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of March 1986**

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Summary

Warm, moist northerlies on the eastern side of a stationary depression had been blowing over New Zealand in the days prior to the flooding. An anticyclone to the south of New Zealand spread cold southeasterlies or easterlies onto the South Island. The subsequent large vertical motions in the warm northerlies, and strong convergence between the two airmasses, led to intense convective rains on the frontal zone over mid and south Canterbury and North Otago. This type of situation can readily bring heavy rain to eastern parts of the South Island, as was the case in the flood of February 1945.

Most of the rain fell within a 12 hour period overnight during 12 and 13 March 1986, with more than 100 mm being recorded over large areas of South Canterbury and North Otago. While the one day totals suggest a return period of the event of at least 75 years with only a five percent chance of being exceeded, the return period of the 12 hour totals are much larger, making these flood producing rains an extremely rare event.

The flood related damage was nearly \$60 million. Had weather surveillance radar been available, damage may have been considerably mitigated through earlier heavy rainfall warnings.

1. INTRODUCTION

On 12 and 13 March 1986, heavy rain fell in mid and south Canterbury and North Otago. Some flooding occurred in Christchurch and Rangiora, but was more extensive further south. The town of Geraldine reported its worst flood since 1929; in Temuka many homes were evacuated, and the entire town of Pleasant Point was evacuated. Many roads in the area were cut, and Timaru was isolated for a time. The Hakataramea Valley, which previously had experienced several years of very dry conditions, suffered severe flood damage and all farms were evacuated.

2. SYNOPTIC ASPECTS

On 10 March 1986, a depression developed in the central Tasman Sea in a pre-existing trough of low pressure (Fig. 1) which had also moved onto the South Island. The depression deepened and remained slow moving under a large upper level low for several days (Fig. 2). Late on 13 March the depression began drifting eastwards, weakening as it crossed central

