 | 0.1 | 1.4 |
| Whakarewarewa | | | | | | | | | | | | | |
| a | 1.1 | 0.6 | 0.7 | 0.4 | 0.5 | 0.3 | 0.2 | 0.2 | 0.6 | 1.0 | 0.8 | 1.8 | 8.2 |
| b | 0.2 | 0 | 0.1 | 0 | 0.1 | 0.1 | 0.3 | 0.5 | 0.4 | 0.4 | 0.2 | 0.3 | 2.6 |
| Murupara | | | | | | | | | | | | | |
| a | 1.9 | 0.7 | 0.6 | 0.1 | 0.1 | 0 | 0 | 0 | 0.3 | 0.4 | 0.5 | 1.5 | 6.1 |
| b | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0 | 0.6 | 0.5 | 1.4 |
| Auckland | | | | | | | | | | | | | |
| a | 0.8 | 0.6 | 0.4 | 0.9 | 0.8 | 1.0 | 1.2 | 0.9 | 1.0 | 0.8 | 1.0 | 1.1 | 10.5 |
| b | 0 | 0 | 0 | 0.1 | 0.3 | 0.8 | 0.8 | 0.8 | 0.8 | 0.5 | 0.3 | 0.2 | 4.6 |
| Wellington | | | | | | | | | | | | | |
| a | 0.4 | 0.3 | 0.3 | 0.3 | 0.5 | 0.5 | 0.3 | 0.3 | 0.4 | 0.3 | 0.5 | 0.5 | 4.6 |
| b | 0.1 | 0.1 | 0.3 | 0.3 | 1.2 | 1.6 | 2.1 | 1.3 | 1.3 | 0.9 | 0.5 | 0.3 | 10.0 |
| Christchurch | | | | | | | | | | | | | |
| a | 0.4 | 0.1 | 0.2 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0.1 | 0 | 0.2 | 0.2 | 1.5 |
| b | 0.3 | 0.1 | 0.2 | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 0.6 | 0.4 | 0.4 | 0.3 | 4.5 |
| New Plymouth | | | | | | | | | | | | | |
| a | 0.8 | 0.6 | 0.8 | 1.5 | 1.9 | 1.6 | 1.6 | 1.6 | 1.0 | 0.8 | 1.2 | 1.5 | 14.9 |
| b | 0.1 | 0 | 0.1 | 0.4 | 0.6 | 1.3 | 1.5 | 1.1 | 0.9 | 0.7 | 0.7 | 0.4 | 7.8 |
| Gisborne | | | | | | | | | | | | | |
| a | 0.4 | 0.1 | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 | 0.5 | 0.5 | 0.5 | 3.5 |
| b | 1.3 | 0.3 | 0.7 | 0.6 | 0.5 | 0.1 | 0.3 | 0.2 | 0.5 | 0.7 | 1.2 | 1.2 | 7.6 |

## 3.3 Snow

Snow is rare in most parts of the Bay of Plenty and is unknown near the coast. Several snowfalls occur each winter on the high country of the Raukumara and Huiarau Ranges and an average of one fall per year has been recorded at the Kaingaroa Forest. The Rotorua area records, on average, one snowfall every three years.

## 3.4 Wind

Although the prevailing windflow over northern New Zealand is west to southwesterly, winds over the Bay of Plenty region are modified by the local topography. Because of the sheltering provided by high country to the west, south and east, the Bay of Plenty lowlands experience considerably less wind than many other parts of the country.

Gales are infrequent but do occasionally occur, mostly from the northeast or southwest. Gusts of 34kt or more are recorded on an average of 30 days per year and gusts over 51kt occur on an average of one day per year. The highest gusts recorded at stations in the region are shown in Table 6. Strong winds occur more frequently near the coast and about the ranges than elsewhere.

TABLE 6: HIGHEST GUSTS RECORDED AT VARIOUS STATIONS.

| Station | Maximum gust (kt) | Direction | Date |
|---|---|---|---|
| Tauranga Airport (1942-83) | 64 | SW | 15.4.69 |
| Whakatane Airport (1959-83) | 79 | E | 10.4.68 |
| Rotorua Airport (1965-83) | 61 | SSE | 9.4.82 |

The mean hourly wind speed at Tauranga (9kt) is similar to that at Auckland but stronger than at Christchurch (8kt) and Dunedin (7kt). The mean hourly wind speed at Rotorua (6kt), however, is one of the lowest in the country (Nelson and Hokitika also have mean wind speeds of 6kt).

Wind roses (mean annual frequency of wind speed and direction) for sites in the Bay of Plenty are shown on Fig. 16. Winds from the west and southwest prevail at Mt Te Aroha (elev. 951m) and at Tauranga, while in the eastern Bay of Plenty, at

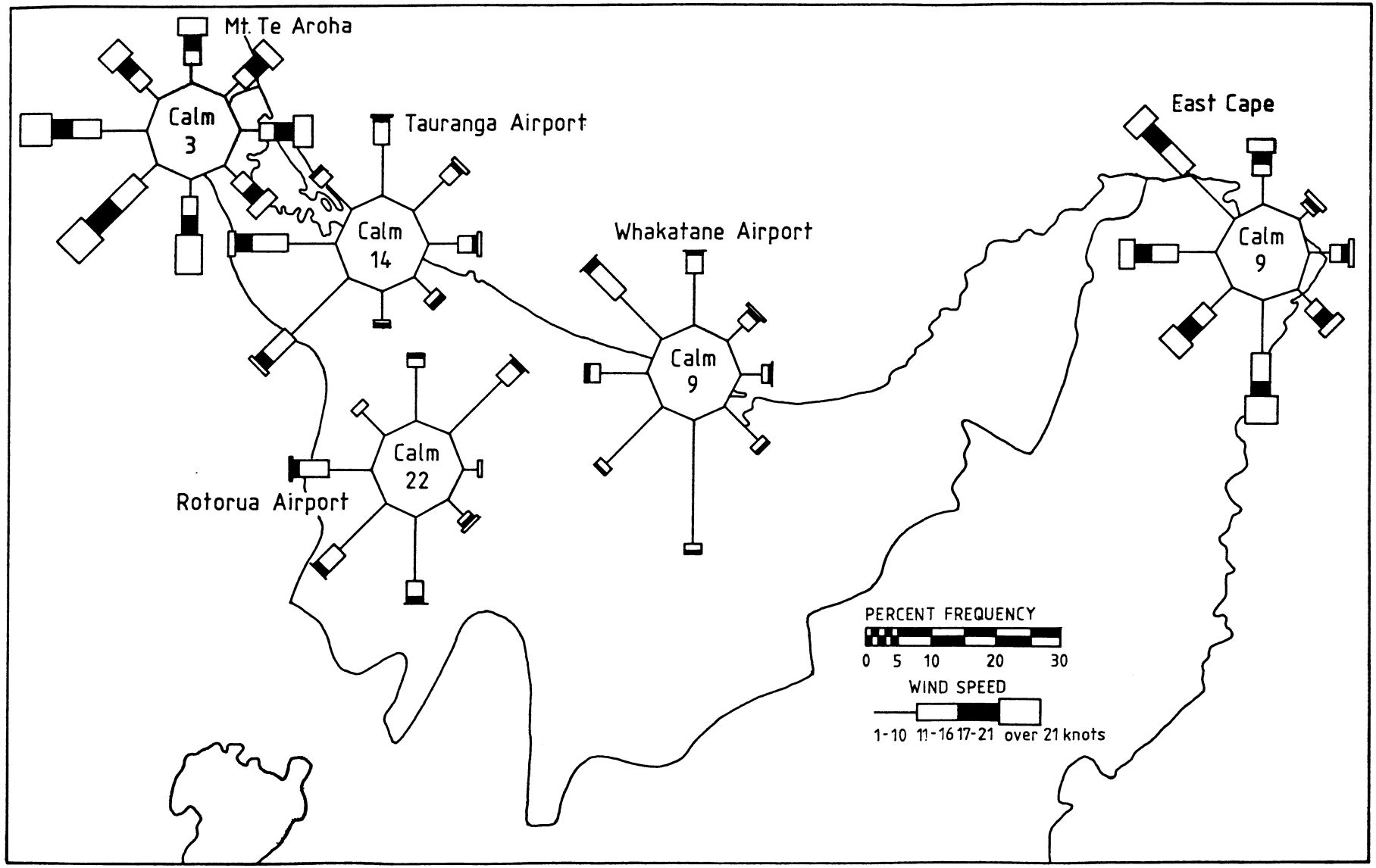



Fig. 16: Mean annual frequency of wind speed and direction.

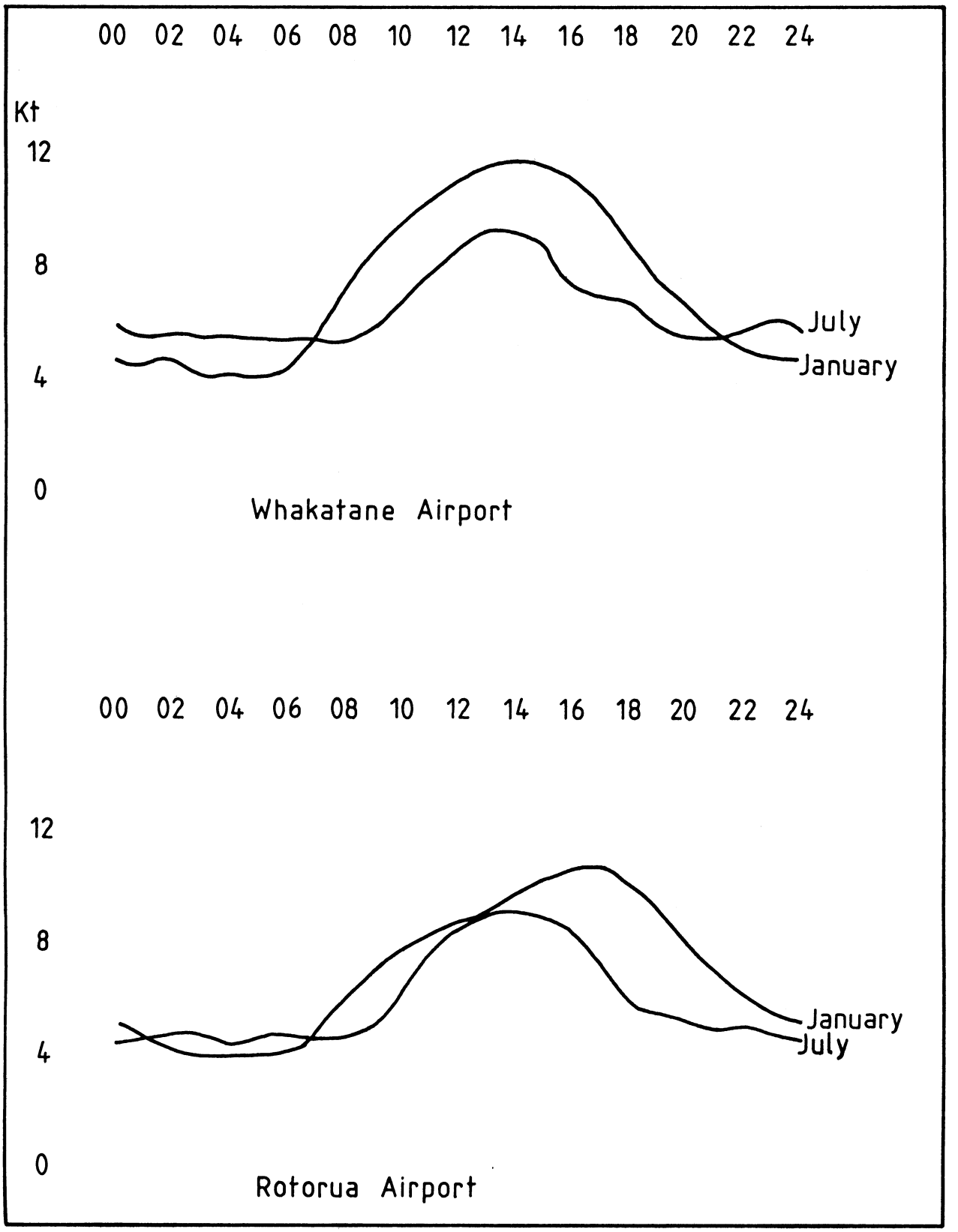



Fig. 17: Diurnal variation of wind speed.

Whakatane and East Cape, northwesterly and southerly winds are the most frequent. At Rotorua the prevailing wind is northeasterly, but winds from between south and west are also common.

As in other parts of New Zealand spring and summer are the windiest seasons, although the variation of mean wind speed between seasons is not large-ranging, from 33% at Tauranga to 21% at Rotorua. There is a marked diurnal variation of wind speed, especially in summer when areas near the coast experience onshore sea breezes during the afternoon as a result of the differential heating of the land and sea. Although the diurnal variation inland is smaller it is still significant during the summer, probably due to the formation of low pressure areas over the North Island on warm days, and the subsequent development of "afternoon breezes". Mean hourly wind speeds for Tauranga, Whakatane and Rotorua Airports are shown in Fig. 17.

