

WATER AND SOIL DIVISION COPY.
Pse return to R.J. Curry

**WELLINGTON
REGIONAL
WATER
BOARD**

**REPORT ON STORM OF
20 December, 1976**

WELLINGTON REGIONAL WATER BOARD

P.O. Box 11-245, WELLINGTON.

3 February, 1977

TO THE CHAIRMAN AND MEMBERS OF THE BOARD

STORM OF 20 DECEMBER, 1976

The following report sets out a number of matters relating to the above storm and makes several recommendations.

Opportunity has been taken to present the hydrological data fairly fully as it is felt that this may be of value to local body engineers and to the Board in the future.

A number of matters warrant further investigation and it is hoped that the administration of watercourses generally will receive due consideration by all concerned.

I submit the report and recommendations for Board acceptance and approval.



R.G. Bishop
Chief Engineer

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WELLINGTON REGIONAL WATER BOARD

P.O. Box 11-245, WELLINGTON.

REPORT ON STORM OF 20 DECEMBER 1976

1. INTRODUCTION

On 20 December 1976 an unusually severe rainstorm affected part of the Wellington Region causing damaging flood flows in parts of Wellington City, Lower Hutt City, Hutt County and Tawa, with lesser effects in other districts. Severe damage to public and private property resulted from the downpour and conditions were such as to warrant the declaration of local Civil Defence Emergencies in limited areas of Lower Hutt City, Hutt County and Upper Hutt City.

The heavy rain over a long period caused numerous landslides with consequent blocking of culverts and public stormwater systems. Flood waters thus migrated from normal channels and caused scouring of private properties and roads in hilly areas with deposition of vast amounts of debris against any obstructions and flooding on the flatter land.

This report covers briefly a description of the event and its effects, a Statement on Costs involved together with observations and conclusions which appear warranted. Recommendations for further action are appended.

2. DESCRIPTION OF EVENT

2.1 Meteorological

On Monday, 20 December, two moist air streams, one flowing approximately from the north and the other from the south, converged over the Hutt Valley. The resultant rise of the mass of moist air and consequent cooling led to extreme rates of precipitation occurring over the Hutt Valley/Wellington area.

2.2 Rainfall

Very heavy rain began falling over the Hutt Valley at about 4.00 a.m. on 20 December 1976. The rain producing cloud drifted slowly in a south-westerly direction, the really heavy rain falling along a line running from above Pinehaven to south of Karori.

The downpour continued until about 2.00 p.m. in Pinehaven and 4.00 p.m. in Wellington after which time it began to ease. Two torrential periods of rain occurred within this

ten hour period, the first three hour period to 7.00 a.m. producing about 100mm (4") over the Pinehaven, Stokes Valley, Taita, Avalon and Belmont areas, with progressively lesser amounts to the south-west. Again, from 9.00 a.m. to 12.00 p.m. 100mm fell over the Pinehaven to Belmont areas with lesser amounts south-west to Karori.

The accumulated rainfall on the 20th, measured at the various automatic recording stations, shows the variations in time and amount of rainfall throughout the day over the region, see Fig. 2.2.3.

At Avalon and Taita extreme rates of rainfall were recorded and such intensities probably occurred also on the Western Hills from Haywards to perhaps as far south as Mount Kaukau.

Of the automatic recording stations, intensities were the highest at the Soil Bureau, D.S.I.R., Taita on the eastern hills. Rainfall at Taita is shown in Table 2.2.1.

TABLE 2.2.1

RAINFALL AT SOIL BUREAU, TAITA

Duration	10 min	20 min	30 min	60 min	2 hrs	6 hrs	12 hrs	24 hrs
Depth mm	10.8	21.6	28.9	49.9	88.6	180.5	258.6	287.6
Intensity mm/hr	64.8	64.8	57.8	49.9	44.3	30.1	21.6	12.0
Intensity ins/hr	2.6	2.6	2.3	2.0	1.7	1.2	0.85	0.47
Corresponding Return Period	10 yr	50-100yr	200 yr	>1000yr	>1000yr	>1000yr	>1000yr	>1000yr

The intensities for durations up to 60 minutes are significant in producing flood peaks from small catchments such as those in the storm affected area. These high intensities occurred between 9.00 a.m. and 10.00 a.m. approximately when these catchments would have been saturated by the preceding rainfall of up to 140mm.

The significant duration for a catchment is the time taken for all parts of a catchment to contribute to run-off at the outlet.

In Figure 2.2.1 - lines are drawn showing the distribution over the affected area of accumulated rainfall from the start of the downpour, taken as 0400 hours to 0900 hours when a slight lull occurred.

Figure 2.2.2 - shows the distribution of accumulated rainfall from the start of the heavy rainfall to 1400 hours. These two five hour periods contained the flood producing rainfall.

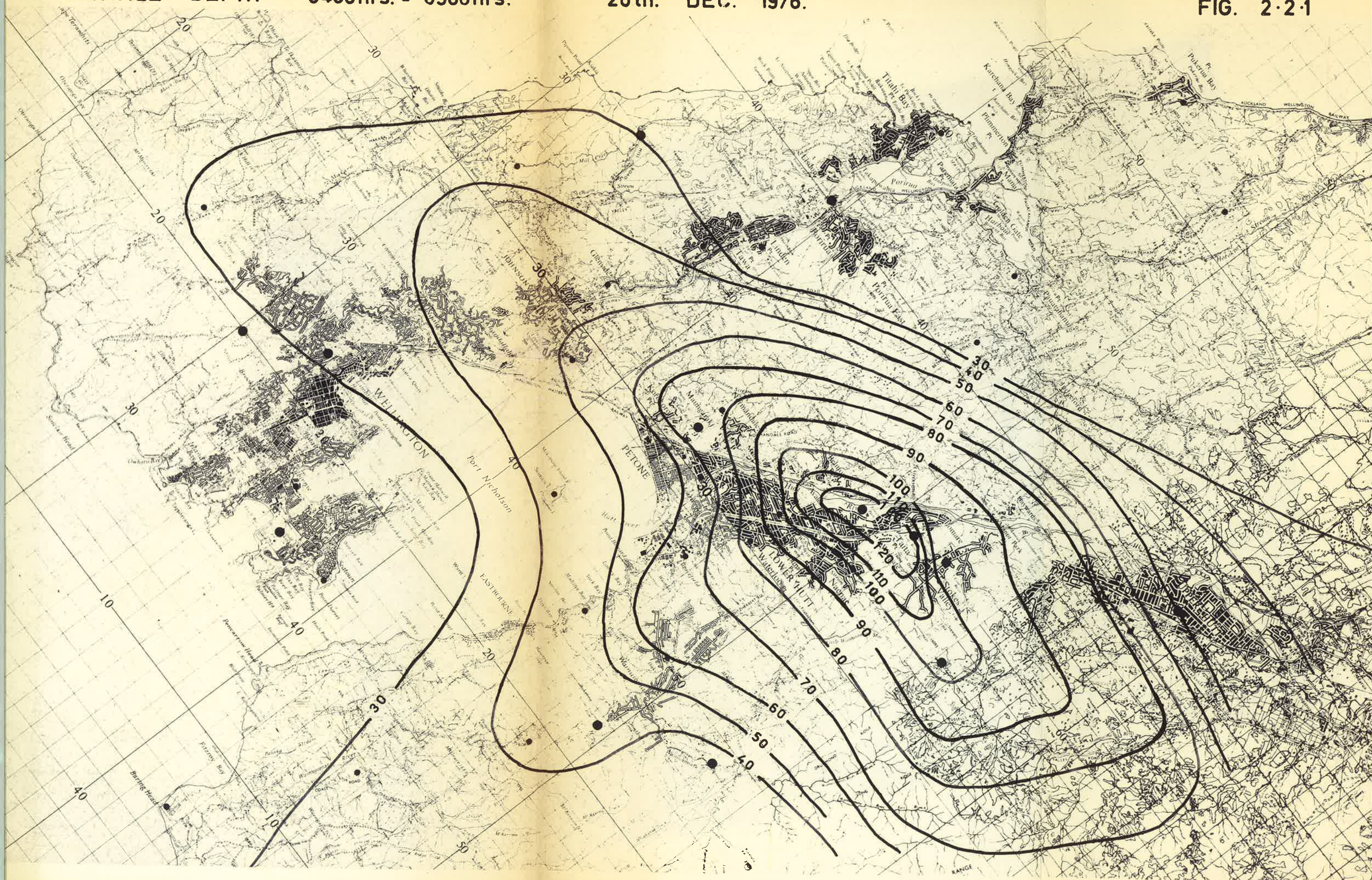
Figure 2.2.4 - shows the maximum rainfall in any 24 hour period during 19 and 20 December 1976.