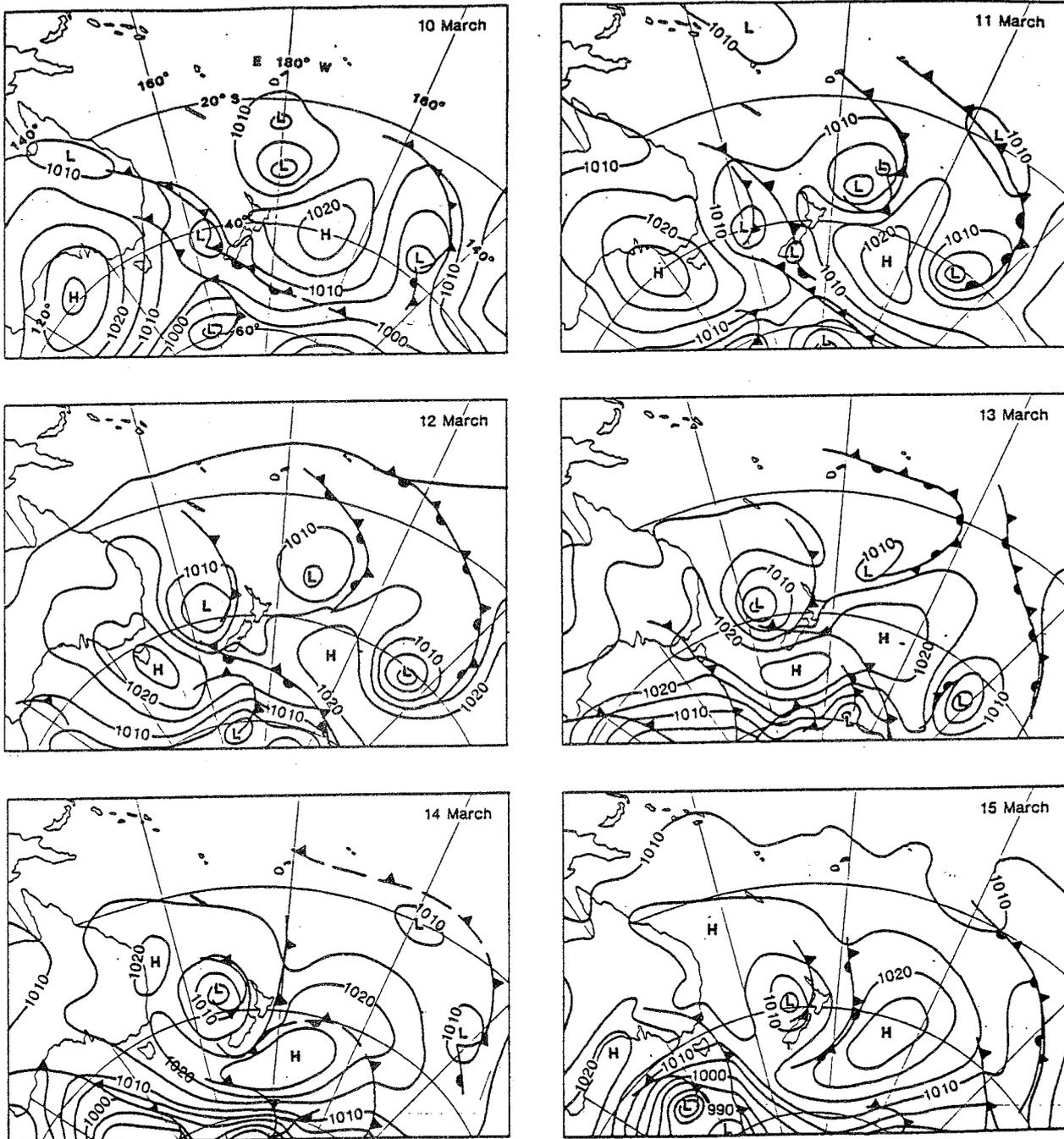


Fig. 1. Sequence of daily weather maps at midnight during 10-15 March 1986

New Zealand two days later. Figure 1 gives a sequence of daily weather maps for midnight during the period 10-15 March 1986.

As the depression developed, there was a tropical cyclone near the Kermadec Islands to the north of New Zealand. Warm air from the tropical cyclone arrived over northern New Zealand early on 10 March. Air temperatures above 2000 m rose by 4-6°C. The supply of warm moist air continued to arrive over New Zealand until early on 12 March, by which time the cyclone had moved well away from New Zealand's longitude.

The warm tropical air mass was subjected to slow ascent, and some cooling and condensation as it flowed over the country around the eastern side of the Tasman Sea depression. A weak trough of low pressure, already existing over the South Island on the 11th, further assisted in the cloud and precipitation generation mechanisms.

An anticyclone, originating in the Australian Bight, moved east into the Tasman Sea on 12 March. Cold southeast-east winds associated with the anticyclone spread onto the South Island by late in the day. A frontal zone on the northern side of the anticyclone moved ahead of the cold airstream to lie east-west over North Canterbury by the 13th.