When pressure gradients are weak on fine summer days, northerly sea breezes of 10 to 15kt develop in many coastal areas and there is evidence to suggest that on some occasions the sea breezes penetrate inland for considerable distances. At night, especially on clear nights, coastal areas experience light winds from the southerly quarter as a result of the drainage of cool air from inland. This effect is also noticeable in some inland places, but directions are more variable due to the rather complex topography. Generally, however, inland areas experience very light winds during most clear nights.

## 3.5 Temperature

Because New Zealand has a relatively small land area and is surrounded by a vast area of ocean, seasonal and diurnal temperature variations are relatively small. However, the Bay of Plenty does have larger variations than many other parts of the country. Because of the prevailing west to southwest flow over the North Island the Bay of Plenty experiences warm foehn winds quite frequently. Average daily maximum temperatures over 20°C are recorded over most of the region during the months December to March and most places have recorded temperatures over 30°C on at least one occasion. The highest temperature so far recorded in the Bay of Plenty is 38.1°C, at Te Teko on 7th February 1973. Inland areas in particular are subject to cold night-time temperatures during winter, especially when clear skies permit rapid radiational cooling. Air temperatures below 0°C are recorded in most parts of the region each winter. The coldest air temperature recorded in the Bay of Plenty to date is -9.4°C, at Kaingaroa Forest on 9th July 1960.

Statistics of the temperature regime are shown in Fig. 18. Temperature normals for the period 1951 to 1980, and the average daily temperature range for selected stations, are shown in Table 7.

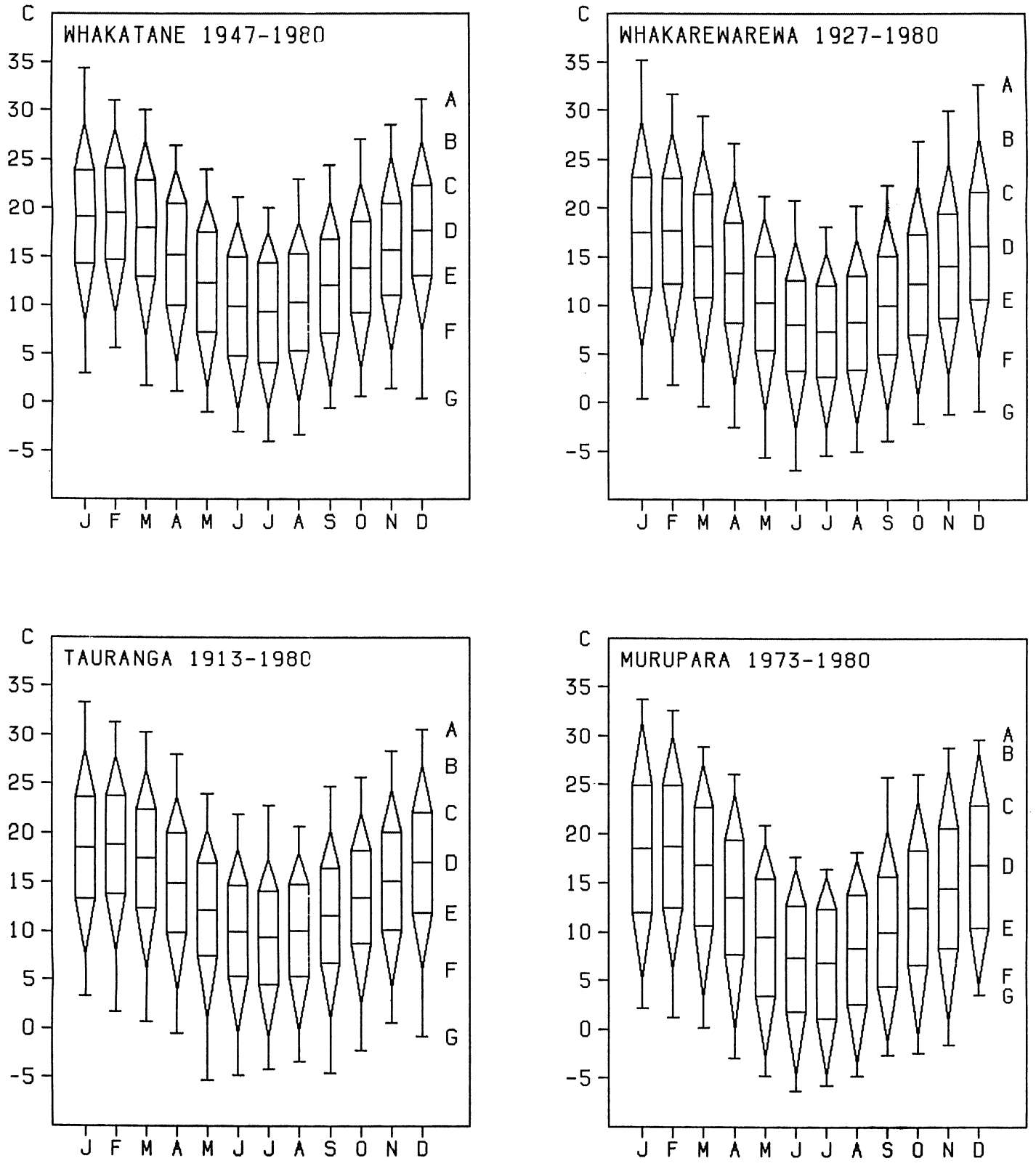



Fig. 18: Monthly temperature statistics.

TABLE 7: MEAN DAILY TEMPERATURE NORMALS (1951-1980)(a) and MEAN DAILY RANGE (b). (Degrees C).
(Stations are arranged in approximate geographic order, NW to SE).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mt Te Aroha | | | | | | | | | | | | | |
| a | 12.9 | 13.5 | 12.0 | 9.1 | 6.7 | 5.2 | 4.0 | 4.6 | 5.7 | 7.5 | 9.6 | 11.3 | 8.5 |
| b | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tauranga Airport | | | | | | | | | | | | | |
| a | 18.9 | 19.3 | 17.8 | 15.3 | 12.4 | 10.2 | 9.4 | 10.4 | 11.8 | 13.6 | 15.4 | 17.4 | 14.3 |
| b | 10.3 | 9.9 | 10.0 | 10.1 | 9.5 | 9.4 | 9.6 | 9.5 | 9.7 | 9.5 | 9.9 | 10.2 | 9.8 |
| Te Puke | | | | | | | | | | | | | |
| a | 18.4 | 18.9 | 17.5 | 14.9 | 11.9 | 9.8 | 9.0 | 10.0 | 11.6 | 13.3 | 15.1 | 16.8 | 13.9 |
| b | 10.6 | 10.3 | 9.8 | 9.5 | 9.5 | 8.5 | 8.9 | 8.8 | 9.0 | 9.7 | 9.9 | 10.2 | 9.5 |
| Rotoehu Forest | | | | | | | | | | | | | |
| a | 17.9 | 18.2 | 16.7 | 14.0 | 10.8 | 8.6 | 7.9 | 9.0 | 10.7 | 12.6 | 14.5 | 16.5 | 13.1 |
| b | 11.3 | 10.9 | 11.1 | 11.3 | 11.1 | 11.0 | 11.1 | 10.9 | 11.3 | 10.9 | 11.1 | 10,9 | 11.1 |
| Edgecumbe | | | | | | | | | | | | | |
| a | 18.6 | 19.0 | 17.5 | 14.9 | 11.9 | 9.6 | 8.9 | 9.9 | 11.5 | 13.5 | 15.4 | 17.1 | 14.0 |
| b | 10.0 | 10.0 | 9.7 | 10.4 | 10.7 | 10.1 | 10.4 | 10.0 | 10.2 | 10.1 | 9.9 | 10.1 | 10.1 |
| Whakatane | | | | | | | | | | | | | |
| a | 19.3 | 19.5 | 18.1 | 15.4 | 12.3 | 9.9 | 9.2 | 10.4 | 12.0 | 13.9 | 15.8 | 17.8 | 14.5 |
| b | 9.6 | 9.4 | 9.9 | 10.5 | 10.3 | 10.2 | 10.3 | 10.0 | 9.7 | 9.4 | 9.5 | 9.2 | 9.8 |
| Kawerau | | | | | | | | | | | | | |
| a | 19.5 | 19.7 | 18.1 | 15.3 | 12.0 | 9.7 | 9.0 | 10.1 | 11.9 | 14.0 | 16.0 | 17.9 | 14.4 |
| b | 11.7 | 11.4 | 11.3 | 11.4 | 10.8 | 10.7 | 10.8 | 10.5 | 10.9 | 11.1 | 11.4 | 11.0 | 11.1 |
| Te Teko | | | | | | | | | | | | | |
| a | 19.2 | 19.4 | 17.9 | 15.1 | 11.9 | 9.5 | 9.0 | 10.0 | 11.6 | 13.6 | 15.6 | 17.7 | 14.2 |
| b | 12.4 | 12.1 | 12.0 | 12.0 | 11.6 | 10.8 | 10.8 | 10.9 | 11.4 | 11.9 | 12.0 | 11.7 | 11.6 |
| Whakarewarewa | | | | | | | | | | | | | |
| a | 17.6 | 17.9 | 16.3 | 13.5 | 10.4 | 8.1 | 7.4 | 8.5 | 10.2 | 12.3 | 14.1 | 16.1 | 12.7 |
| b | 11.4 | 10.9 | 10.6 | 10.3 | 9.7 | 9.4 | 9.4 | 9.7 | 10.1 | 10.3 | 10.7 | 11.0 | 10.3 |
| Rotorua Airport | | | | | | | | | | | | | |
| a | 17.6 | 17.8 | 16.3 | 13.5 | 10.4 | 8.1 | 7.3 | 8.5 | 10.2 | 12.1 | 14.0 | 16.0 | 12.7 |
| b | 10.4 | 10.4 | 9.7 | 9.6 | 9.1 | 9.0 | 8.9 | 8.6 | 8.7 | 9.4 | 9.5 | 9.8 | 9.4 |
| Tarawera Forest | | | | | | | | | | | | | |
| a | 18.4 | 18.4 | 16.7 | 13.6 | 10.4 | 8.1 | 7.3 | 8.6 | 10.4 | 12.8 | 14.9 | 16.9 | 13.0 |
| b | 12.9 | 13.0 | 12.7 | 13.0 | 13.0 | 12.4 | 12.4 | 12.1 | 12.2 | 12.6 | 12.6 | 12.3 | 12.6 |
| Waiotapu Forest | | | | | | | | | | | | | |
| a | 16.5 | 16.8 | 15.2 | 12.3 | 9.2 | 6.8 | 5.9 | 7.3 | 9.2 | 11.2 | 13.1 | 15.0 | 11.5 |
| b | 13.8 | 13.7 | 13.6 | 13.1 | 12.1 | 11.4 | 11.3 | 11.8 | 12.5 | 12.5 | 13.0 | 13.1 | 12.6 |

Table 7 (cont)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atiamuri Power Station | | | | | | | | | | | | | |
| a | 17.8 | 18.0 | 16.0 | 13.0 | 10.0 | 7.6 | 6.6 | 8.0 | 9.8 | 12.0 | 14.0 | 16.2 | 12.4 |
| b | 12.7 | 13.0 | 12.3 | 11.3 | 10.3 | 9.6 | 10.6 | 10.2 | 10.2 | 10.7 | 11.2 | 11.7 | 11.2 |
| Kaingaroa Forest | | | | | | | | | | | | | |
| a | 16.3 | 16.5 | 14.8 | 11.7 | 8.7 | 6.3 | 5.5 | 6.7 | 8.5 | 10.7 | 12.6 | 14.7 | 11.1 |
| b | 11.5 | 11.2 | 10.9 | 10.3 | 9.4 | 9.0 | 8.9 | 9.3 | 10.0 | 10.5 | 10.8 | 11.1 | 10.3 |
| Broadlands | | | | | | | | | | | | | |
| a | 16.8 | 17.5 | 15.5 | 12.5 | 9.0 | 6.6 | 5.9 | 7.4 | 9.3 | 11.6 | 13.4 | 15.2 | 11.7 |
| b | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Minginui Forest | | | | | | | | | | | | | |
| a | 16.8 | 17.0 | 15.0 | 11.8 | 8.5 | 6.3 | 5.8 | 7.0 | 8.9 | 11.2 | 13.2 | 15.3 | 11.4 |
| b | 13.6 | 12.7 | 12.9 | 12.8 | 12.2 | 11.7 | 11.3 | 11.5 | 12.2 | 12.6 | 13.1 | 13.0 | 12.4 |
| Opotiki | | | | | | | | | | | | | |
| a | 18.5 | 18.9 | 17.7 | 15.2 | 12.3 | 9.9 | 9.2 | 10.2 | 11.5 | 13.4 | 15.1 | 17.0 | 14.1 |
| b | 8.7 | 8.4 | 9.2 | 9.9 | 9.9 | 9.9 | 10.1 | 9.6 | 9.5 | 8.7 | 8.9 | 8.5 | 9.3 |
| Waimana | | | | | | | | | | | | | |
| a | 18.6 | 18.8 | 17.3 | 14.2 | 10.8 | 8.4 | 7.7 | 9.0 | 11.0 | 13.3 | 15.1 | 17.1 | 13.4 |
| b | 11.3 | 11.1 | 11.4 | 12.3 | 12.9 | 12.4 | 12.8 | 11.8 | 11.3 | 11.3 | 11.0 | 10.8 | 11.7 |

## 3.6 Frosts

3.6.1 Air Frosts. Air frosts are defined as occasions when the air temperature in a standard meteorological screen falls below 0°C. In general, frosts are infrequent close to the moderating effects of the sea. They are more common in inland valleys where "ponding" of cold air occurs, and at high altitudes due to the decrease of temperature with height.