RAINFALL DEPTH

0400hrs. - 0900hrs.

20th. DEC. 1976.

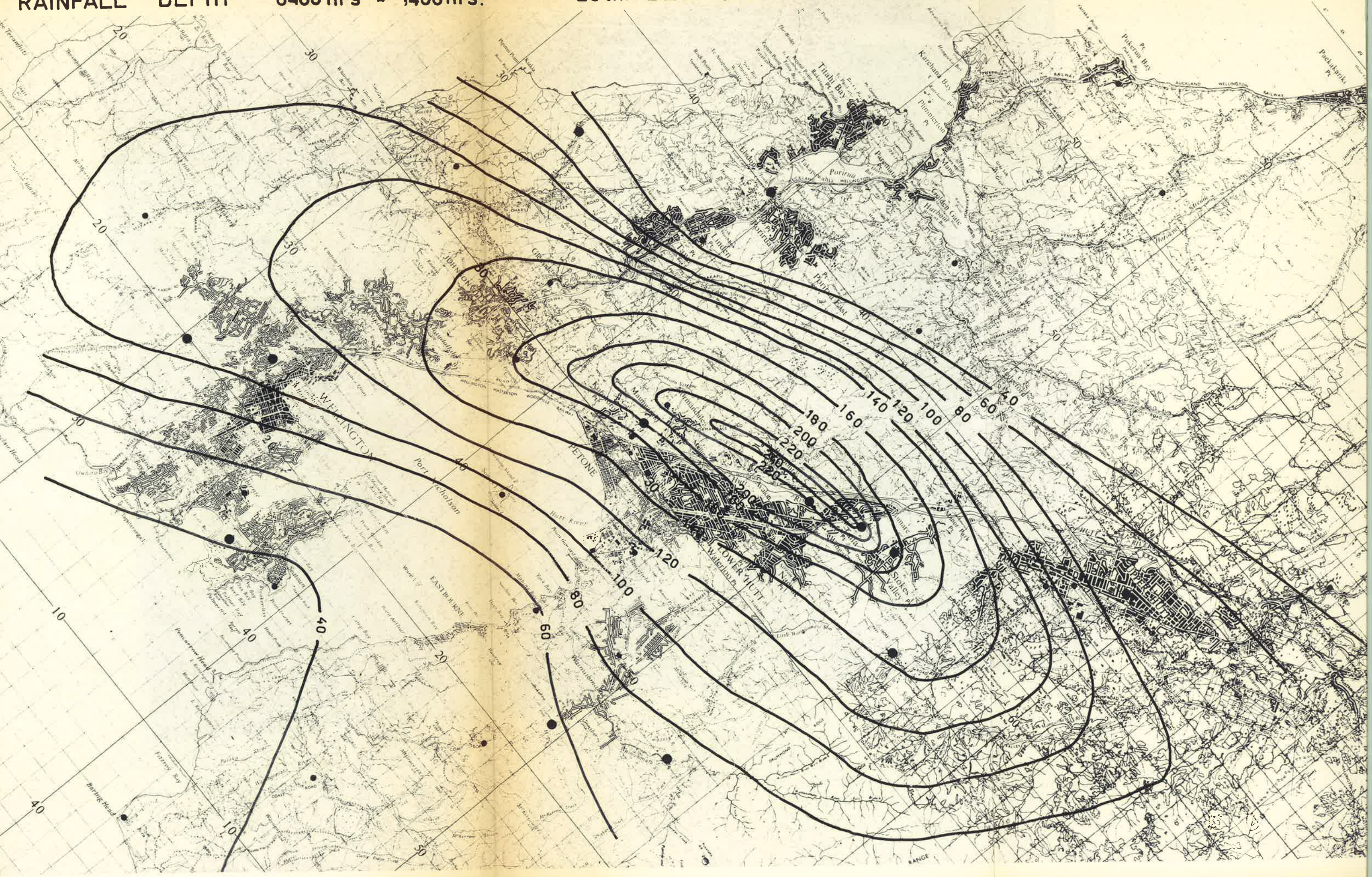
FIG. 2-2-1



RAINFALL DEPTH 0400 hrs - 1400hrs.

20th. DEC. 1976.