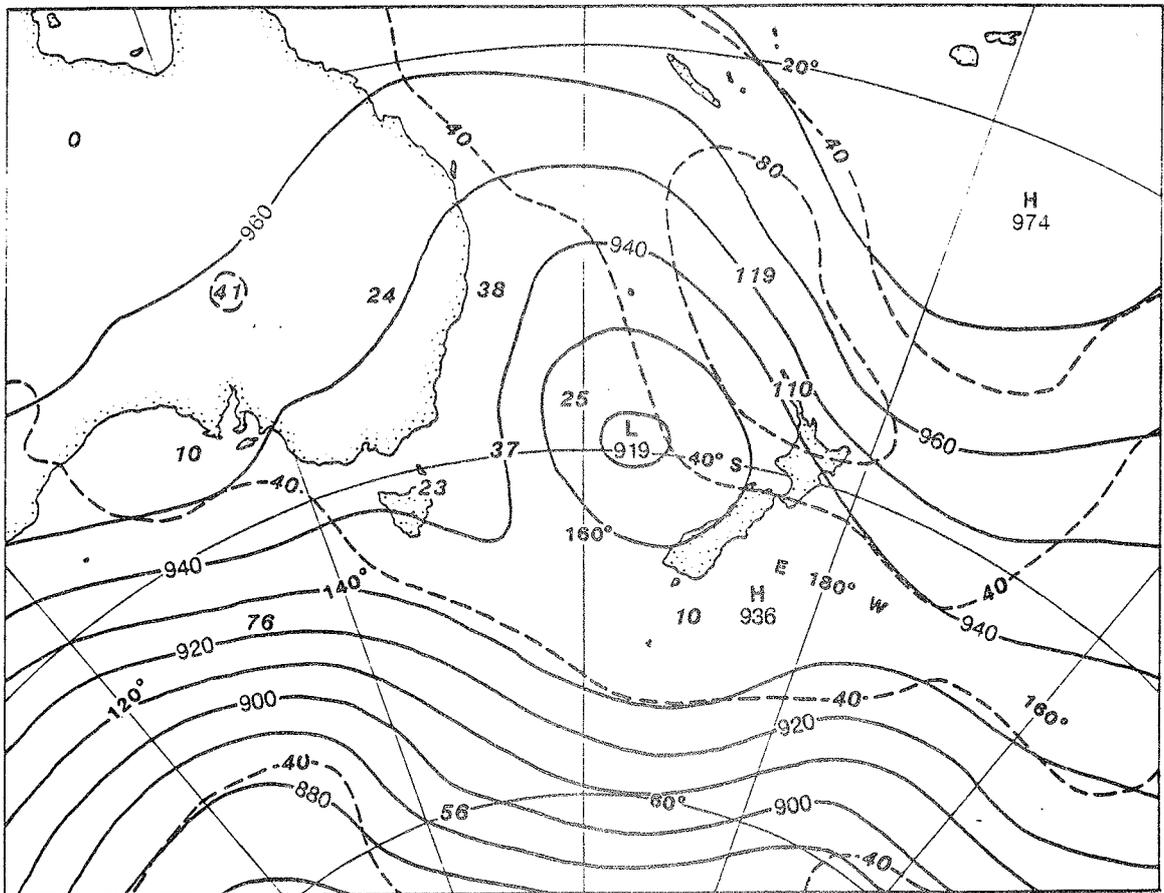


Fig. 2. 300 hPa analysis for 6 a.m. on 13 March 1986

On the northeastern side of the upper level 300 hPa low, was a cyclonically curved jetstream (Fig. 2). Ascending motions, favoured on the poleward exit region of jetstreams, occurred in the vicinity and above the frontal zone over Canterbury. Considerable vertical motion results in the