The average frequency of air frosts in the Bay of Plenty varies from about five per year near the coast to over 50 per year in many inland areas. The frostiest parts of the region are the Kaingaroa Plateau and the high country of the Raukumara Ranges and Urewera National Park. The mean annual frequency of air frosts is shown in Fig. 19 and the average dates of the first and last frosts are shown on Figs. 20a and b.

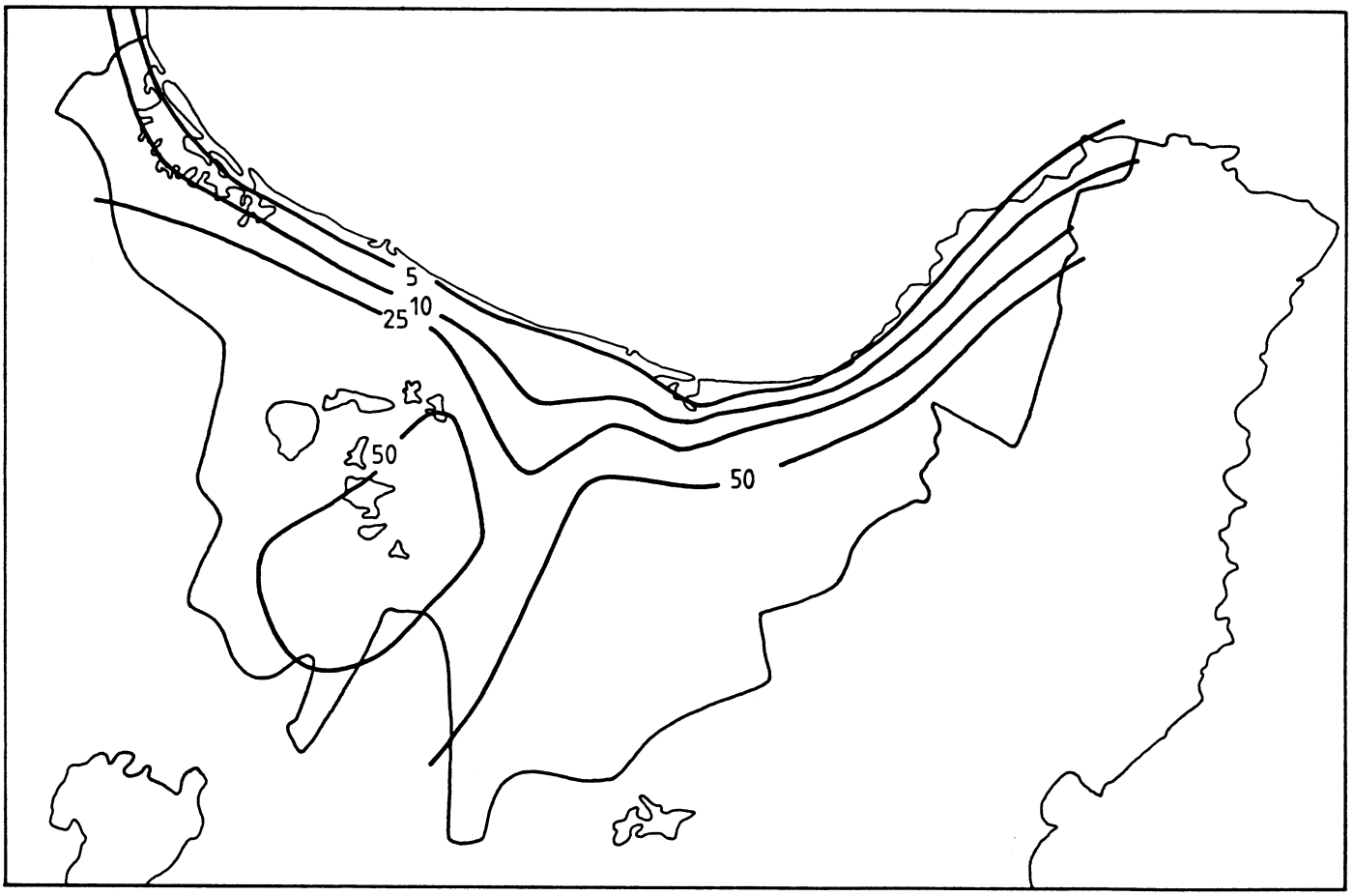



Fig. 19: Mean annual frequency of air frosts (days).

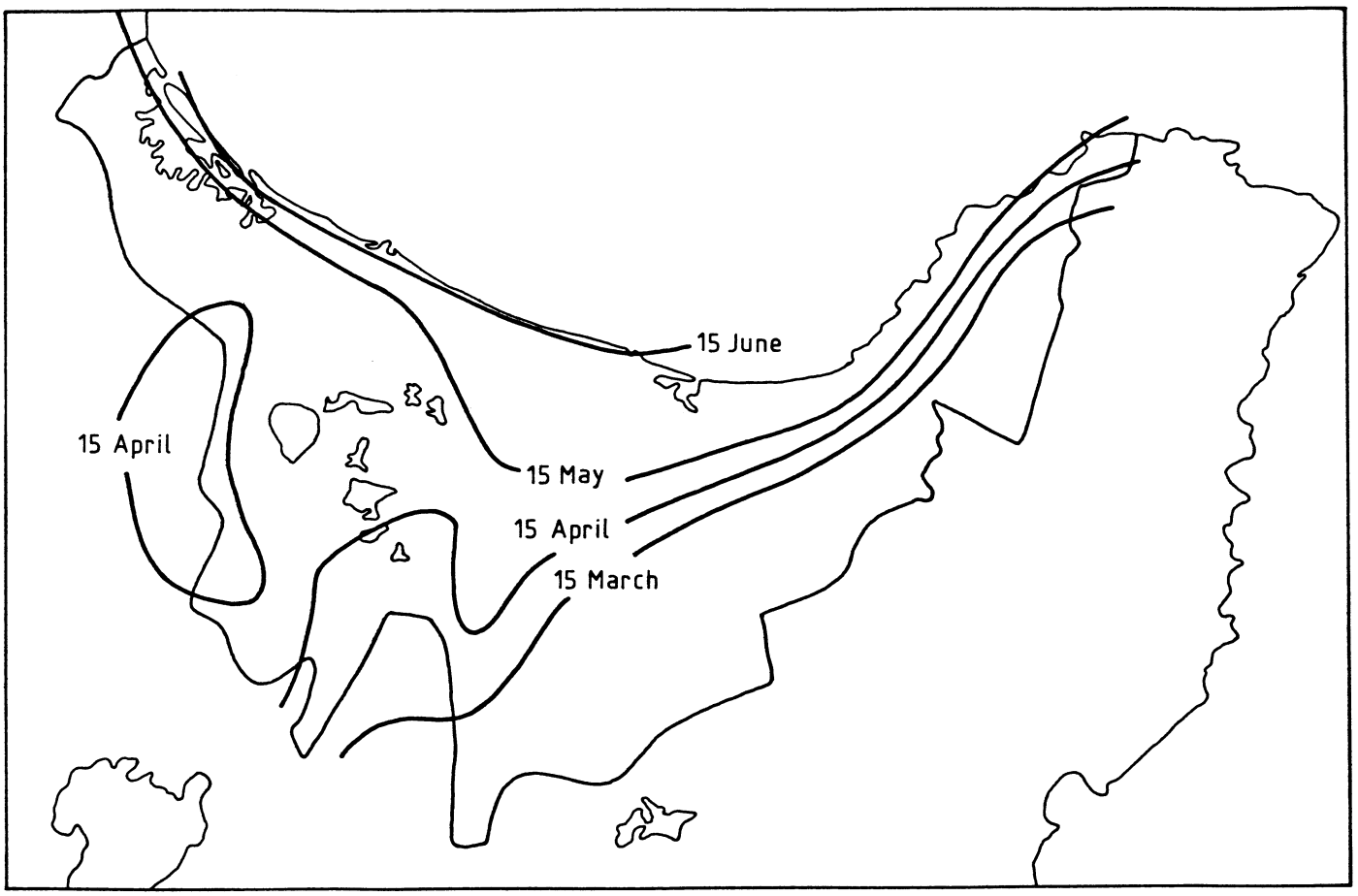



Fig. 20a: Average date of the first air frost.

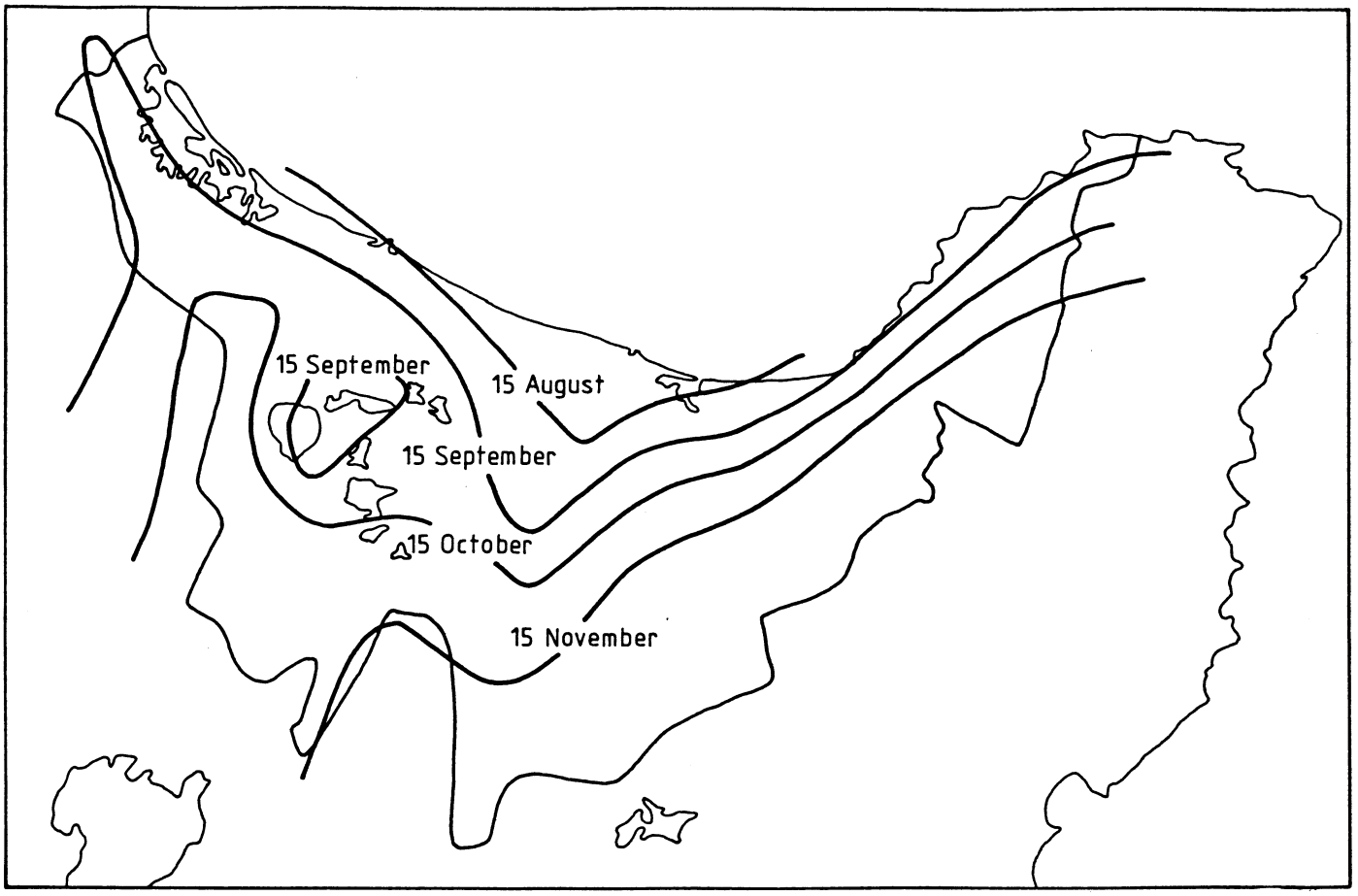



Fig. 20b: Average date of the last air frost.

3.6.2 Ground Frosts. Ground frosts, defined as occasions when the grass minimum temperature falls to -1.0°C or less, occur most frequently when clear skies permit rapid radiational cooling at night.

The distribution of ground frosts is similar to that of air frosts. Areas close to the coast generally have less than 50 ground frosts each year while many inland areas record ground frosts on an average of over 100 days per year. The average annual frequency of ground frosts is shown in Fig. 21.