FIG. 2-2-2



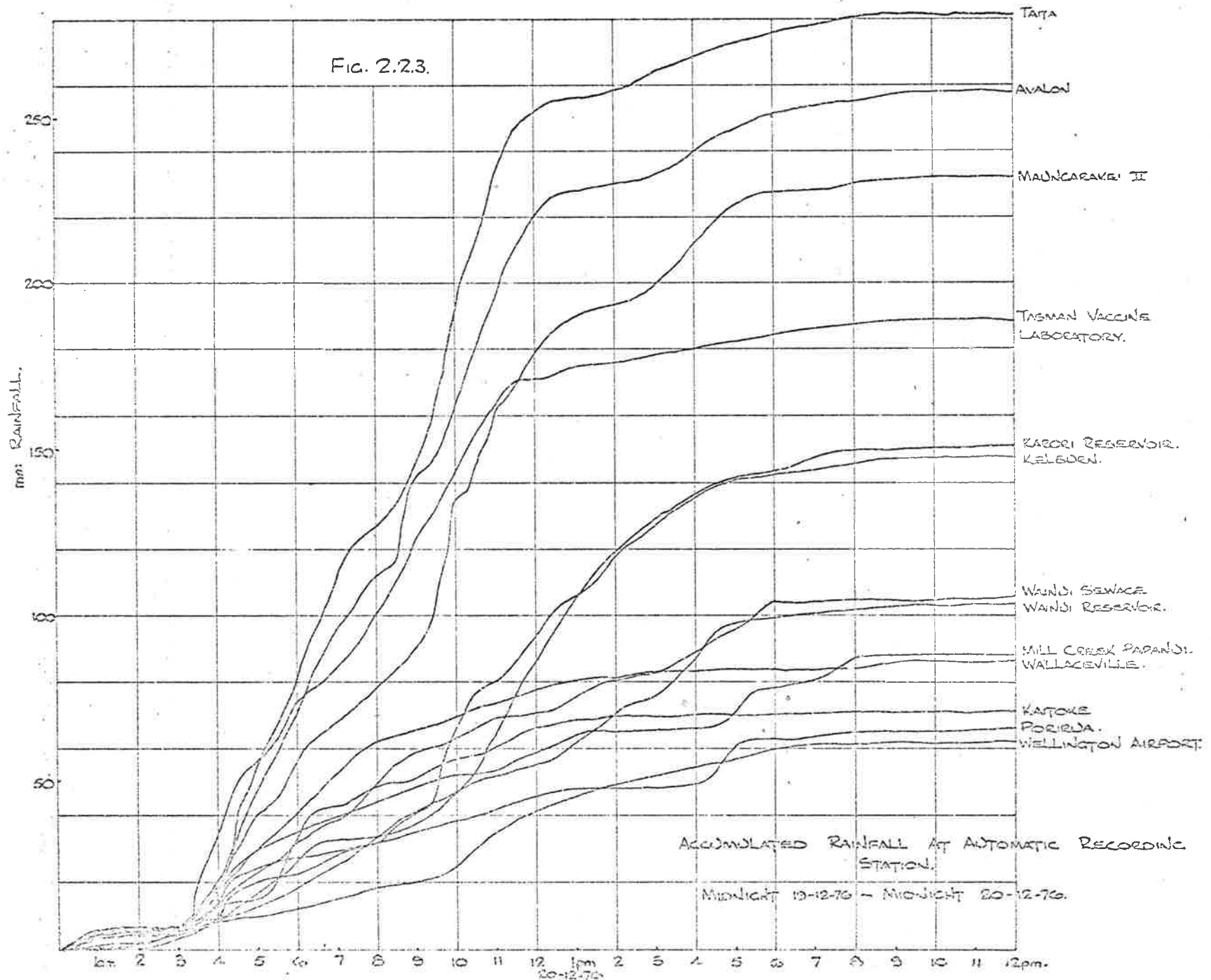
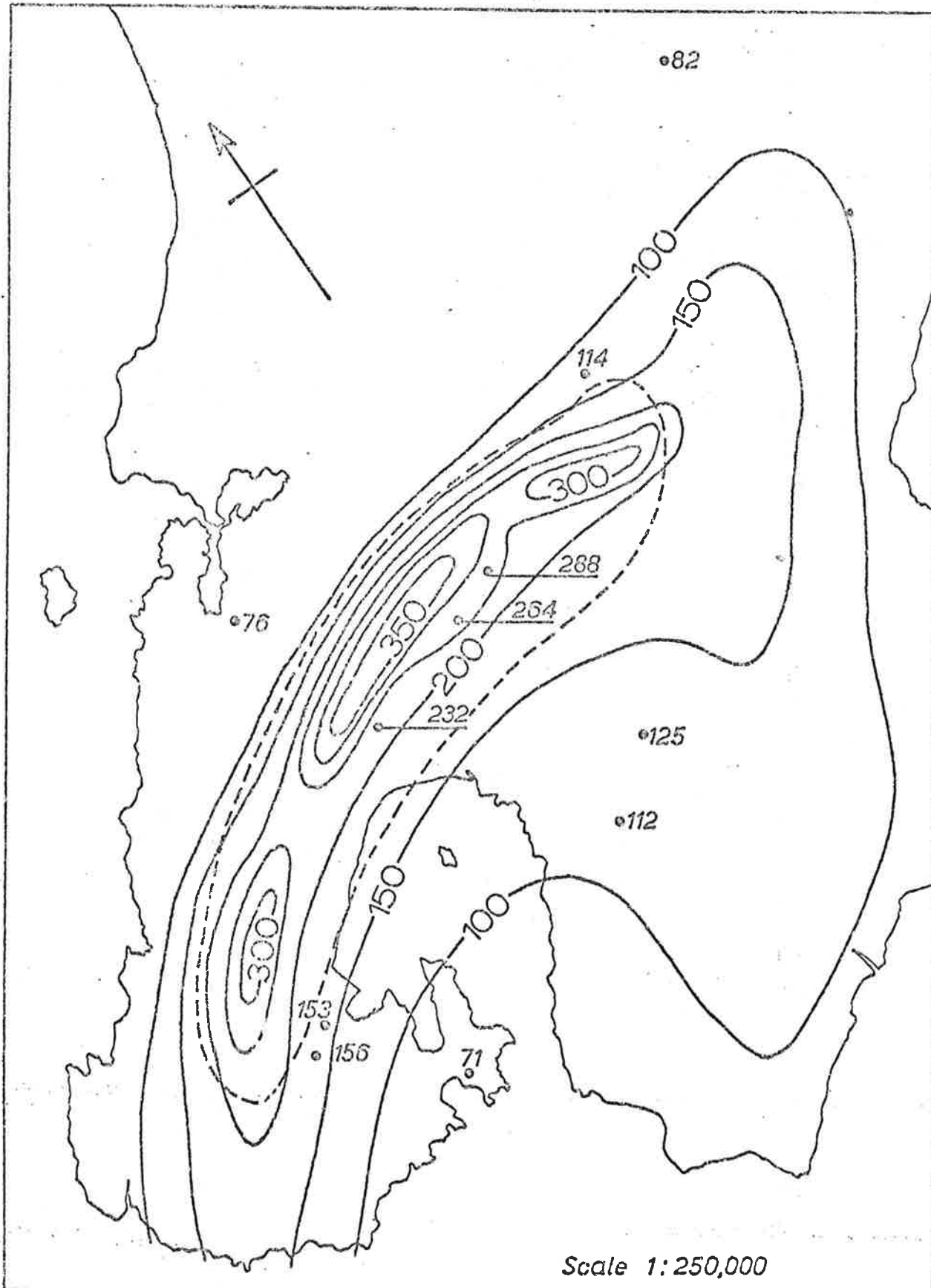


Figure 2.2.4



The maximum rainfall in any 24 hour period during 19 and 20 December 1976. Isohyets are drawn at 50mm intervals from 100mm to 350mm. All points within the dotted line received rainfalls of return period greater than 50 years.

Fig.2 Tomlinson, A.I. 1977 The Wellington and Hutt Valley Flood of 20 December 1976. N.Z.Met.S.Tech.Inf.Circ.154.

2.3 Run-off

After the first three hours of heavy rainfall, all water-courses were running full or had overflowed. Following the renewed downpour after a slight easing of the rainfall, run-off from saturated catchments flooded roads and properties as the capacity of the watercourses was exceeded or as they became choked by debris.

Figure 2.3.1 - shows catchments where estimates of peak discharges have been made. The dashed line shows the area contributing to flow in the Hutt River below Upper Hutt Basin and above Melling Bridge. (The return period of the flood peak in the Hutt River at Lower Hutt was 5-10 years.).

Tables 2.3.1 and 2.3.2 list the catchments and estimates of peak discharges. Estimates of peak flows at Kaitoke, Pauatahanui and Mill Creek are based on discharge rating curves at automatic water level recording stations, operated by the Ministry of Works and Development. These figures are considered to be accurate to at least plus or minus ten per cent.

Peak flow in the Kaiwhara Stream was calculated by Mr. C. Davidson, Consulting Engineer, from data supplied through the Wellington City Council and is considered accurate to within plus or minus 20 per cent.

The estimate for Percy's Reserve was based on spillway flow plus pipe flow for the detention dam with data on pipe flow and ponding volume being supplied through Climie Spencer and Holmes Miller, Consulting Engineers.

Data for the Heretaunga Drain was supplied through Upper Hutt City Council and the Pinchaven estimate obtained by subtracting the drain flow from the estimated flow at weirs downstream of the Pinchaven inflow.

The Taita Catchment No.5 information has been supplied by D.S.I.R., Taita Soil Bureau by Dr. R.J. Jackson.

The remaining estimates in Table 2.3.1 are based on slope area, weir flow or culvert flow measurements. The Porirua measurement was supplied through the Ministry of Works and Development, other measurements being carried out by Wellington Regional Water Board staff. These latter estimates are considered to be accurate to plus or minus 15 per cent.

Data in Table 2.3.2 on the Hutt River is based on flow gaugings by current meter carried out during the flood by Wellington Regional Water Board and Ministry of Works and Development staff. The peak rates of run-off are expressed in cumecs (cubic metres per second) and millimetres per hour. The mm/hour run-off is directly comparable to rainfall intensity in mm/hour. That is to say that the average rainfall intensity over the significant duration for a catchment must exceed, or for 100 per cent run-off equal the peak rate of run-off.