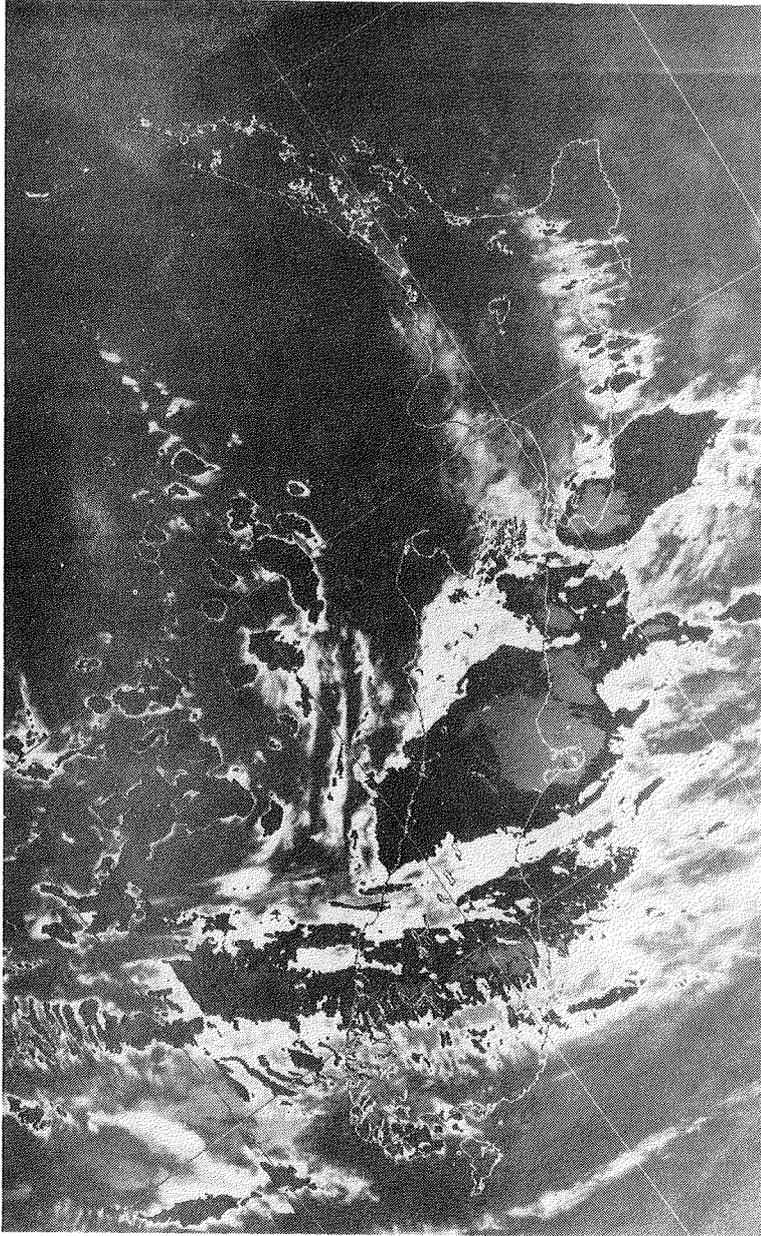


Fig. 3. Enhanced infra-red satellite photograph taken at about 3 a.m. on 13 March 1986. The grey-black band lying east-west across Canterbury represents the dense cloud of the frontal zone

warm airmass in a narrow strip immediately adjacent to the surface front (Browning, 1985). This region of strong ascent, together with the intense low-level convergence that subsequently resulted between the warm moist northerlies and the colder east to southeast winds, was responsible for the relatively narrow band of extremely heavy convective rain at the surface front. An indication of the strength of the convergence can be noted in the fact that the thermal gradient in the lowest 300-500 m was 6-7°C.

Individual mesoscale cells of heavy rain on the frontal zone moved slowly southwards within the largescale northerly airstream. The deep seated nature of this mesoscale (convective) activity is seen in the high-resolution infra-red satellite imagery taken about 3 a.m. on 13 March 1986 (Fig. 3). Cloud top temperatures over Canterbury in the region of enhanced activity are -60 to -70°C, indicating heights of about 13000 m. Although Fig. 3 shows a single large rain cell with a diameter of about 130 km, hourly rainfall measurements provided by the Christchurch Drainage Board indicate that at least two mesoscale rain cells passed over Christchurch. Two rainfall intensity maxima occurred between 11 pm on 12 March and 1 am on 13 March, with another towards dawn.

In South Canterbury and North Otago, the presence of ranges near the coast also aided in the ascent of the airmasses, and may be partly responsible for the large rainfalls that were recorded.

The rapid movement of the anticyclone was largely responsible for the clearance of the rain. As the high pressure area moved northeast during 13 March, the flow on the southern side of the frontal zone turned northeast, reducing considerably its activity. The front moved off New Zealand late on 13 March, as the Tasman Sea depression began to drift eastwards.

3. RAINFALL

Rainfall distribution

Soil moisture levels in Canterbury and North Otago were already fairly high when light rain starting falling over the region on the afternoon of 11 March 1986. Rainfall amounts in the preceding month were well above normal. Although Canterbury received between 150 and 200 percent of normal rainfall for February, many areas in South Canterbury and North Otago had two to three times their usual February totals. The magnitude of the flood was enhanced as the rain could not percolate through the soils due to their already saturated nature.