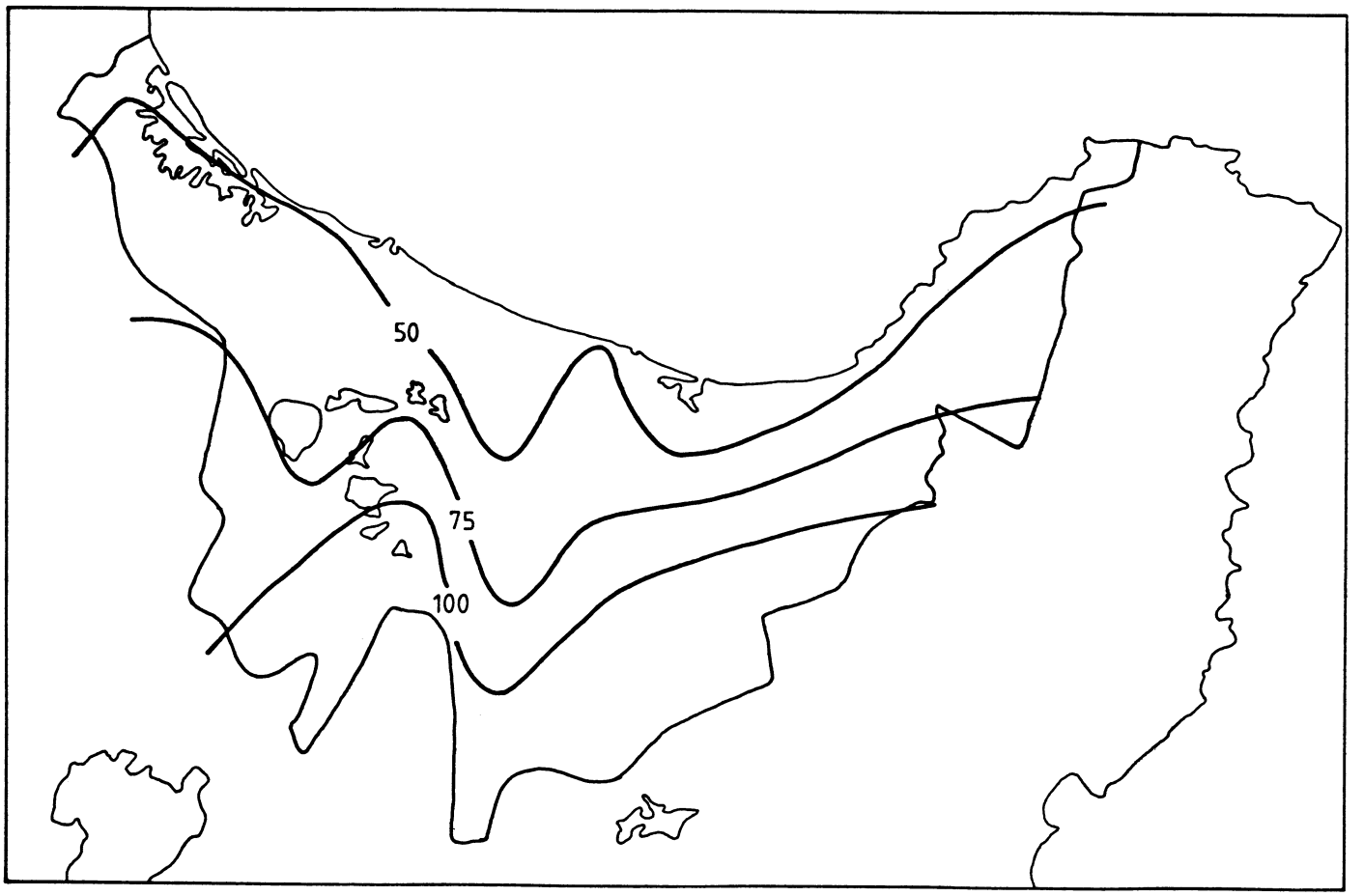



Fig. 21: Mean annual fequency of ground frosts (days).

## 3.7 Earth Temperatures

Soil temperatures have important effects on the germination of seeds and the growth of plants.

Temperatures at depths of 10cm, 30cm and 1m in the soil are measured daily at 9am by some climatological stations. The variability of earth temperatures is less than that of air temperatures and decreases with depth. Mean monthly and annual earth temperatures for the Bay of Plenty region can be seen in Table 8.

TABLE 8: MEAN ANNUAL AND MONTHLY EARTH TEMPERATURES.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tauranga Airport | | | | | | | | | | | | | |
| 10cm | 19.4 | 19.4 | 18.0 | 15.1 | 11.6 | 9.3 | 8.2 | 9.3 | 11.0 | 13.5 | 15.9 | 18.0 | 14.1 |
| Te Puke | | | | | | | | | | | | | |
| 10cm | 20.3 | 20.1 | 18.0 | 14.5 | 10.2 | 8.1 | 7.1 | 8.2 | 10.4 | 13.6 | 16.0 | 18.5 | 13.8 |
| 20cm | 21.6 | 21.8 | 20.1 | 17.0 | 13.2 | 10.6 | 9.4 | 10.3 | 12.1 | 14.9 | 17.5 | 19.9 | 15.7 |
| 1m | 18.8 | 19.7 | 19.6 | 18.5 | 16.4 | 14.1 | 12.3 | 11.7 | 12.3 | 13.7 | 15.5 | 17.3 | 15.8 |
| Edgecumbe | | | | | | | | | | | | | |
| 10cm | 20.1 | 20.3 | 18.1 | 14.7 | 10.7 | 8.2 | 7.2 | 8.4 | 10.6 | 13.8 | 16.5 | 18.5 | 13.9 |
| 30cm | 21.4 | 21.9 | 20.1 | 17.2 | 13.6 | 10.9 | 9.6 | 10.5 | 12.4 | 15.1 | 17.9 | 19.8 | 15.9 |
| Whakarewarewa | | | | | | | | | | | | | |
| 10cm | 18.9 | 18.8 | 16.8 | 13.6 | 10.2 | 7.7 | 6.3 | 7.3 | 9.6 | 12.5 | 15.1 | 17.3 | 12.8 |
| 30cm | 20.5 | 20.8 | 19.3 | 16.5 | 13.1 | 10.3 | 8.7 | 9.4 | 11.3 | 14.0 | 16.5 | 18.7 | 14.9 |

## 3.8 Fog

The most common type of fog in the Bay of Plenty is radiation fog, formed when the air cools to its dew-point on clear nights, allowing the water vapour in the air to condense. Coastal areas occasionally experience sea fogs, and extensive low cloud, with very moist onshore flows. Another type of fog sometimes seen in the region is "steaming fog". This forms, normally on cold nights, when the water vapour evaporating off lakes and rivers condenses as is rises into the cool air, giving the impression of steam rising off the water surface. Fogs also sometimes form when the humidity of the air near the ground has been raised by falling rain.

The frequency of fog in the region varies considerably. Many inland areas experience frequent fogs; for example Minginui has an average of 63 days each year with fog. On the other hand, fogs are rare at Kawerau, Te Teko and Rotoehu Forest, occurring on an average of 3 days at Kawerau and Te Teko and on only one

day per year at Rotoehu. Fogs at some inland places are sometimes slow to clear and may persist until early afternoon. High country areas experience frequent fogs, often because the ranges are enveloped in cloud.

## 3.9 Sunshine

The extensive sheltering from the prevailing winds provided by high country to the west, south and east of the Bay of Plenty, makes the region one of the sunniest parts of New Zealand - Whakatane (which records the highest sunshine total in the region) has an average of 2329 hours of bright sunshine per year, only slightly less than Blenheim (New Zealand's sunniest centre) which has an average annual sunshine total of 2447 hours.

Coastal parts of the region are the sunniest, receiving about 55% of the possible sunshine. Cloudiness increases inland and Whakarewarewa records only about 45% of the possible sunshine. Statistics of sunshine totals are shown in Fig. 22.

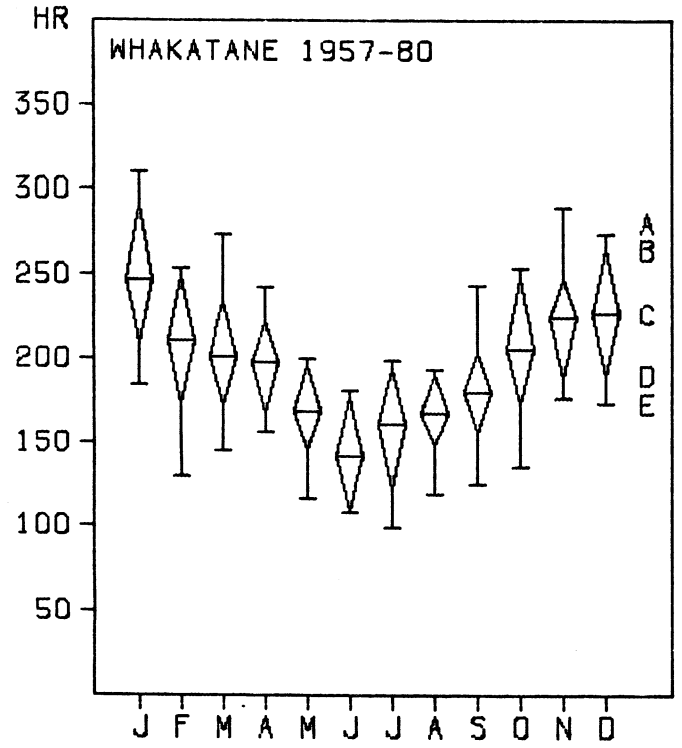
## 3.10 Solar Radiation

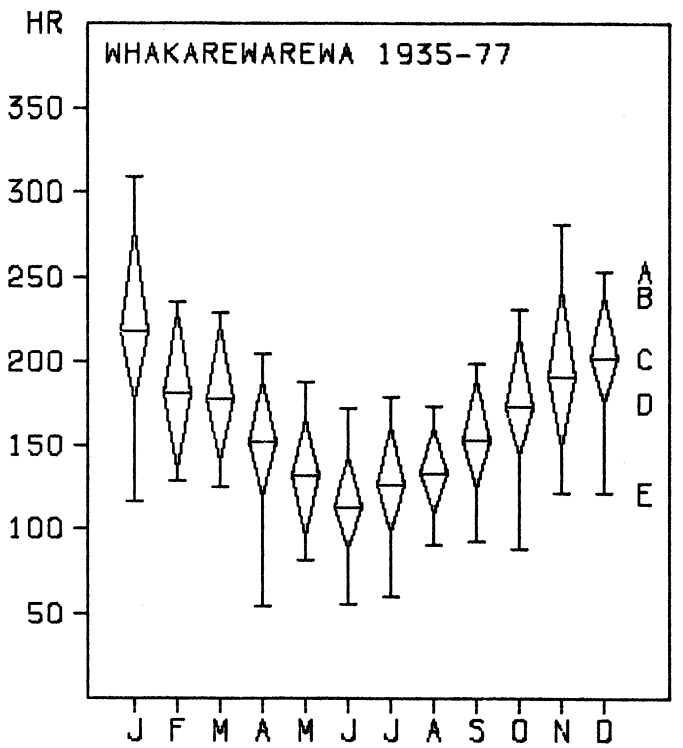
The only records of solar radiation available for the region are from Rotorua Airport. However, solar radiation values calculated from sunshine totals, using a regression equation developed by de Lisle, are available and are included in Table 9.

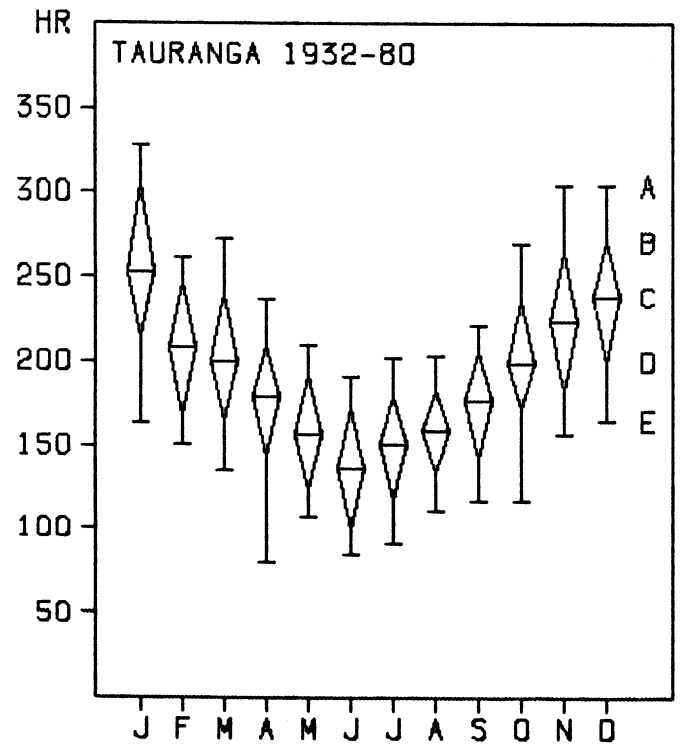
TABLE 9: MONTHLY AND ANNUAL SOLAR RADIATION (megajoules/sq. metre/day).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tauranga Airport* | 24.6 | 21.8 | 17.5 | 13.2 | 9.2 | 7.6 | 8.3 | 10.8 | 14.9 | 18.8 | 23.2 | 24.2 | 16.2 |
| Whakatane* | 24.8 | 22.2 | 18.0 | 13.7 | 9.4 | 7.8 | 8.5 | 11.2 | 15.4 | 19.4 | 23.4 | 24.1 | 16.5 |
| Te Teko* | 24.6 | 22.6 | 18.0 | 13.5 | 9.4 | 7.8 | 8.5 | 11.0 | 15.3 | 19.7 | 23.7 | 23.8 | 16.5 |
| Rotorua | 23.1 | 20.3 | 16.3 | 12.2 | 8.8 | 7.0 | 8.1 | 10.4 | 13.7 | 18.5 | 21.9 | 23.3 | 15.3 |
| Whakarewarewa* | 23.4 | 20.5 | 16.3 | 12.1 | 8.3 | 6.8 | 7.4 | 9.6 | 13.7 | 17.5 | 21.6 | 22.6 | 15.0 |
| Opotiki* | 23.4 | 20.5 | 16.3 | 12.1 | 8.3 | 6.8 | 7.4 | 9.6 | 13.7 | 17.5 | 21.6 | 22.6 | 15.0 |

* radiation calculated from sunshine records.