The rates of run-off of about 20mm/hour or higher in Tables 2.3.1 and 2.3.2 indicate rates of rainfall (or intensities) of 25mm/hour or more, a very high figure.

TABLE 2.3.1
REGIONAL RUNOFF ESTIMATES 20.12.76

CATCHMENT OR PART OF CATCHMENT	REF. FIG. 2.3.1	PEAK DISCHARGE (cumecs)	CATCHMENT AREA (sq. kms)	PEAK RATE OF RUNOFF (mm/hour)	EST. RET. PERIOD (yrs.)
Kaitoke		204	88.8	8	
Pautahanui	1	27	38.4	2.5	
Porirua	2	105	41.0	9	50
East Branch Porirua Stream	3	55	4.5	44	200
Mill Creek	4	2.6	9.35	1	
Pinehaven	5	30	4.7	23	100
Heretaunga Drain	6	15	6.5	8	
Stokes Valley	7	34	7.1	17	100
Taita Catchment No. 5	8	.65	0.04	58	200
Upper Waiwhetu	9	25	8.1	11	
Percy Reserve	10	4	0.76	19	
Korokoro Stream	11	90	16.0	20	100 50
Kaiwharawhara Strm	12	80	15.6	19	50

Note 1 cumec ≐ 35.3 cusecs

1 sq.km ≐ 0.386 sq. miles ≐ 247.1 acres

25.4mm/hr run-off ≐ 1 inch/hr run-off ≐ 1 cusec/acre run-off



TABLE 2.3.2
HUTT CATCHMENT RUNOFF

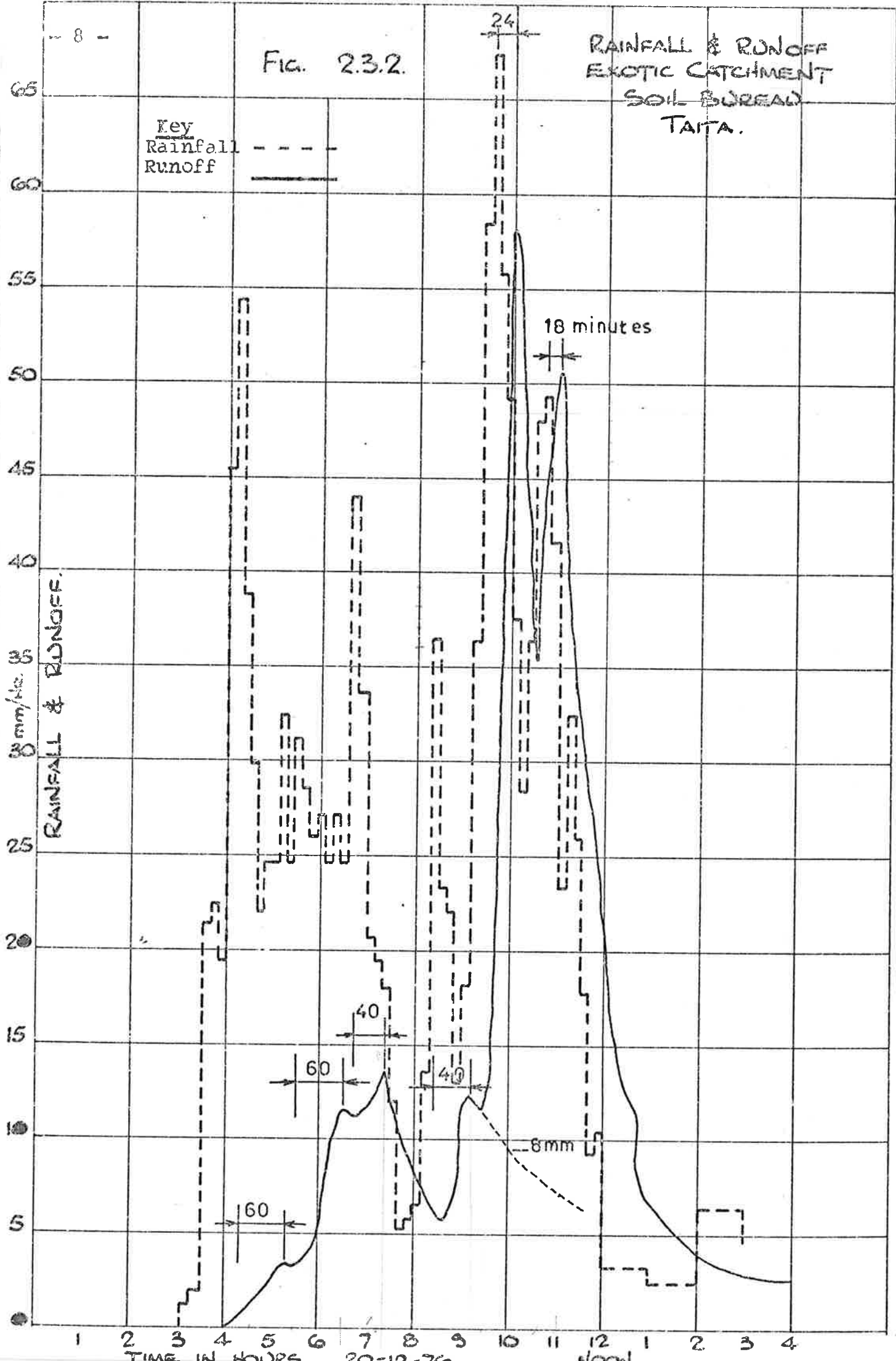
REF. FIG. 2.3.1		DISCHARGE ESTIMATES (cumecs)		CATCHMENT PEAK DISCHARGE (cumecs)	CATCHMENT AREA (sq. kms)	PEAK RATE OF RUNOFF (mm/hour)
A	Flow at Melling Bridge		1190			
B	Flow at Birchville	600		600	427	5
C	Inflow from Whakatikei	110		110	80	5
D	Inflow from Upper Hutt	75		75	35	8
E	Sub Total = B + C + D Flow above Lower Hutt		785			
	Difference = A - E Contribution from Lower Hutt		405	405	65	23

1 cumec ≐ 35.3 cusecs
1 sq.km ≐ 0.386 sq. miles ≐ 247.1 acres
25.4mm/hr ≐ 1 inch/hr ≐ 1 cusec/acre
run-off run-off run-off

FIG. 2.3.2.

RAINFALL & RUNOFF
EXOTIC CATCHMENT
SOIL BUREAU
TAITA.

Key
Rainfall - - -
Runoff ———



A plot of rainfall and corresponding run-off from an experimental catchment at Taita Soil Bureau is shown in Fig. 2.3.2. This is an excellent example of the response of a small catchment to a succession of 'bursts' of heavy rainfall, each having a duration which is significant for the catchment. Although the area is only 4 hectares, larger catchments of a size such as those in the storm affected area will respond similarly. Significant durations will be longer for a larger catchment and intensities lower yielding a lower unit rate of run-off.

There are two major factors affecting peak rates of run-off and both are well illustrated in Fig. 2.3.2. These are firstly, peak rates of rainfall over the significant duration for the catchment and secondly the condition of the catchment at the time of rainfall.

Referring to Fig. 2.3.2 at the onset of heavy rain, a burst of rain at a rate of 54mm/hour occurred. The corresponding catchment run-off peak measured 3mm/hour. A rainfall rate of 44mm/hour occurred at about 7.00 a.m. and this produced a 13mm/hour run-off, a four-fold increase in peak run-off for a lesser rate of rainfall. At this stage, only about 25 per cent of the rainfall had appeared as run-off. After further rain, a burst of almost 70mm/hour occurred and with allowance for some run-off from previous rainfall, say, 8mm/hour, the corresponding peak run-off was 50mm/hour. This represents a peak run-off to rainfall ratio of 0.7 or 70 per cent run-off coefficient. Run-off from the second rainfall period is almost 90 per cent of the total rainfall.