Figure 4 shows the distribution of rainfall for the 24 hours from 9 a.m. on 12 March to 9 a.m. on 13 March. Figure 4 shows heavy rainfalls of more than 100 mm occurred in a relatively narrow elongated area extending from Methven in the north to Duntroon in the south. Another area of high rainfall occurred on the Kakanui Mountains in North Otago. The distribution of rainfall shows some orographic influences. Rainfall was most intense in a narrow strip from Waihi Gorge, northwest of Geraldine, to Cave and Pareora River Gorge with more than 200 mm being recorded. Highest recorded totals for 12 March 1986 include 214 mm at Mount Horrible, 203 mm at Waihi, 193 mm at Woodbury and 178 mm at Mount Cecil. It is highly probable that rainfalls

may have exceeded 250 mm in the Cave Hill-Totara Valley area, and on the hills just north of Kakahu State Forest.

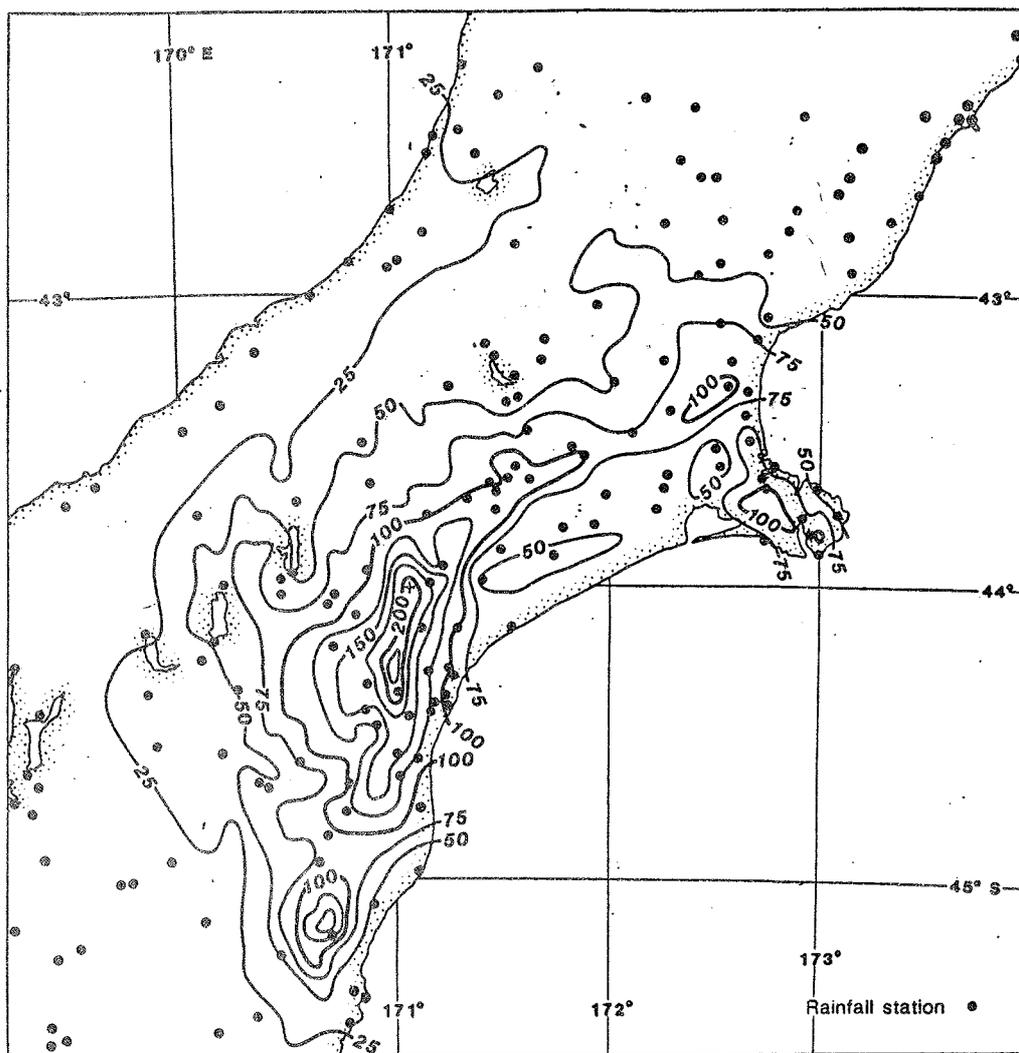


Fig. 4. Distribution of rainfall for 12 March 1986.
Note rainfall is from 9 a.m. on 12 March to 9 a.m. on 13 March