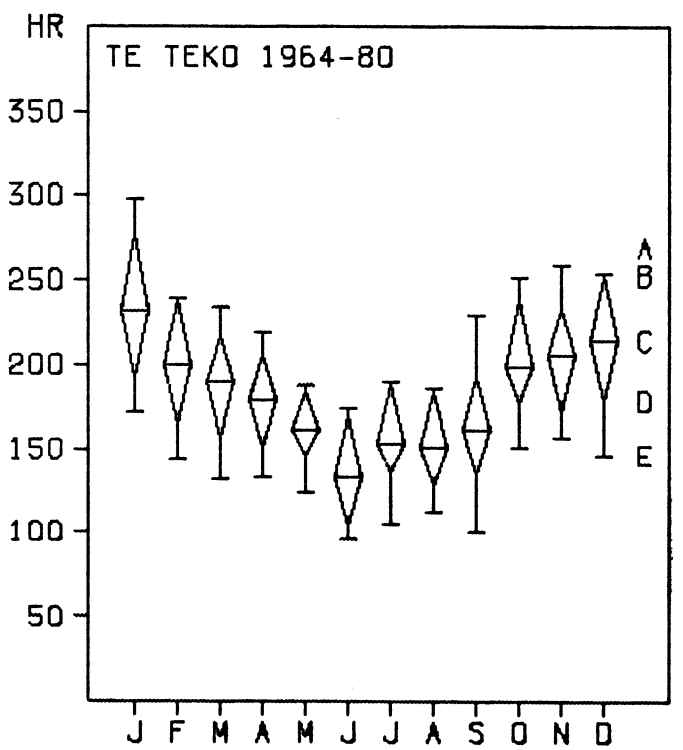




Fig. 22: Monthly sunshine statistics.

KEY
A: HIGHEST RECORDED
B: 90 PERCENTILE
C: MEAN
D: 10 PERCENTILE
E: LOWEST RECORDED

# 4. PARAMETERS DERIVED FROM OBSERVATIONS

## 4.1 Soil Water Balance

It is possible to estimate the amount of water available in the soil for plant growth, if the following assumptions are made:

1. That the soil has a fixed water capacity. A capacity of 75mm is often used.

2. That rainfall raises the soil water content until the maximum capacity is reached. Any further rain then becomes runoff.

3. Soil water is depleted by the combined effects of evaporation and plant transpiration. The combined effect of these processes is called "evapotranspiration".

4. When all of the available soil moisture has been depleted by evapotranspiration, a deficit is said to exist, i.e. there is insufficient moisture available for plant growth.

Soil water balance summaries for selected sites are shown in Table 10.

TABLE 10: DAILY SOIL WATER BALANCE SUMMARY.
(Soil moisture capacity = 75mm).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tauranga | | | | | | | | | | | | | |
| PE | 148 | 116 | 95 | 57 | 31 | 21 | 24 | 38 | 62 | 93 | 123 | 141 | 949 |
| RR | 85 | 94 | 116 | 123 | 129 | 140 | 132 | 129 | 108 | 117 | 89 | 101 | 1363 |
| DE | 70 | 47 | 24 | 4 | 0 | 0 | 0 | 0 | 0 | 3 | 23 | 49 | 220 |
| ND | 16 | 13 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 12 | 60 |
| RO | 8 | 20 | 32 | 48 | 82 | 116 | 108 | 93 | 54 | 44 | 11 | 17 | 633 |
| NR | 0 | 1 | 2 | 2 | 6 | 10 | 10 | 9 | 5 | 3 | 1 | 1 | 50 |
| Edgecumbe | | | | | | | | | | | | | |
| PE | 149 | 121 | 96 | 57 | 32 | 20 | 26 | 39 | 58 | 93 | 120 | 138 | 949 |
| RR | 101 | 93 | 141 | 114 | 131 | 138 | 89 | 182 | 164 | 115 | 77 | 102 | 1447 |
| DE | 56 | 59 | 21 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 26 | 47 | 211 |
| ND | 14 | 15 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 12 | 57 |
| RO | 18 | 9 | 61 | 37 | 80 | 112 | 65 | 141 | 115 | 46 | 12 | 10 | 706 |
| NR | 1 | 1 | 2 | 3 | 4 | 8 | 6 | 11 | 7 | 3 | 1 | 1 | 48 |
| Whakatane | | | | | | | | | | | | | |
| PE | 151 | 120 | 99 | 58 | 31 | 22 | 26 | 40 | 65 | 97 | 124 | 144 | 977 |
| RR | 83 | 104 | 122 | 105 | 135 | 129 | 132 | 127 | 100 | 105 | 88 | 105 | 1335 |
| DE | 69 | 50 | 25 | 5 | 1 | 0 | 0 | 0 | 0 | 3 | 26 | 46 | 225 |
| ND | 16 | 13 | 9 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 7 | 12 | 62 |
| RO | 4 | 19 | 41 | 33 | 80 | 106 | 108 | 88 | 46 | 31 | 12 | 16 | 584 |
| NR | 0 | 1 | 2 | 2 | 6 | 8 | 9 | 7 | 4 | 2 | 1 | 1 | 43 |

Table 10 (cont)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kawerau | | | | | | | | | | | | | |
| PE | 107 | 91 | 79 | 54 | 37 | 24 | 24 | 29 | 41 | 60 | 76 | 94 | 716 |
| RR | 115 | 148 | 169 | 129 | 183 | 160 | 171 | 180 | 154 | 136 | 99 | 157 | 1801 |
| DE | 17 | 20 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 45 |
| ND | 5 | 7 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 17 |
| RO | 45 | 63 | 90 | 67 | 131 | 133 | 146 | 152 | 116 | 88 | 37 | 66 | 1134 |
| NR | 2 | 2 | 3 | 4 | 6 | 8 | 9 | 10 | 7 | 6 | 2 | 4 | 63 |
| Whakarewarewa | | | | | | | | | | | | | |
| PE | 125 | 95 | 78 | 47 | 25 | 15 | 18 | 31 | 52 | 77 | 105 | 121 | 789 |
| RR | 107 | 104 | 108 | 120 | 138 | 137 | 129 | 131 | 118 | 127 | 104 | 116 | 1439 |
| DE | 35 | 25 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 17 | 97 |
| ND | 10 | 8 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 33 |
| RO | 22 | 26 | 36 | 53 | 101 | 120 | 111 | 101 | 72 | 59 | 25 | 23 | 749 |
| NR | 1 | 1 | 2 | 3 | 8 | 11 | 11 | 9 | 7 | 5 | 2 | 1 | 61 |

where PE is the potential evapotranspiration (mm)
RR is the rainfall (mm)
DE is the evapotranspiration deficit (mm)
ND is the number of days with deficit
RO is the runoff (water surplus) (mm)
NR is the number of days with runoff

Actual soil moisture capacity may differ from 75mm according to soil type, land aspect and vegetation cover.

Coastal areas record an average of about 60 days per year when a soil moisture deficit exists. Inland areas on the other hand have an average of only 20 to 30 such days. As would be expected deficits occur almost entirely during the summer months.

The average frequency of days with runoff varies from between 40 and 50 near the coast to around 60 inland.

## 4.2 Degree-Day Totals

Degree-day totals, the sum of daily departures of mean temperature (in deg C) from a specified base temperature, give an indication of the likely growth of plants and the heating and cooling requirements of buildings.

4.2.1 Growing Degree-Days. If other conditions for plant growth (rainfall, soil fertility etc) are favourable it can be assumed that plants will reach maturity when an appropriate number of degree-days above a specified base temperature have occurred. The mean frequency of growing degree-days for a site can therefore provide valuable information regarding the area's suitability for a certain crop.

Average growing degree-day totals are shown in Table 11.

TABLE 11: AVERAGE GROWING DEGREE-DAY TOTALS.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base 5°C | | | | | | | | | | | | | |
| Tauranga Airport | 422 | 392 | 391 | 300 | 226 | 154 | 137 | 161 | 198 | 264 | 309 | 378 | 3331 |
| Whakatane | 431 | 400 | 397 | 300 | 226 | 145 | 134 | 161 | 207 | 273 | 318 | 391 | 3383 |
| Te Teko | 431 | 395 | 391 | 291 | 217 | 133 | 128 | 152 | 192 | 260 | 312 | 384 | 3286 |
| Whakarewarewa | 378 | 353 | 341 | 246 | 168 | 94 | 80 | 104 | 150 | 220 | 267 | 338 | 2739 |
| Minginui Forest | 353 | 328 | 301 | 195 | 118 | 53 | 42 | 60 | 110 | 186 | 237 | 313 | 2296 |
| Base 10°C | | | | | | | | | | | | | |
| Tauranga Airport | 267 | 252 | 236 | 150 | 79 | 31 | 20 | 30 | 55 | 110 | 159 | 223 | 1613 |
| Whakatane | 276 | 260 | 242 | 150 | 79 | 27 | 19 | 30 | 62 | 119 | 168 | 236 | 1669 |
| Te Teko | 276 | 255 | 236 | 142 | 71 | 22 | 16 | 24 | 51 | 108 | 162 | 229 | 1591 |
| Whakarewarewa | 223 | 213 | 186 | 100 | 40 | 9 | 5 | 8 | 24 | 72 | 118 | 183 | 1180 |
| Minginui Forest | 198 | 188 | 147 | 61 | 18 | 3 | 1 | 2 | 12 | 49 | 93 | 159 | 931 |

4.2.2 Heating and Cooling Degree-Days. Cooling degree-days, computed in the same way as growing degree-days, can be used to calculate the air conditioning requirements of buildings. Similarly heating degree-days, calculated from accumulated departures below a threshold temperature, can be used to assess the heating requirements of homes and commercial buildings. The normal frequencies of heating and cooling degree-days in the Bay of Plenty region are shown in Tables 12 and 13.

TABLE 12: AVERAGE COOLING DEGREE-DAY TOTALS.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base 20°C | | | | | | | | | | | | | |
| Tauranga Airport | 9 | 12 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 29 |
| Whakatane | 11 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 36 |
| Te Teko | 13 | 14 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 40 |
| Whakarewarewa | 4 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 |
| Minginui Forest | 5 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 12 |

TABLE 13: AVERAGE HEATING DEGREE-DAY TOTALS.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base 10°C | | | | | | | | | | | | | |
| Tauranga Airport | 0 | 0 | 0 | 0 | 8 | 28 | 39 | 24 | 7 | 1 | 0 | 0 | 108 |
| Whakatane | 0 | 0 | 0 | 0 | 8 | 33 | 41 | 24 | 5 | 1 | 0 | 0 | 112 |
| Te Teko | 0 | 0 | 0 | 1 | 9 | 40 | 43 | 28 | 9 | 2 | 0 | 0 | 132 |
| Whakarewarewa | 0 | 0 | 0 | 4 | 28 | 69 | 85 | 60 | 24 | 7 | 1 | 0 | 278 |
| Minginui Forest | 0 | 0 | 2 | 16 | 58 | 117 | 134 | 108 | 54 | 18 | 6 | 1 | 514 |
| Base 20°C | | | | | | | | | | | | | |
| Tauranga Airport | 52 | 40 | 79 | 150 | 239 | 297 | 329 | 304 | 252 | 202 | 141 | 90 | 2174 |
| Whakatane | 45 | 35 | 74 | 150 | 239 | 306 | 332 | 304 | 243 | 192 | 132 | 79 | 2131 |
| Te Teko | 48 | 39 | 81 | 159 | 248 | 318 | 338 | 313 | 258 | 205 | 139 | 86 | 2231 |
| Whakarewarewa | 91 | 72 | 125 | 204 | 298 | 360 | 391 | 363 | 300 | 245 | 183 | 128 | 2759 |
| Minginui Forest | 115 | 96 | 165 | 255 | 350 | 414 | 443 | 415 | 342 | 279 | 213 | 153 | 3241 |

## 4.3 Vapour Pressure and Relative Humidity

The water vapour content of air can be expressed in several ways, the most commonly used being vapour pressure and relative humidity. Vapour pressure is that part of the total air pressure which results from the presence of water vapour. Relative humidity expresses the actual vapour pressure as a percentage of the saturation vapour pressure at the ambient temperature. Relative humidity is therefore normally highest in the morning at the time of the minimum temperature and lowest during the afternoon when temperatures are at their warmest. The moisture content of air varies according to the source of the air and its trajectory. Air from the tropics normally has a high moisture content (hence the heavy rain often associated with north to northeast airstreams) while air from the south is drier. The Bay of Plenty, with substantial sheltering from all directions except the north, experiences considerable variations of vapour pressure and of relative humidity. Air from the south must cross substantial areas of high country before reaching the region and therefore loses much of its moisture before reaching the Bay of Plenty.