Also illustrated in Fig. 2.3.2 is the reduction in the response time between rainfall burst and run-off peak as the rain continues. This response time is an approximation to the significant duration. Hence the run-off coefficient differs considerably for a 'wet' or 'dry' catchment as does the significant duration.

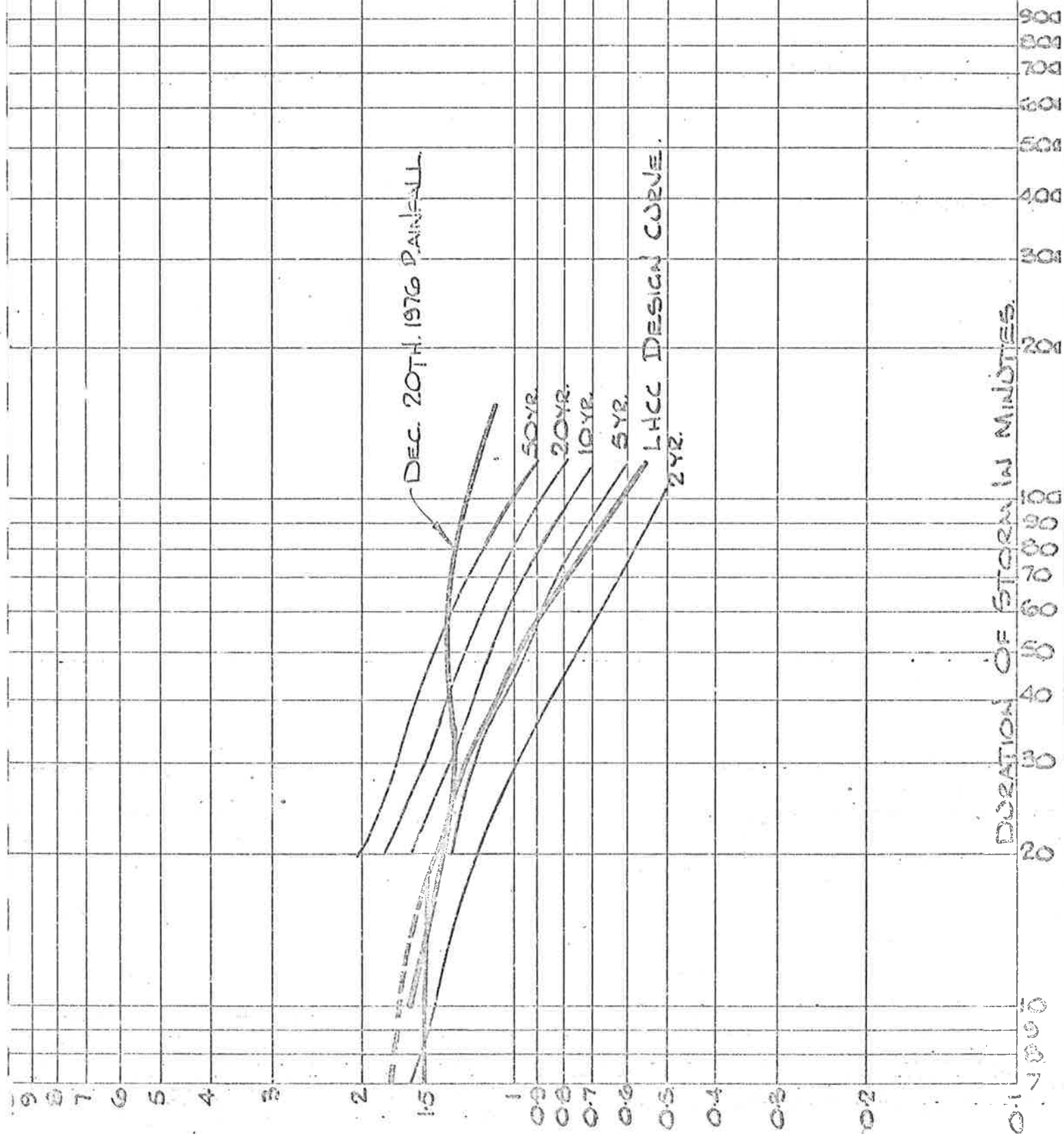
Run-off Design

A common basis for design is to estimate the significant duration for the catchment concerned, select for this duration the rainfall intensity for the chosen return period and combine this with a run-off coefficient. The run-off coefficient is selected rather arbitrarily as an 'average' value, and is generally not varied with different return periods. The Wellington City Council design rainfall curve with run-off coefficient table, see Fig. 2.3.3, is an example of this design procedure. The Lower Hutt City Council design rainfall curve is also shown in Fig. 2.3.4.

The combining of peak rainfall intensities isolated from the general rainfall within which they fell; that is taking no account of antecedent conditions, using an average run-off coefficient unrelated to the catchment condition consequent on the general rainfall, is an unsatisfactory but common approach.

Where the economic consequences of inadequate design may be large, as is often the case in urban areas, a more generous approach to design is warranted, particularly relating to provision to cope with flooding without disastrous consequences when the design storm is exceeded.

FIG. 2.3.4.



INTENSITY (i) INCHES/HOUR.

HUTT VALLEY RAINFALL INTENSITIES.

$$i = 0.9 \times \frac{98}{t^{0.41}}$$

$$= \frac{88.2}{t^{0.41}}$$

Rainfall

Since as early as 1863 (Kelburn) it has not been the practice of the N.Z. Meteorological Service to relate rainfall to general observations of run-off on an official basis. Hence rainfall data alone cannot more than in a general sense be used to determine run-off frequencies.

Table 2.4.3 has been supplied by the N.Z. Meteorological Service and is Table I of N.Z. Meteorological Technical Information Circular 154, Tomlinson, A.I. 1977 - The Wellington and Hutt Valley Flood of 20 December 1976. This is yet to be published. The table lists maximum daily rainfalls recorded at various long term stations, return periods (Gumbel Analysis) and the maximum 24 hour rainfall in the 20 December storm. The rainfall station at Baring Head is included, and Fig. 2.4.1 (Table IV Met. Publication) shows rainfalls observed on 26 December 1939 (the largest known flood in the Hutt River occurred on 18 December 1939). Approximate isohyets have been sketched in. This storm apparently had even higher rainfalls than those on December 20th although it appears to have been smaller in areal extent. Other daily rainfalls exceeding the theoretical 100 year events have occurred at Kelburn, Lower Hutt and Wainuiomata. The average of these maximum daily rainfalls is 190mm (7½ inches) while the average 100 year event is about 200mm (8 inches) per day. At the automatic rainfall stations of Kelburn and Lower Hutt, the records which are used to derive design frequencies, the maximum 24 hour rainfalls have been 157mm (6 inches) at Kelburn and 136mm (5½ inches) at Lower Hutt. At Kelburn with 48 years of automatic records the 100 year 24 hour rainfall is 166mm (Gumbel). This agrees well with the 160mm derived from daily records for 113 years. At Lower Hutt with 28 years of automatic records the 100 year 24 hour rainfall is 160mm (Gumbel). This is the same as the 160mm derived from the daily records for 48 years. Hence statistics derived from the automatic records do not appear misleading in relation to the longer term daily records.

Conclusions from Historical Data

A general conclusion can be drawn from the historical rainfall data. Anywhere within the Wellington-Hutt Valley Region could experience a daily rainfall of 200mm (8 inches) with a theoretical return period of 100 years. Daily falls of greater than 200mm have occurred at least 5 times in the region, within the 113 year period of the record, and the consequences of these rainfalls should be considered in design.