Intensity of rainfall

Rainfall accumulation graphs, based on data from recording raingauges at Rangiora, Gleniti Reservoir, Timaru Airport, Waimate and Lake Waitaki are given in Fig. 5. Steady continuous rain fell during the 12th. Exceptionally heavy rain broke out almost simultaneously over Canterbury between 10.30 and 11.30 pm on 12 March. In North Otago, the heavy rain began some two or three hours later. Over 75 percent of the total rain for the 12th occurred between the onset of heavy rain and 9 am on the 13th; a period of less than 12 hours. Just as the heavy rain began abruptly, the

rain ceased as abruptly and the skies cleared. Derived rates of rainfall accumulation during the period of heavy rainfall were about 11 mm per hour.

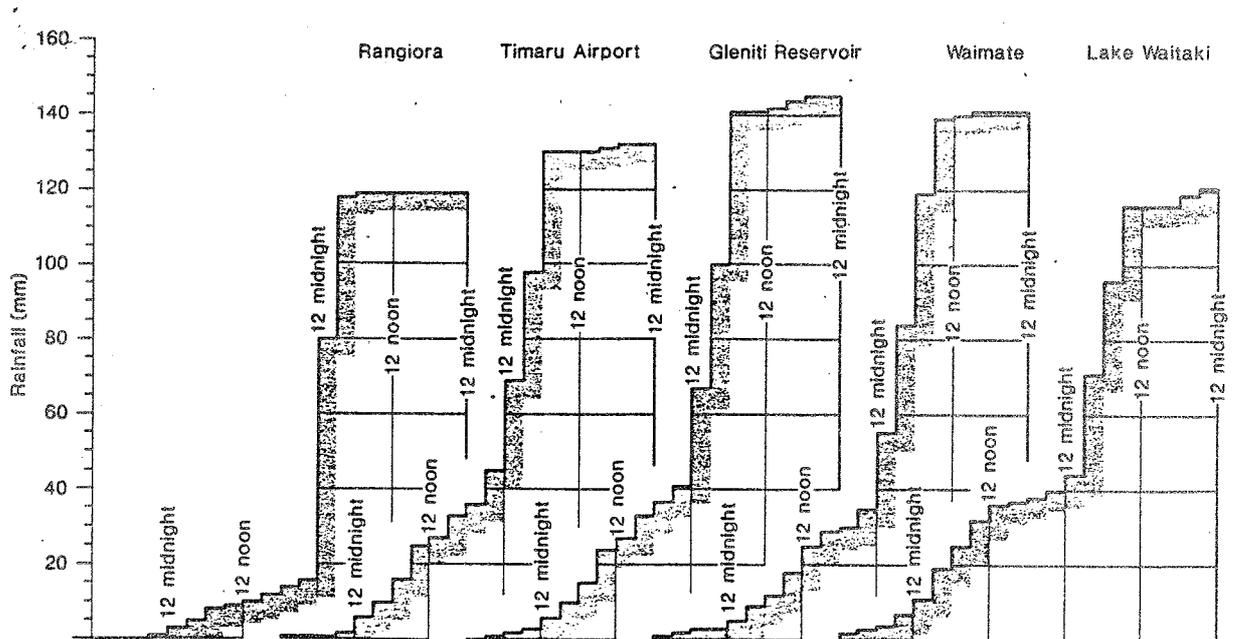


Fig. 5. Rainfall accumulations from recording rain gauges during 11-13 March 1986

A table of maximum rainfalls for durations from 30 minutes to 12 hours is given in Table 1 together with the onset and finishing times of the heavy rains. These data were compiled from recording rain gauges.

Table 1. Maximum rainfalls (mm) for specified durations on 12-13 March 1986

Location	Duration					Onset Time of Heavy 12 March (p.m.)	Finish rainfall 13 March (a.m.)
	30M	60M	2HR	6HR	12HR		
Rangiora	20	37	66	101	112	11.30	5.30
Highbank	12	23	38	80	90	11.00	7.30
Kakahu Forest	-	29	50	106	145	-	-
Gleniti Res.	13	21	37	64	105	10.30	9.00
Timaru	10	19	31	69	94	10.30	9.00
Adair	12	23	35	82	105	10.30	9.00
Lake Waitaki	8	15	23	58	77	2.30*	10.30

* Morning of 13 March 1986.