The diurnal variation of relative humidity at Rotorua is shown in Table 14 and mean 9 am relative humidities for selected stations are shown in Table 15. It is immediately apparent that diurnal variations (due to changes in temperature) are considerably larger than seasonal variations.

TABLE 14: MEAN RELATIVE HUMIDITY (%) AT ROTORUA.

| Hour | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0000 | 88 | 88 | 89 | 90 | 90 | 90 | 90 | 90 | 89 | 88 | 88 | 89 |
| 0600 | 90 | 91 | 92 | 92 | 91 | 91 | 91 | 91 | 90 | 90 | 89 | 89 |
| 1200 | 63 | 63 | 66 | 68 | 72 | 75 | 74 | 73 | 68 | 66 | 64 | 64 |
| 1800 | 69 | 69 | 73 | 77 | 82 | 84 | 82 | 80 | 76 | 73 | 71 | 70 |

## 5. MARINE WEATHER CONDITIONS

The area of the Pacific Ocean which is bounded by the Bay of Plenty region is sheltered from the prevailing west to southwest swells of its latitude zone by the land mass of New Zealand. Consequently high waves are less frequent than in corresponding western areas. Similarly it is protected from the cool ocean currents induced by the prevailing westerly winds, but is influenced by the warm East Auckland Current which has a subtropical origin.

TABLE 15: MEAN 9AM VAPOUR PRESSURE (hPa) (a) AND RELATIVE HUMIDITY (%) (b).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tauranga Airport | | | | | | | | | | | | | |
| a | 16.0 | 16.5 | 15.6 | 13.8 | 11.8 | 10.1 | 9.5 | 10.2 | 11.1 | 12.3 | 13.4 | 14.9 | 12.9 |
| b | 71 | 73 | 76 | 80 | 82 | 83 | 84 | 82 | 77 | 74 | 72 | 72 | 77 |
| Te Puke | | | | | | | | | | | | | |
| a | 16.8 | 17.1 | 16.2 | 14.5 | 11.8 | 10.2 | 9.6 | 10.4 | 11.2 | 12.3 | 13.2 | 15.1 | 13.2 |
| b | 76 | 78 | 77 | 81 | 82 | 85 | 84 | 82 | 77 | 74 | 75 | 75 | 79 |
| Rotoehu Forest | | | | | | | | | | | | | |
| a | 16.1 | 16.8 | 15.9 | 13.9 | 11.5 | 9.4 | 8.9 | 10.0 | 11.0 | 12.0 | 13.1 | 14.7 | 12.8 |
| b | 72 | 76 | 80 | 86 | 88 | 89 | 89 | 86 | 77 | 73 | 71 | 71 | 80 |
| Whakatane | | | | | | | | | | | | | |
| a | 16.9 | 17.4 | 16.3 | 13.8 | 11.6 | 9.6 | 9.2 | 10.1 | 11.4 | 12.7 | 14.2 | 15.8 | 13.3 |
| b | 72 | 76 | 79 | 83 | 87 | 89 | 89 | 86 | 83 | 75 | 74 | 73 | 81 |
| Te Teko | | | | | | | | | | | | | |
| a | 17.5 | 17.3 | 17.2 | 14.1 | 11.1 | 9.5 | 9.2 | 10.2 | 12.1 | 13.5 | 14.8 | 16.7 | 13.6 |
| b | 75 | 76 | 83 | 85 | 87 | 88 | 89 | 87 | 84 | 78 | 83 | 81 | 83 |
| Whakarewarewa | | | | | | | | | | | | | |
| a | 14.6 | 15.2 | 14.2 | 12.2 | 10.3 | 8.8 | 8.3 | 8.9 | 9.8 | 10.9 | 11.9 | 13.4 | 11.5 |
| b | 75 | 78 | 80 | 84 | 87 | 87 | 88 | 85 | 80 | 76 | 74 | 74 | 87 |
| Kaingaroa Forest | | | | | | | | | | | | | |
| a | 13.9 | 14.2 | 13.5 | 11.9 | 9.4 | 8.1 | 7.8 | 8.3 | 9.2 | 10.2 | 11.2 | 12.6 | 10.9 |
| b | 76 | 79 | 81 | 85 | 87 | 87 | 87 | 85 | 83 | 77 | 74 | 75 | 81 |
| Murupara | | | | | | | | | | | | | |
| a | 15.3 | 15.8 | 14.6 | 12.6 | 9.7 | 8.4 | 8.0 | 8.9 | 10.1 | 11.5 | 12.4 | 14.2 | 11.8 |
| b | 77 | 81 | 80 | 88 | 92 | 92 | 92 | 88 | 82 | 77 | 77 | 78 | 84 |
| Minginui Forest | | | | | | | | | | | | | |
| a | 14.8 | 14.8 | 14.0 | 11.6 | 9.0 | 8.0 | 7.8 | 8.6 | 9.5 | 10.8 | 12.1 | 13.2 | 11.2 |
| b | 74 | 77 | 81 | 85 | 87 | 87 | 87 | 84 | 79 | 74 | 72 | 73 | 80 |

## 5.1 Sea Surface Temperatures

The east coast of the North Island from North Cape to East Cape, swept by the East Auckland current, has the warmest seas around New Zealand. Average sea surface temperatures range from around 14°C in August up to 20-21°C during February. The temperature of the sea exerts a considerable influence on air temperatures in coastal regions and this effect can be clearly seen in Fig. 23 which compares mean monthly sea surface temperatures in the Bay of Plenty with mean air temperatures at Tauranga and Rotorua. Note that temperatures at coastal locations such as Tauranga vary less than at inland sites like Rotorua.

5.2.2 Sea and Swell Waves. Sea and swell wave characteristics in the Bay of Plenty are determined by the area's exposure to the prevailing winds and by the sheltering provided by the North Island. Thus sea waves from the west are the most frequent (due to the prevailing westerly flow), while swells from the east and north predominate due to the long fetches available in those directions and the sheltering given by the North Island. The prevailing easterly flow over the Pacific Ocean to the north of New Zealand produces a persistent easterly swell in the latitude of northern New Zealand, especially during the summer and autumn when the belt of southeasterly trade winds tends to lie further south than in other seasons.

The sea and swell wave roses presented in Fig. 24 were obtained from analyses by Reid and Collen (N.Z. Met. Service 1983) using reports made by ships in a two-degree square centred at 37°S 177°E. A total of approximatly 1200 observations, made between 1975 and 1980, were used in the analyses for this square.

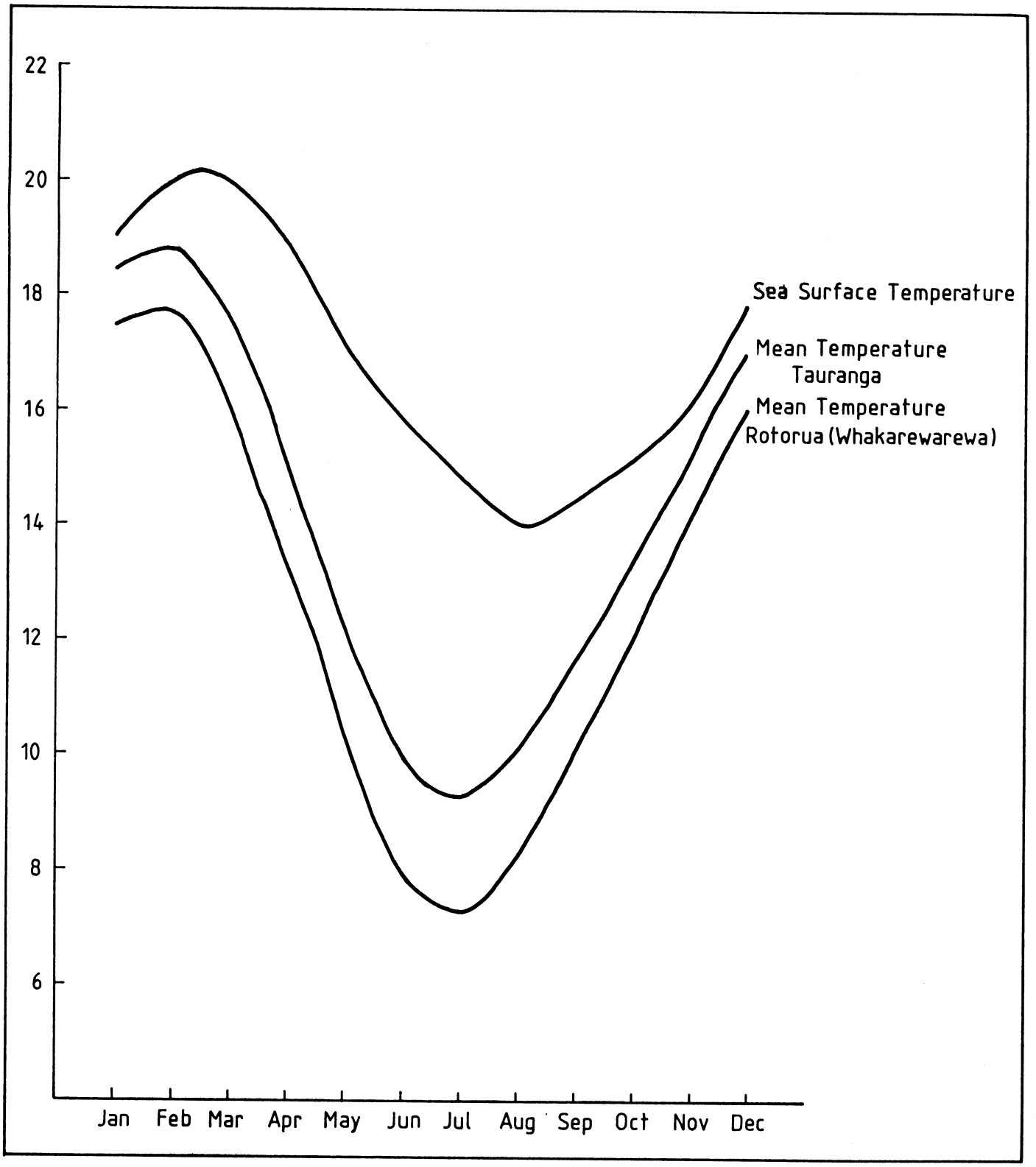



Fig. 23: Annual variation of mean air and sea surface temperatures.

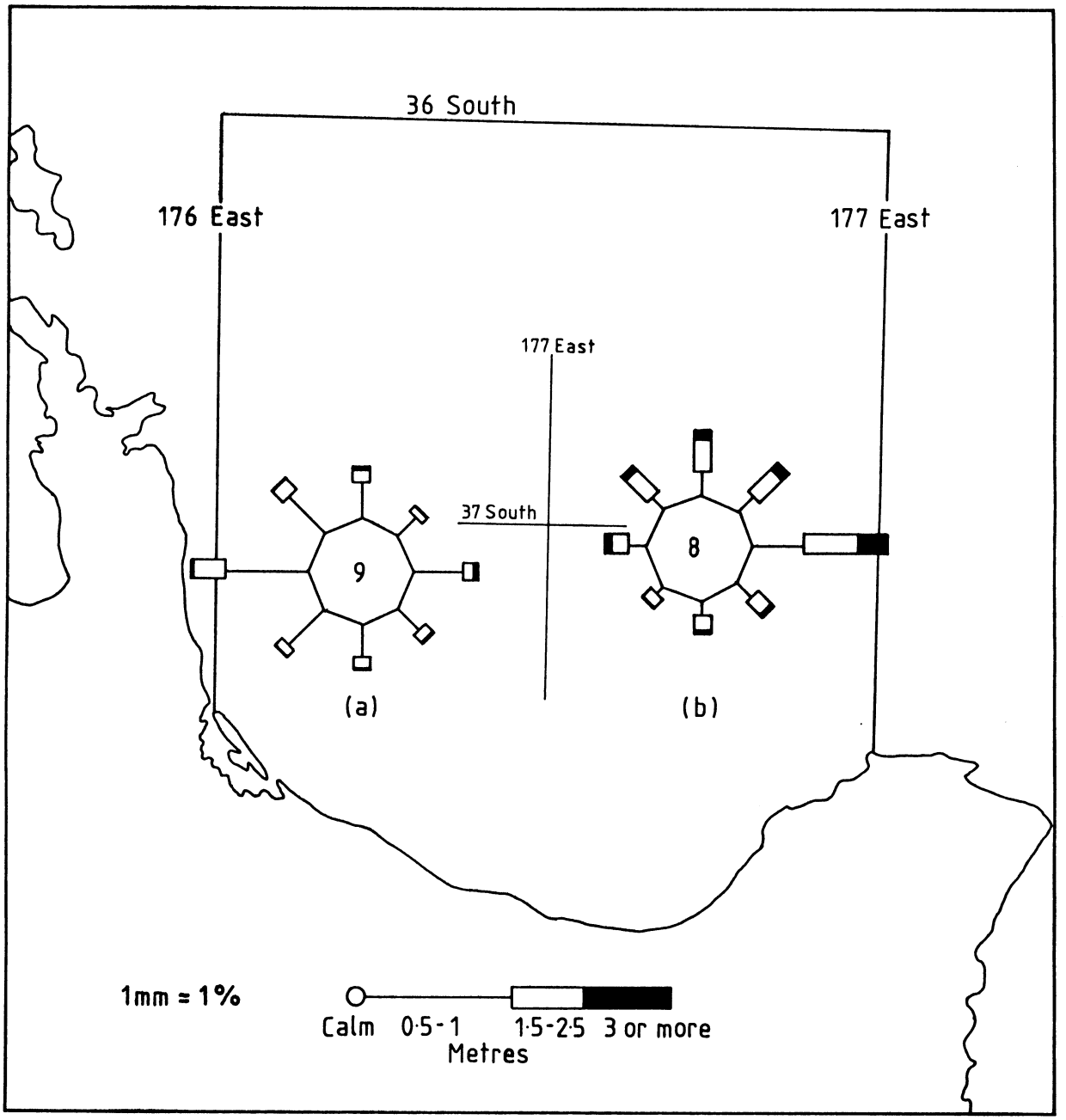



Fig. 24: Wind wave (a) and swell (b) roses based on ship reports in a 2-degree square centred on 37°S 177°E.