From the relatively scant historical flow information, it can be concluded that throughout the Region some of the watercourses proved inadequate in April 1966 and in May 1974 while in December 1976 many watercourses overflowed at an early stage.

TABLE 2.4.3

ESTIMATES OF THE 50 AND 100 YEAR RETURN PERIOD
VALUES FOR DAILY RAINFALL (mm) AT A SELECTION
OF STATIONS WITH LONG PERIOD RECORDS IN THE
WELLINGTON AREA

	Length of Record (years)	Maximum 1-day Rainfall Recorded (up to 1975)	Return Period		Maximum 24-hr Rainfall in the Dec. 1976 Storm
			50 year	100 year	
Haring Head	40	387*	145	170	-
Beacon Hill	55	156*	150	175	-
Plimmerton	28	112	135	-	-
Brooklyn Reservoir	35	147	150	-	-
Kelburn	113	217	140	160	153
Karori Reservoir	93	161	170	205	157
Trentham	45	146	150	175	-
Korokoro	28	118	135	-	-
Wallaceville	36	127	135	-	114
Waiwhetu	51	162	170	200	-
Lower Hutt	48	126	145	160	264
Wainuiomata	80	320	285	310	125
Orongorongo	48	265	265	285	-

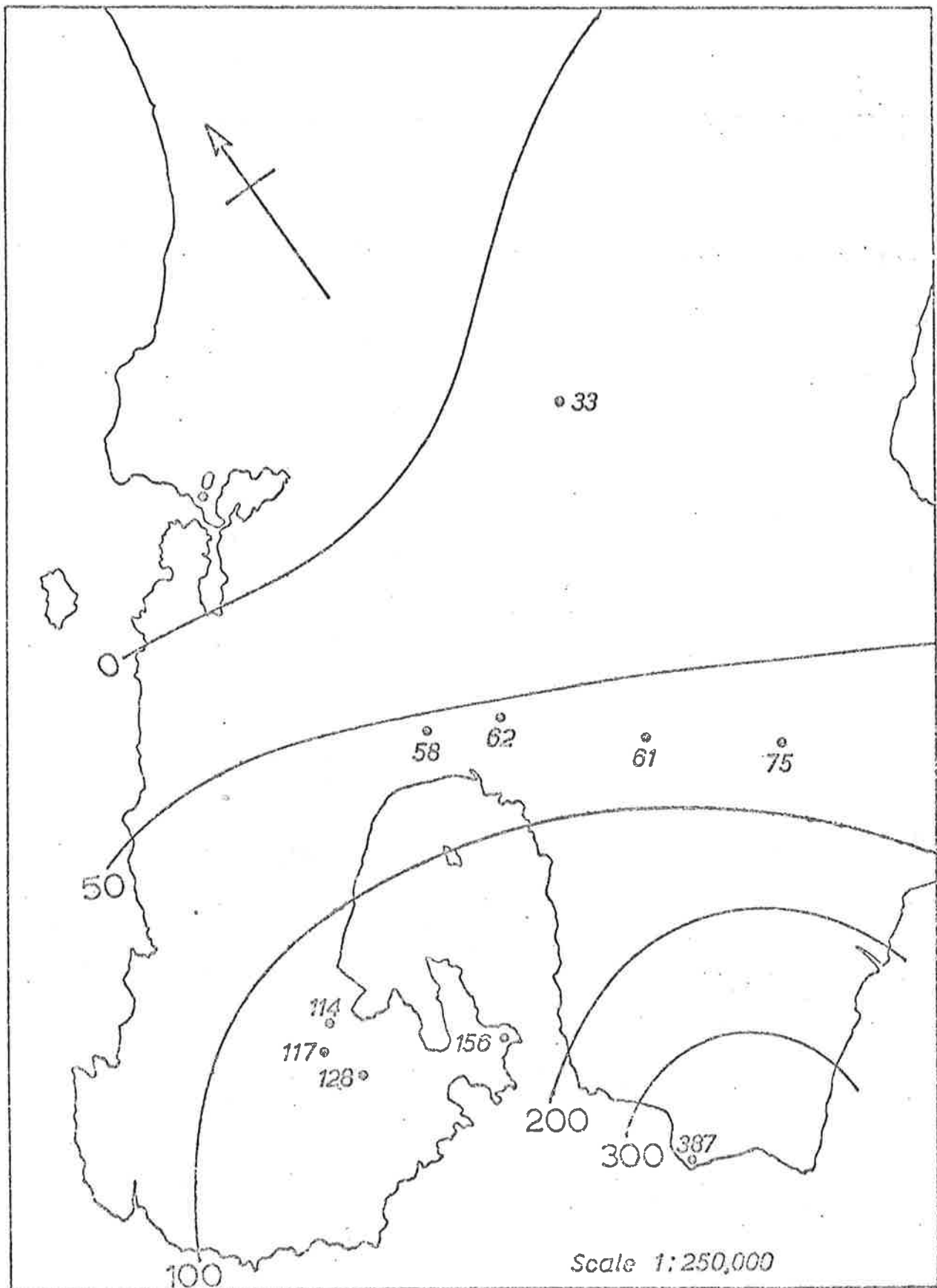
* On 26 December 1939

Note: Daily rainfalls are those recorded each day at 0900 hours and are the total rainfall that has fallen in 24 hours up to 0900 hours.

Maximum 24 hour rainfalls are the largest rainfalls to occur in any 24 hour period.

Table 1 Tomlinson, A.I. 1977 The Wellington and Hutt Valley
from Flood of 20 December 1976.
N.Z.Met.S.Tech.Inf.Circ.154.

Figure 2.4.1



The rainfall recorded between 0900 hours on 26.12.1939 and 0900 hours on 27.12.1939. Since there are relatively few observations the isoyets (drawn at 0.50mm, 100mm, 200mm and 300mm) must be interpreted as very approximate.

Fig.4
from

Tomlinson, A.I. 1977 The Wellington and Hutt Valley Flood of 20 December 1976. N.Z.Met.S.Tech.Inf.Circ.154.

2.5 Statistical Analysis

Discussion on the theoretical return period of the 20 December flood (and associated damage) can only be based on a statistical analysis of available rainfall data as no long term flow record from any of the small catchments is available.

(At Taita flow records are available from 1961, short term. The previous maximum from the exotic catchment was 9.7mm per hour in April 1966. On 20 December 58mm per hour was the maximum flow rate.)

Automatic rainfall records from Kelburn from 1928 to 1975 (note that this excludes the 20 December rainfall) and at Lower Hutt from 1948 to 1975 have been analysed by the Water and Soil Division of the Ministry of Works and Development. The results are shown in Tables 2.5.1 and 2.5.2. There is no meaningful difference between the distributions chosen to model the rainfall observations.

The return periods of the 20 December rainfalls for the various time intervals are summarised below: -

TABLE 2.5.3

Duration	10min	20min	30min	60min	2hrs	6hrs	12hrs	24hrs
Kelburn	6.7	12.0	17.2	29.1	39.9	88.0	125.5	153.0
Return Period	2.33	5	10	50	100	200	200	50
Lower Hutt	6.9	12.3	18.6	35.0	60.6	154.7	230.6	264.5
Return Period	2.33	2.33-5	10	50	200	≥1000	≥1000	>1000

An analysis of the shorter record at Taita 1961-1975 was also done and a comparison made with Lower Hutt for 1961-75. Results are shown in Table 2.5.4. For durations of 60 minutes and over at Taita the return period exceeds 1000 years. The difference between the results at Taita and Lower Hutt may be attributed to the shortness of record and the areal variability of particularly short period intense rainfalls.