Several locations in South Canterbury recorded their highest ever one-day totals. However, they were at sites with less than 20 years of records. Some notable exceptions are given in Table 2. These stations all lie in or near the regions of maximum rainfall displayed in Fig. 4.

Table 2. Maximum recorded one-day rainfalls (mm)

Location	Amount	Previous record	Date	Length of record (yrs)
Woodbury	193	138	Jan 1975	18
Kakahu Bush	163	122	May 1932	74
Hunters	126	99	May 1972	29
Foxdown	115	105	Apr 1951	49
Timaru Air.	115	79	Jan 1980	29

Recurrence of heavy rainfalls

Heavy rainfalls over some specific duration can be compared against their frequency of recurrence. Estimates of the 50-year and 100-year maximum rainfalls over one-day durations have been calculated according to a method proposed by Revfeim (1983). Table 3 gives such estimates for a selection of South Canterbury stations. In many places within South Canterbury, the 50-year event rainfall over one-day has a value between 100 and 120 mm, while the 100-year event value is mostly between 115 and 135 mm. Most of the stations in Table 3 have amounts exceeding the 100-year event; at some stations it is exceeded by a considerable margin.

At Kakahu Bush, 163 mm is the average maximum for 800 years. While the same size event has a 43 percent chance of being exceeded (Revfeim, 1984), it is also an 80-year event with only a 5 percent chance of being exceeded. Similarly at the 5 percent level of significance for Tengawai, Foxdown, and Mt Nimrod, the T-year return periods are 17 years, 3 years and 77 years respectively. Assuming that the data series were interpreted correctly, it is likely that the very heavy rains in the narrow zone from Geraldine to the Waitaki River which led to the flooding, were at least a 75-year event at the 5 percent level of significance.

Since most of the rain for 12 March fell within a period of 12 hours, event return periods will be much more spectacular than those attributed to the one-day falls. At Gleniti Reservoir, the 12-hour maximum rainfall was 105 mm. This amount is the average maximum for 400 years with only a five percent chance of being exceeded. Comparing this with the one-day fall of 124 mm, the latter amount is only a 50-year event at the same level of significance.

Table 3. Estimates of the 50 and 100-year rainfalls for daily rainfall at a selection of South Canterbury stations

	Number of observations	Rainfall (mm) for 2 March	Predicted maxima in T-years	
			50-years	100-years
Fairlie	39	113	97	105
Tengawai	66	133	114	124
Heatherleigh	13	167	104	114
Mt Nimrod	18	153	113	123
Foxdown	25	115	123	135
Melford Hills	15	130	109	120
Kakahu Bush	25	163	119	130
Smithfield	17	93	92	100
Orari Estate	81	93	133	145
Timaru	83	73	100	110
Pleasant Point	44	150*	109	119
Gleniti Reservoir	18	124	94	103
Temuka	21	97	96	105
Sodwall Hunter	13	156	105	115
Hunters	19	126	113	123
Moanaroa	13	113	104	114

* Estimated from Fig. 4.

Historical perspective

Previous documented floods in South Canterbury occurred in February 1868 and in February 1945 (Edie, Seelye and Raeside, 1946).

Extensive flooding occurred over the east of the South Island during 20 and 21 February 1945. Not only was South Canterbury affected, but flooding also resulted in parts of mid Canterbury, north and south Otago and eastern Southland. The extent of the flooding during March 1986 was not as great as the earlier one, which was confined largely to coastal areas in mid and south Canterbury and North Otago.

The synoptic situation in the February 1945 flood was similar to that of March 1986, with warm moist northerlies being advected over the South Island on the eastern side of a slow moving depression. Rising pressures over southern New Zealand and cold southeasterly winds ensured extensive and persistent rain over the eastern South Island from Banks Peninsula southwards.