## 6. SUMMARY

The topography of the North Island has a profound effect on the weather of the Bay of Plenty region. The sheltering provided by high country on three sides produces a climate that is one of the sunniest and least windy in New Zealand. However, the mean annual rainfall is not less than for other parts of the country, although there is considerable rainfall variability. Most of the rainfall in the region, and especially heavy rain, occurs when northerly airstreams of tropical origin are forced to ascend over the land. Temperatures too are subject to considerable variability. The seas of the Bay of Plenty, because of the presence of a warm ocean current and sheltering provided by the North Island, are among the calmest and warmest in New Zealand.

## ACKNOWLEDGEMENTS

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# APPENDIX

## Climatological Tables

*B76621 **TAURANGA AIRPORT** GRID REFS. NZMS 1, 1 63360 N058675609 NZMS 260, 1 50000 U14924873 LAT. 37 40S LONG. 176 12E HT. 4 M.

| | PERIOD | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINFALL. MILLIMETRES | | | | | | | | | | | | | | |
| HIGHEST MONTHLY/ANNUAL TOTAL | 1898-1980 | 532 | 343 | 504 | 383 | 311 | 381 | 348 | 253 | 274 | 357 | 285 | 447 | 2049 |
| 90 PERCENTILE VALUE | 1898-1980 | 173 | 194 | 203 | 232 | 221 | 216 | 217 | 219 | 188 | 225 | 152 | 179 | 1730 |
| MEAN | 1898-1980 | 91 | 92 | 114 | 119 | 129 | 136 | 131 | 125 | 109 | 118 | 86 | 99 | 1349 |
| 10 PERCENTILE VALUE | 1898-1980 | 17 | 21 | 26 | 35 | 45 | 50 | 54 | 59 | 46 | 31 | 35 | 38 | 1047 |
| LOWEST MONTHLY/ANNUAL TOTAL | 1898-1980 | 1 | 7 | 5 | 10 | 13 | 19 | 2 | 14 | 16 | 11 | 14 | 4 | 772 |
| AVERAGE RAIN DAYS, 1.0MM OR MORE | 1941-1980 | 7 | 7 | 9 | 9 | 10 | 11 | 12 | 13 | 11 | 11 | 9 | 9 | 118 |
| MAXIMUM 1-DAY RAINFALL | 1910-1980 | 134 | 160 | 178 | 239 | 116 | 164 | 135 | 97 | 156 | 130 | 105 | 163 | 239 |
| MAXIMUM 2-DAY RAINFALL | 1910-1980 | 149 | 161 | 262 | 250 | 136 | 206 | 226 | 103 | 158 | 209 | 122 | 210 | 262 |
| TEMPERATURE OF THE AIR. DEGREES CELSIUS | | | | | | | | | | | | | | |
| HIGHEST RECORDED | 1913-1980 | 33.3 | 31.3 | 30.3 | 27.9 | 23.9 | 21.9 | 22.8 | 20.7 | 24.7 | 25.6 | 28.3 | 30.6 | 33.3 |
| AVERAGE MONTHLY/ANNUAL MAXIMUM | 1913-1980 | 28.4 | 27.7 | 26.3 | 23.6 | 20.3 | 18.3 | 17.3 | 17.9 | 20.2 | 22.0 | 24.3 | 26.8 | 29.2 |
| AVERAGE DAILY MAXIMUM | 1913-1980 | 23.6 | 23.7 | 22.4 | 20.0 | 16.9 | 14.7 | 14.1 | 14.8 | 16.4 | 18.2 | 20.1 | 22.1 | 18.9 |
| MEAN | 1913-1980 | 18.5 | 18.8 | 17.4 | 14.9 | 12.2 | 10.0 | 9.3 | 10.1 | 11.6 | 13.4 | 15.1 | 17.0 | 14.0 |
| AVERAGE DAILY RANGE | 1913-1980 | 10.3 | 9.9 | 10.0 | 10.1 | 9.5 | 9.4 | 9.6 | 9.5 | 9.7 | 9.5 | 9.9 | 10.2 | 9.8 |
| AVERAGE DAILY MINIMUM | 1913-1980 | 13.3 | 13.8 | 12.4 | 9.9 | 7.4 | 5.3 | 4.5 | 5.3 | 6.7 | 8.7 | 10.2 | 11.9 | 9.1 |
| AVERAGE MONTHLY/ANNUAL MINIMUM | 1913-1980 | 7.5 | 7.9 | 6.0 | 3.9 | 1.0 | -0.6 | -1.0 | -0.3 | 1.0 | 2.5 | 4.2 | 6.0 | -1.7 |
| LOWEST RECORDED | 1913-1980 | 3.3 | 1.7 | 0.7 | -0.6 | -5.3 | -4.8 | -4.2 | -3.4 | -4.6 | -2.3 | 0.6 | -0.9 | -5.3 |
| TEMPERATURE OF THE GROUND. DEGREES CELSIUS | | | | | | | | | | | | | | |
| LOWEST GRASS MINIMUM RECORDED | 1931-1980 | -2.7 | -2.3 | -5.1 | -5.7 | -8.9 | -9.4 | -9.4 | -9.4 | -8.1 | -6.7 | -6.1 | -3.9 | -9.4 |
| AVERAGE GRASS MINIMUM | 1931-1980 | 10.1 | 10.7 | 9.2 | 6.3 | 3.6 | 1.6 | 0.8 | 1.8 | 3.0 | 4.9 | 6.8 | 8.9 | 5.6 |
| AVERAGE AT 10 CM DEPTH | 1963-1980 | 19.4 | 19.4 | 18.0 | 15.1 | 11.6 | 9.3 | 8.2 | 9.3 | 11.0 | 13.5 | 15.9 | 18.0 | 14.1 |
| FROST. | | | | | | | | | | | | | | |
| AVERAGE DAYS OF GROUND FROST | 1941-1980 | 0.1 | 0.1 | 0.4 | 1.8 | 6.7 | 11.2 | 13.3 | 10.8 | 7.1 | 3.7 | 1.4 | 0.3 | 56.9 |
| AVERAGE DAYS OF AIR FROST | 1941-1980 | . | . | . | . | 0.4 | 1.6 | 2.3 | 0.8 | 0.2 | . | . | . | 5.3 |
| RELATIVE HUMIDITY. (%) | | | | | | | | | | | | | | |
| AVERAGE AT 9 A.M. | 1931-1980 | 71 | 73 | 76 | 80 | 82 | 83 | 84 | 82 | 77 | 74 | 72 | 72 | 77 |
| VAPOUR PRESSURE. MILLIBARS | | | | | | | | | | | | | | |
| AVERAGE AT 9 A.M. | 1941-1980 | 16.0 | 16.5 | 15.6 | 13.8 | 11.8 | 10.1 | 9.5 | 10.2 | 11.1 | 12.3 | 13.4 | 14.9 | 12.9 |
| SUNSHINE. TOTAL HOURS | | | | | | | | | | | | | | |
| HIGHEST | 1935-1980 | 328 | 261 | 272 | 237 | 209 | 191 | 202 | 203 | 220 | 268 | 304 | 304 | 2478 |
| MEAN | 1935-1980 | 252 | 208 | 200 | 178 | 157 | 136 | 151 | 159 | 176 | 199 | 223 | 238 | 2277 |
| % OF POSSIBLE | 1935-1980 | 58 | 57 | 54 | 56 | 53 | 50 | 52 | 50 | 52 | 51 | 55 | 54 | 54 |
| LOWEST | 1935-1980 | 163 | 151 | 135 | 80 | 107 | 84 | 91 | 111 | 117 | 116 | 157 | 164 | 1962 |
| WIND. | | | | | | | | | | | | | | |
| AVERAGE DAYS OF GUSTS OF | | | | | | | | | | | | | | |
| 63 KM/HR OR MORE | 1959-1980 | 1.8 | 1.1 | 1.9 | 2.5 | 3.3 | 3.5 | 3.6 | 3.3 | 3.8 | 4.0 | 3.1 | 2.1 | 34.0 |
| 96 KM/HR OR MORE | 1959-1980 | . | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | . | . | 0.3 | 0.1 | . | 1.1 |
| MEAN HOURLY WINDSPEED. KM/HR | 1970-1979 | 17 | 17 | 16 | 16 | 15 | 14 | 16 | 16 | 18 | 21 | 19 | 19 | 17 |
| SPECIAL PHENOMENA. AVERAGE DAYS OF | | | | | | | | | | | | | | |
| SNOW | 1972-1980 | . | . | . | . | . | . | . | . | . | . | . | . | . |
| HAIL | 1941-1980 | . | . | . | . | 0.1 | 0.1 | . | 0.2 | . | 0.2 | 0.2 | 0.1 | 0.9 |
| THUNDER | 1955-1980 | 0.7 | 0.3 | 0.4 | 0.3 | 0.8 | . | 0.3 | 0.3 | 0.3 | 0.5 | 0.4 | 0.5 | 4.8 |
| GALE | 1941-1980 | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 1.9 |
| FOG | 1941-1980 | 1.0 | 1.3 | 1.7 | 2.0 | 2.8 | 1.9 | 1.5 | 1.1 | 1.2 | 1.1 | 0.5 | 0.3 | 16.4 |

*OBSERVATIONS ARE FROM VARIOUS SITES, 1898-1941.

*B86124 **WHAKAREWAREWA** GRID REFS NZMS 1, 1:63360 N076731013 NZMS 260, 1:50000 U16960327 LAT 38 10S LONG 176 16E HT 307 M