The nature of the flood on 20 December is best considered in the light of the 6 hour rainfalls. As catchments became saturated short bursts of rainfall of the significant duration produced peak rates of run-off higher than those that would have occurred from catchments in an average 'wet' condition. High rates of run-off continued for long periods. The amount of debris

deposited and the consequent cost of removal therefore reflect more the duration of rainfall than the peak discharge. Where roadways were scoured this action also continued over long periods. Where the ability of watercourses to discharge was governed by outlet conditions, such as in the Petone area and the Waiwhetu area, inflows over a long period in excess of outflows caused flooding as water ponded, again a condition related to the 6 hour duration rather than the significant duration.

2.6 Magnitude of Event

Hence taking the 6 hour duration as representing the magnitude of the flood a return period, in terms of the data on which design for run-off has been based to date in the region, of 1000 years or more can be assigned to the event of 20 December.

The return period of the peak discharges will be a little in excess of the return period of the rainfall intensity over the significant duration. In the 20 December event the return period can be taken as lying between 50 and 200 years (note that the intensities at Kelburn are lower than for Lower Hutt but that the centre of the storm did not cover Kelburn).

RAINFALL FREQUENCY ANALYSIS - ANNUAL EXTREMES (Depth in mm)

KELBURN E14272 1928-1975

Return Period (Yrs)	Distribution Type	Time Interval							
		10 min	20 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs
2.33	Log Pearson	7.5	10.2	12.6	17.3	24.2	44.3	59.1	79.2
	Log Pearson Adj.	7.5	10.2	12.5	17.2	24.2	44.2	58.9	79.1
	E.V.I. Dist.	7.4	10.3	12.6	17.3	23.9	44.2	59.0	78.5
	Jenkinson	7.5	10.0	12.3	16.8	24.3	43.3	59.7	81.6
	Gumbel	7.4	10.4	12.8	17.3	23.9	44.2	59.3	78.9
	Log Normal	7.5	10.5	12.9	17.6	24.3	44.9	60.1	78.6
5	Log Pearson	8.8	12.4	15.2	20.2	28.2	52.5	71.3	98.3
	Log Pearson Adj.	8.8	12.3	15.1	20.1	28.2	52.4	71.2	98.2
	E.V.I. Dist.	8.8	12.3	15.0	20.1	28.2	52.5	71.1	97.5
	Jenkinson	8.8	12.6	15.4	20.2	28.2	52.4	71.1	100.1
	Gumbel	8.8	12.7	15.6	20.5	28.1	53.2	72.6	98.8
	Log Normal	8.8	12.5	15.4	20.4	28.2	52.9	71.8	98.5
10	Log Pearson	9.9	14.4	17.5	22.7	31.3	59.6	82.0	114.4
	Log Pearson Adj.	9.9	14.4	17.5	22.8	31.3	59.7	82.1	114.5
	E.V.I. Dist.	10.0	13.9	17.0	22.5	31.6	59.4	80.9	113.0
	Jenkinson	9.8	14.7	17.9	23.0	31.4	59.8	81.4	115.2
	Gumbel	10.0	14.7	17.9	23.1	31.5	60.5	83.5	115.0
	Log Normal	9.9	14.2	17.3	22.5	31.2	59.1	81.2	114.0
20	Log Pearson	11.0	16.6	20.2	25.5	34.5	67.2	93.6	131.3
	Log Pearson Adj.	11.0	16.7	20.3	25.6	34.5	67.4	94.0	131.6
	E.V.I. Dist.	11.2	15.5	18.9	24.7	34.9	65.9	90.3	127.9
	Jenkinson	10.9	16.7	20.3	25.7	34.4	66.9	90.7	129.6
	Gumbel	11.1	16.5	20.1	25.5	34.8	67.5	93.9	130.5
	Log Normal	11.0	15.8	19.2	24.6	34.2	65.2	90.4	129.7

Return Period (Yrs)	Distribution Type	Time Interval							
		10 min	20 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs
50	Log Pearson	12.2	19.2	23.3	28.7	37.9	75.8	107.0	150.5
	Log Pearson Adj.	12.2	19.5	23.6	29.0	38.0	76.4	108.0	150.9
	E.V.I. Dist.	12.6	17.5	21.3	27.7	39.2	74.3	102.5	147.1
	Jenkinson	12.2	19.2	23.5	29.2	38.4	76.2	102.8	148.4
	Gumbel	12.6	18.9	22.9	28.7	39.0	76.6	107.3	150.6
	Log Normal	12.1	17.5	21.3	26.8	37.3	71.8	100.5	147.1
100	Log Pearson	13.1	21.5	26.0	31.4	40.6	83.0	118.3	166.1
	Log Pearson Adj.	13.1	22.0	26.5	31.8	40.7	83.9	119.8	166.8
	E.V.I. Dist.	13.7	19.1	23.1	29.9	42.5	80.7	111.6	161.5
	Jenkinson	13.2	21.2	25.8	31.8	41.3	83.1	111.9	162.4
	Gumbel	13.7	20.7	25.0	31.1	42.2	83.3	117.4	165.7
	Log Normal	13.0	18.9	22.9	28.5	39.8	76.9	108.4	161.0
200	Log Pearson	14.0	24.0	28.9	34.1	43.2	90.4	130.0	181.9
	Log Pearson Adj.	14.0	24.6	29.7	34.8	43.4	91.7	132.2	183.0
	E.V.I. Dist.	14.8	20.6	24.9	32.0	45.7	87.0	120.7	175.9
	Jenkinson	14.1	23.1	28.1	34.4	44.2	89.9	120.9	176.4
	Gumbel	14.8	22.5	27.2	33.5	45.4	90.1	127.5	180.7
	Log Normal	13.9	20.3	24.5	30.2	42.1	81.9	116.2	174.9
1000	Log Pearson	14.7	26.2	31.5	36.5	45.5	96.8	140.2	195.7
	Log Pearson Adj.	14.8	27.0	32.5	37.4	45.7	98.4	143.0	197.0
	E.V.I. Dist.	17.4	24.1	29.1	37.1	53.1	101.6	141.8	209.1
	Jenkinson	16.4	27.5	33.6	40.4	51.0	105.9	141.9	208.8
	Gumbel	17.3	26.7	32.1	39.1	52.7	105.8	150.8	215.4
	Log Normal	14.6	21.4	25.8	31.6	44.1	86.1	122.8	186.8
Previous Max.	Depth	13.0	22.0	25.0	31.0	40.0	77.0	134.0	157.0
Dec. 20th Max.	Depth	6.7	12.0	17.2	29.1	39.9	88.0	125.5	153.0

RAINFALL FREQUENCY ANALYSIS - ANNUAL EXTREMES (Depth in mm)