The distribution of rainfall in both floods was similar, but the maximum precipitation area in the 1945 flood lay to the north of Geraldine, and to the south in the 1986 flood. Most of the rain fell in the 1945 flood in a 36 hour period (Edie, Seelye and Raeside, 1946), compared to the 10 to 12 hours in 1986. Although total rainfalls in some areas of South

Canterbury were generally two to three times greater in the flood of 1945, it does appear that the intensity of rain in the maximum fall regions during March 1986 was greater. For example, at Geraldine the estimated mean intensity of rainfall was 11 mm per hour on 12 March 1986 compared with 8 mm per hour during 20-21 February 1945.

4. DAMAGE ASSESSMENT

Damage estimates collected by insurance companies, the Insurance Council of New Zealand, and other organisations indicate a cost due to flooding of nearly \$60 million. Present (June 1986) insurance claims have amounted to about \$23 million, but some claims, such as 'loss of profit' are

Table 4. Estimates of March 1986 flood damage

Damage	Cost (\$ millions)
State highways	2.2
Local authority roads (19 bridges with structural damage)	15.7
Water supply damage	2.3
Waste water damage	0.3
Irrigation schemes	0.7
Railway tracks	1.0
Post Office communications	1.0
Power Board's lines and equipment	0.1
Housing repairs and replacements (430 houses were evacuated, 84 will never be reoccupied. Domestic insurance claims amounted to \$6.5- 7 million.)	9.0*
Commercial and industrial property (83 were affected. Ninety percent of claims were for stock, the rest for buildings)	16.5
Farm damage. (325 farms badly affected. 1200 km of fencing destroyed. 300 ha of grain lost. 300 tonnes of stored grain lost.)	5.0
South Canterbury Catchment Board repairs	2.5
Waitaki Catcment Commission repairs	0.3
Total damage	56.6

* Estimates have been put at between \$8-10 million.

yet to be assessed. Several properties were not insured, others were under-insured, and these reflect in the low insurance payouts than would otherwise be the case.

Damage estimates are given in Table 4

The cost of the damage in other recent South Island floods have been estimated at just over \$6 million in the Marlborough-Nelson Bays flood of July 1983 (Quayle, Pointer and Challands, 1983). In contrast, for the Southland flood of January 1984, damage was initially put at \$46 million (Hill and Quayle, 1984), but more recently has been estimated at between \$70-80 million.

Heavy rainfall and flood warnings were issued for the March 1986 flood. Such warnings may not have been received in time by the relevant authorities to take necessary action, or the warnings did not indicate the severity of the flood. In any flood, some damage is inevitable because fixtures cannot be moved out of the way. Moveable items and stock can be shifted if sufficient warning is given. In this particular flood, it is not possible to estimate how much may have been saved if warnings were entirely adequate. However, in the 'Commercial and industrial properties' category listed in Table 4, if all stock claimed for had been saved this would have amounted to a considerable saving of nearly \$15 million.

The intense mesoscale activity in the rain producing system is difficult to track by conventional means. High resolution satellite imagery is not frequent enough for this purpose. The only real-time method of handling small scale systems is to use weather surveillance radar. Had this been available in March 1986, more timely warnings with a better indication of the amounts of rain could have been given.

Since 1980, six disastrous floods have occurred within New Zealand. A network of five weather surveillance radars has been proposed by the Meteorological Service to provide an almost complete coverage of the country. One of these radars, sited on Banks Peninsula, would have covered this rare event. At a cost of nearly \$2 million each, weather radar could have saved the nation many times its cost in providing timely warnings of heavy rain and subsequent intensity.

5. ACKNOWLEDGMENTS

We are indebted to the following for additional rainfall information: North Canterbury Catchment Board, Christchurch Drainage Board, South Canterbury Board, Waitaki Catchment Commission and the Otago Catchment Board. Mr I. Miller and Mrs G. Thompson collated the Catchment Board's information and prepared preliminary maps of the rainfall distribution. Estimates of damage were provided by Mr J. Dogger of SIMU in Timaru on behalf of the New Zealand Insurance Council.

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