| | PERIOD | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINFALL. MILLIMETRES | | | | | | | | | | | | | | |
| HIGHEST MONTHLY/ANNUAL TOTAL | 1899-1980 | 352 | 313 | 400 | 487 | 464 | 324 | 294 | 305 | 308 | 294 | 267 | 351 | 2580 |
| 90 PERCENTILE VALUE | 1899-1980 | 230 | 211 | 220 | 215 | 259 | 216 | 219 | 194 | 216 | 198 | 176 | 188 | 1787 |
| MEAN | 1899-1980 | 107 | 103 | 108 | 119 | 138 | 137 | 129 | 131 | 118 | 127 | 104 | 118 | 1439 |
| 10 PERCENTILE VALUE | 1899-1980 | 15 | 26 | 28 | 39 | 49 | 62 | 52 | 66 | 53 | 49 | 41 | 40 | 1108 |
| LOWEST MONTHLY/ANNUAL TOTAL | 1899-1980 | 1 | 2 | 7 | 13 | 25 | 29 | 15 | 17 | 23 | 25 | 15 | 12 | 823 |
| AVERAGE RAIN DAYS, 1.0MM OR MORE | 1951-1980 | 8 | 8 | 8 | 9 | 11 | 11 | 12 | 12 | 11 | 12 | 10 | 11 | 123 |
| MAXIMUM 1-DAY RAINFALL | 1899-1980 | 127 | 180 | 135 | 151 | 174 | 119 | 93 | 136 | 117 | 86 | 90 | 157 | 180 |
| MAXIMUM 2-DAY RAINFALL | 1899-1980 | 148 | 202 | 174 | 210 | 194 | 160 | 173 | 162 | 140 | 105 | 107 | 227 | 227 |
| TEMPERATURE OF THE AIR. DEGREES CELSIUS | | | | | | | | | | | | | | |
| HIGHEST RECORDED | 1927-1980 | 35.2 | 31.6 | 29.4 | 26.6 | 21.2 | 20.8 | 18.1 | 20.2 | 22.3 | 26.8 | 29.9 | 32.7 | 35.2 |
| AVERAGE MONTHLY/ANNUAL MAXIMUM | 1927-1980 | 28.9 | 27.6 | 26.0 | 22.9 | 19.0 | 16.6 | 15.4 | 16.8 | 19.3 | 22.4 | 24.6 | 27.1 | 29.7 |
| AVERAGE DAILY MAXIMUM | 1927-1980 | 23.2 | 23.1 | 21.4 | 18.5 | 15.1 | 12.7 | 12.0 | 13.1 | 15.1 | 17.3 | 19.4 | 21.6 | 17.7 |
| MEAN | 1927-1980 | 17.5 | 17.7 | 16.1 | 13.4 | 10.3 | 8.0 | 7.3 | 8.3 | 10.0 | 12.2 | 14.1 | 16.1 | 12.6 |
| AVERAGE DAILY RANGE | 1927-1980 | 11.4 | 10.9 | 10.6 | 10.3 | 9.7 | 9.4 | 9.4 | 9.7 | 10.1 | 10.3 | 10.7 | 11.0 | 10.3 |
| AVERAGE DAILY MINIMUM | 1927-1980 | 11.8 | 12.2 | 10.8 | 8.2 | 5.4 | 3.3 | 2.6 | 3.4 | 5.0 | 7.0 | 8.7 | 10.6 | 7.4 |
| AVERAGE MONTHLY/ANNUAL MINIMUM | 1927-1980 | 5.7 | 6.0 | 3.8 | 1.6 | -0.9 | -2.7 | -2.7 | -2.2 | -0.9 | 0.7 | 2.8 | 4.5 | -3.5 |
| LOWEST RECORDED | 1927-1980 | 0.4 | 1.8 | -0.4 | -2.5 | -5.6 | -6.9 | -5.4 | -5.0 | -3.9 | -2.1 | -1.2 | -0.9 | -6.9 |
| TEMPERATURE OF THE GROUND. DEGREES CELSIUS | | | | | | | | | | | | | | |
| LOWEST GRASS MINIMUM RECORDED | 1928-1980 | -3.7 | -2.9 | -3.8 | -6.3 | -7.4 | -9.9 | -9.0 | -10.5 | -8.3 | -6.8 | -6.5 | -3.2 | -10.5 |
| AVERAGE GRASS MINIMUM | 1928-1980 | 8.6 | 9.2 | 7.7 | 5.1 | 2.5 | 0.4 | -0.4 | 0.4 | 1.7 | 3.9 | 5.7 | 8.0 | 4.4 |
| AVERAGE AT 10 CM DEPTH | 1951-1980 | 18.9 | 18.8 | 16.8 | 13.6 | 10.2 | 7.7 | 6.3 | 7.3 | 9.6 | 12.5 | 15.1 | 17.3 | 12.8 |
| AVERAGE AT 30 CM DEPTH | 1951-1980 | 20.5 | 20.8 | 19.3 | 16.5 | 13.1 | 10.3 | 8.7 | 9.4 | 11.3 | 14.0 | 16.5 | 18.7 | 14.9 |
| FROST. | | | | | | | | | | | | | | |
| AVERAGE DAYS OF GROUND FROST | 1928-1980 | 0.3 | 0.1 | 0.7 | 2.7 | 9.3 | 13.5 | 15.6 | 12.9 | 9.7 | 4.7 | 2.0 | 0.4 | 71.9 |
| AVERAGE DAYS OF AIR FROST | 1927-1980 | . | . | . | 0.4 | 2.3 | 7.2 | 8.7 | 5.9 | 2.2 | 0.5 | 0.1 | 0.1 | 27.4 |
| RELATIVE HUMIDITY. (%) | | | | | | | | | | | | | | |
| AVERAGE AT 9 A.M. | 1951-1980 | 75 | 78 | 80 | 84 | 87 | 87 | 88 | 85 | 80 | 76 | 74 | 74 | 81 |
| VAPOUR PRESSURE. MILLIBARS | | | | | | | | | | | | | | |
| AVERAGE AT 9 A.M. | 1941-1980 | 14.6 | 15.2 | 14.2 | 12.2 | 10.3 | 8.8 | 8.3 | 8.9 | 9.8 | 10.9 | 11.9 | 13.4 | 11.5 |
| SUNSHINE. TOTAL HOURS | | | | | | | | | | | | | | |
| HIGHEST | 1935-1977 | 308 | 235 | 229 | 205 | 187 | 171 | 178 | 172 | 199 | 231 | 281 | 254 | 2215 |
| MEAN | 1935-1977 | 217 | 181 | 177 | 152 | 131 | 113 | 126 | 132 | 153 | 173 | 191 | 202 | 1948 |
| % OF POSSIBLE | 1935-1977 | 50 | 49 | 48 | 48 | 44 | 42 | 44 | 42 | 45 | 44 | 47 | 46 | 46 |
| LOWEST | 1935-1977 | 116 | 128 | 125 | 55 | 81 | 56 | 61 | 90 | 93 | 88 | 121 | 121 | 1624 |
| WIND. | | | | | | | | | | | | | | |
| MEAN DAILY WINDRUN. KILOMETRES | 1951-1980 | 152 | 139 | 135 | 137 | 140 | 139 | 137 | 141 | 158 | 163 | 171 | 162 | 148 |
| SPECIAL PHENOMENA. AVERAGE DAYS OF | | | | | | | | | | | | | | |
| SNOW | 1951-1980 | . | . | . | . | . | . | 0.1 | . | . | . | . | . | 0.1 |
| HAIL | 1951-1980 | 0.2 | . | 0.1 | . | 0.1 | 0.1 | 0.3 | 0.5 | 0.4 | 0.4 | 0.2 | 0.3 | 2.6 |
| THUNDER | 1955-1980 | 1.1 | 0.6 | 0.7 | 0.4 | 0.5 | 0.3 | 0.2 | 0.2 | 0.6 | 1.0 | 0.8 | 1.8 | 8.2 |
| GALE | 1951-1980 | 0.1 | 0.1 | 0.2 | 0.4 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | 2.8 |
| FOG | 1951-1980 | 0.2 | 0.6 | 1.3 | 2.7 | 3.3 | 3.6 | 3.2 | 2.8 | 1.0 | 0.6 | 0.2 | 0.2 | 19.7 |

*INCLUDES OBSERVATIONS FROM RAINFALL STATION 1899-1927, AND FROM VARIOUS SITES 1927-1951.

B76993 **WHAKATANE** GRID REFS. NZMS 1, 1:63360 N069407255 NZMS 260, 1:50000 W15584531 LAT. 37 58S LONG. 176 57E HT 2 M.

| | PERIOD | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINFALL. MILLIMETRES | | | | | | | | | | | | | | |
| HIGHEST MONTHLY/ANNUAL TOTAL | 1947-1980 | 201 | 327 | 442 | 310 | 355 | 208 | 251 | 312 | 255 | 233 | 234 | 293 | 1949 |
| 90 PERCENTILE VALUE | 1947-1980 | 153 | 190 | 270 | 214 | 247 | 192 | 233 | 173 | 177 | 187 | 155 | 199 | 1781 |
| MEAN | 1947-1980 | 83 | 101 | 121 | 105 | 131 | 131 | 130 | 126 | 101 | 105 | 89 | 105 | 1328 |
| 10 PERCENTILE VALUE | 1947-1980 | 18 | 23 | 40 | 23 | 59 | 49 | 61 | 60 | 41 | 37 | 39 | 44 | 1050 |
| LOWEST MONTHLY/ANNUAL TOTAL | 1947-1980 | 12 | 14 | 10 | 7 | 27 | 35 | 34 | 51 | 18 | 24 | 22 | 29 | 919 |
| AVERAGE RAIN DAYS, 1.0MM OR MORE | 1947-1980 | 8 | 7 | 8 | 8 | 10 | 10 | 10 | 11 | 10 | 10 | 9 | 9 | 110 |
| MAXIMUM 1-DAY RAINFALL | 1947-1980 | 75 | 109 | 139 | 201 | 93 | 99 | 89 | 115 | 100 | 97 | 111 | 130 | 201 |
| MAXIMUM 2-DAY RAINFALL | 1947-1980 | 85 | 158 | 212 | 235 | 111 | 118 | 151 | 141 | 130 | 142 | 123 | 189 | 235 |
| TEMPERATURE OF THE AIR. DEGREES CELSIUS | | | | | | | | | | | | | | |
| HIGHEST RECORDED | 1947-1980 | 34.4 | 31.0 | 30.0 | 26.4 | 24.0 | 21.1 | 20.0 | 23.0 | 24.4 | 27.0 | 28.5 | 31.1 | 34.4 |
| AVERAGE MONTHLY/ANNUAL MAXIMUM | 1947-1980 | 28.6 | 28.0 | 26.8 | 23.9 | 20.9 | 18.6 | 17.5 | 18.5 | 20.6 | 22.6 | 25.3 | 26.8 | 29.5 |
| AVERAGE DAILY MAXIMUM | 1947-1980 | 23.9 | 24.1 | 22.9 | 20.5 | 17.5 | 15.0 | 14.4 | 15.3 | 16.8 | 18.6 | 20.5 | 22.3 | 19.3 |
| MEAN | 1947-1980 | 19.1 | 19.5 | 18.0 | 15.2 | 12.3 | 9.9 | 9.3 | 10.3 | 12.0 | 13.9 | 15.7 | 17.7 | 14.4 |
| AVERAGE DAILY RANGE | 1947-1980 | 9.6 | 9.4 | 9.9 | 10.5 | 10.3 | 10.2 | 10.3 | 10.0 | 9.7 | 9.4 | 9.5 | 9.2 | 9.8 |
| AVERAGE DAILY MINIMUM | 1947-1980 | 14.3 | 14.7 | 13.0 | 10.0 | 7.2 | 4.8 | 4.1 | 5.3 | 7.1 | 9.2 | 11.0 | 13.1 | 9.5 |
| AVERAGE MONTHLY/ANNUAL MINIMUM | 1947-1980 | 8.3 | 9.1 | 6.7 | 4.1 | 1.4 | -0.8 | -0.7 | 0.0 | 1.4 | 3.5 | 5.2 | 7.3 | -1.4 |
| LOWEST RECORDED | 1947-1980 | 3.0 | 5.6 | 1.7 | 1.1 | -1.0 | -3.0 | -4.0 | -3.3 | -0.6 | 0.6 | 1.4 | 0.4 | -4.0 |
| TEMPERATURE OF THE GROUND. DEGREES CELSIUS | | | | | | | | | | | | | | |
| LOWEST GRASS MINIMUM RECORDED | 1947-1980 | -0.5 | -0.3 | -2.8 | -2.4 | -5.8 | -7.7 | -8.3 | -6.1 | -4.8 | -2.8 | -2.8 | -1.7 | -8.3 |
| AVERAGE GRASS MINIMUM | 1947-1980 | 12.2 | 12.8 | 11.1 | 7.9 | 4.8 | 2.6 | 1.9 | 3.4 | 4.8 | 6.8 | 8.6 | 10.8 | 7.3 |
| FROST. | | | | | | | | | | | | | | |
| AVERAGE DAYS OF GROUND FROST | 1971-1980 | . | . | . | . | 1.9 | 4.7 | 5.4 | 2.3 | 1.0 | . | . | . | 15.3 |
| AVERAGE DAYS OF AIR FROST | 1971-1980 | . | . | . | . | 0.1 | 1.4 | 2.2 | 0.6 | 0.1 | . | . | . | 4.4 |
| RELATIVE HUMIDITY. (%) | | | | | | | | | | | | | | |
| AVERAGE AT 9 A.M. | 1947-1980 | 72 | 76 | 79 | 83 | 87 | 89 | 89 | 86 | 83 | 75 | 74 | 73 | 81 |
| VAPOUR PRESSURE. MILLIBARS | | | | | | | | | | | | | | |
| AVERAGE AT 9 A.M. | 1947-1980 | 16.9 | 17.4 | 16.3 | 13.8 | 11.6 | 9.6 | 9.2 | 10.1 | 11.4 | 12.7 | 14.2 | 15.8 | 13.3 |
| SUNSHINE. TOTAL HOURS | | | | | | | | | | | | | | |
| HIGHEST | 1957-1980 | 310 | 254 | 273 | 242 | 200 | 180 | 199 | 193 | 243 | 254 | 289 | 273 | 2518 |
| MEAN | 1957-1980 | 247 | 210 | 201 | 198 | 168 | 142 | 161 | 167 | 179 | 206 | 224 | 226 | 2329 |
| % OF POSSIBLE | 1957-1980 | 57 | 58 | 55 | 62 | 57 | 52 | 56 | 53 | 53 | 53 | 55 | 51 | 55 |
| LOWEST | 1957-1980 | 184 | 129 | 145 | 157 | 117 | 109 | 99 | 119 | 124 | 135 | 176 | 172 | 2105 |
| SPECIAL PHENOMENA. AVERAGE DAYS OF | | | | | | | | | | | | | | |
| THUNDER | 1955-1971 | 0.1 | 0.1 | 0.2 | . | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.4 | 0.1 | 1.7 |

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