FLOWER HUTT E14195 1948-1975

Return Period (Yrs)	Distribution Type	Time Interval							
		10 min	20 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs
2.33	Log Pearson	7.8	11.3	13.2	18.4	26.0	44.8	57.6	81.4
	Log Pearson Adj.	7.7	11.1	12.9	18.1	25.6	44.3	56.9	81.2
	E.V.I. Dist.	7.9	11.6	13.6	18.3	26.4	45.6	58.4	80.5
	Jenkinson	8.0	10.8	12.8	18.2	25.2	42.1	55.7	84.4
	Gumbel	8.0	11.7	13.8	18.9	26.8	45.7	59.0	81.1
	Log Normal	8.0	11.8	14.0	19.1	27.1	46.3	59.7	82.2
5	Log Pearson	9.8	14.0	15.9	22.0	31.2	53.4	69.3	98.2
	Log Pearson Adj.	9.7	13.8	15.5	21.7	30.8	53.5	68.6	98.1
	E.V.I. Dist.	9.7	14.1	16.0	22.0	31.1	54.5	69.4	97.3
	Jenkinson	10.2	14.2	16.3	22.3	31.7	52.6	69.5	100.8
	Gumbel	10.2	15.1	17.4	23.2	33.0	56.7	72.7	99.1
	Log Normal	9.9	14.4	16.6	22.5	32.0	54.9	70.7	98.6
10	Log Pearson	11.7	16.8	18.9	25.5	36.5	62.5	80.6	112.5
	Log Pearson Adj.	11.7	16.8	18.7	25.5	36.4	62.6	80.6	112.6
	E.V.I. Dist.	11.1	16.1	18.0	24.6	35.0	61.7	78.3	110.9
	Jenkinson	12.0	16.9	19.2	25.7	37.0	61.1	80.7	114.2
	Gumbel	12.0	17.9	20.2	26.6	38.1	65.6	83.9	113.7
	Log Normal	11.5	16.5	18.6	25.2	35.9	61.6	79.4	111.8
20	Log Pearson	13.8	20.2	22.6	29.7	42.7	72.5	93.7	127.4
	Log Pearson Adj.	14.0	20.5	23.0	30.2	43.4	73.5	95.1	128.0
	E.V.I. Dist.	12.5	18.1	19.8	27.2	38.7	68.6	86.8	123.9
	Jenkinson	13.7	19.6	22.0	28.9	42.0	69.3	91.4	127.0
	Gumbel	13.7	20.6	23.0	30.0	43.0	74.2	94.7	127.7
	Log Normal	13.0	18.6	20.7	27.8	39.8	68.4	88.0	124.9

TABLE 2.5.2 CONTINUED

Return Period (Yrs)	Distribution Type	Time Interval							
		10 min	20 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs
50	Log Pearson	16.4	24.4	27.5	34.9	50.5	84.5	109.8	144.3
	Log Pearson Adj.	16.9	25.5	29.0	36.2	52.5	87.0	113.3	145.6
	E.V.I. Dist.	14.3	20.6	22.3	30.5	43.5	77.6	97.9	140.8
	Jenkinson	15.9	23.0	25.5	33.1	48.5	79.8	105.3	143.6
	Gumbel	15.9	24.0	26.5	34.3	49.3	85.3	108.6	145.9
	Log Normal	14.8	21.0	22.9	30.6	44.0	75.6	97.3	139.2
100	Log Pearson	18.7	28.4	32.1	39.6	57.6	95.1	124.1	158.0
	Log Pearson Adj.	19.5	30.3	35.1	41.8	61.1	99.4	130.2	160.1
	E.V.I. Dist.	15.7	22.5	24.1	33.0	47.1	84.3	106.2	153.5
	Jenkinson	17.6	25.5	28.2	36.2	53.4	87.8	115.7	156.0
	Gumbel	17.6	26.6	29.2	37.5	54.1	93.6	119.0	159.5
	Log Normal	16.2	22.9	24.6	32.8	47.2	81.3	104.6	150.4
200	Log Pearson	21.2	32.8	37.5	44.7	65.5	106.6	139.7	172.0
	Log Pearson Adj.	22.4	35.8	42.5	48.3	70.9	113.1	149.2	174.9
	E.V.I. Dist.	17.0	24.4	25.9	35.4	50.7	91.0	114.5	165.1
	Jenkinson	19.3	28.1	30.9	39.3	58.3	95.6	126.1	168.4
	Gumbel	19.3	29.2	31.9	40.7	58.8	101.9	129.4	173.0
	Log Normal	17.5	24.7	26.3	34.9	50.4	86.8	111.7	161.4
1000	Log Pearson	23.4	36.8	42.4	49.3	72.5	116.8	153.6	184.2
	Log Pearson Adj.	25.0	41.0	49.5	54.1	80.0	125.4	166.3	187.8
	E.V.I. Dist.	20.2	28.7	30.1	41.2	59.0	106.5	133.6	195.4
	Jenkinson	23.2	34.0	37.1	46.5	69.6	113.9	150.1	197.1
	Gumbel	23.1	35.2	38.0	48.2	69.8	121.1	153.4	204.4
	Log Normal	18.7	26.3	27.8	36.7	53.1	91.5	117.8	170.9
Previous Max. Dec. 20th Max.	Depth Depth	17.0 6.9	30.0 12.3	33.0 18.6	42.0 35.0	58.0 60.6	107.0 154.7	130.0 230.6	136.0 264.5

RAINFALL FREQUENCY ANALYSIS - ANNUAL EXTREMES (Depth in mm)
SOIL BUREAU TAITA - E 14192 AND AVALON - E14195 - 1961-1975

Station & Return Period(Yrs)	Distribution Type	Time Interval							
		10 min	20 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs
Taita 2.33	Log Pearson	6.9	10.7	12.9	18.2	25.5	46.8	66.7	86.5
	Jenkinson	7.5	11.1	14.0	19.2	26.5	47.4	70.7	94.4
	Gumbel	7.1	10.9	13.0	18.0	25.7	46.5	65.5	86.9
Avalon 2.33	Log Pearson	7.6	11.4	13.5	18.2	27.0	46.2	58.5	87.2
	Jenkinson	7.9	10.7	12.8	17.1	26.1	42.1	56.2	93.7
	Gumbel	8.0	12.6	14.6	19.5	28.6	47.8	60.8	86.9
Taita 10	Log Pearson	10.6	15.6	18.4	24.5	34.8	65.5	94.4	124.1
	Jenkinson	11.0	16.1	18.9	24.6	35.7	66.3	95.4	126.7
	Gumbel	11.0	16.0	18.9	25.1	35.8	67.3	96.4	126.8
Avalon 10	Log Pearson	12.1	17.4	20.0	25.9	39.8	70.2	88.6	120.9
	Jenkinson	12.6	19.9	22.7	28.5	42.6	71.2	91.4	123.3
	Gumbel	12.8	20.6	23.2	29.5	42.9	74.9	94.0	123.5
Taita 20	Log Pearson	12.6	18.1	21.2	27.4	39.6	74.1	106.2	142.9
	Jenkinson	12.5	18.2	21.0	27.0	39.7	74.4	106.1	140.5
	Gumbel	12.6	18.3	21.4	28.1	40.2	76.2	109.7	144.0
Avalon 20	Log Pearson	14.8	23.6	26.7	33.4	48.4	84.0	106.5	137.0
	Jenkinson	14.7	23.8	27.0	33.4	49.7	83.8	106.5	136.0
	Gumbel	14.8	24.0	26.9	33.8	49.0	86.6	108.3	139.3

TABLE 2.5.4 CONTINUED

Return Period (Yrs)	Distribution Type	Time Interval							
		10 min	20 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs
Taita 50	Log Pearson	15.0	21.2	24.4	30.4	45.2	83.7	118.7	164.6
	Jenkinson	14.4	21.0	23.7	30.0	44.8	84.9	119.9	158.5
	Gumbel	14.8	21.2	24.7	32.0	45.9	87.8	126.9	166.3
Avalon 50	Log Pearson	18.2	33.6	37.2	44.8	59.8	101.0	128.9	154.9
	Jenkinson	17.3	29.0	32.5	39.8	58.8	100.0	126.1	152.5
	Gumbel	17.5	28.5	31.7	39.3	57.0	101.7	126.8	159.7
Taita 100	Log Pearson	17.0	23.8	27.1	32.8	49.9	91.4	128.1	182.6
	Jenkinson	15.9	23.1	25.7	32.3	48.6	92.8	130.2	172.0
	Gumbel	16.4	23.3	27.2	34.9	50.1	96.5	139.8	182.9
Avalon 100	Log Pearson	21.4	45.3	49.3	57.4	70.9	116.2	149.5	169.6
	Jenkinson	19.3	32.8	36.7	44.5	65.7	112.2	140.8	164.8
	Gumbel	19.5	31.8	35.3	43.5	62.9	113.1	140.6	175.0
Taita 1000	Log Pearson	21.2	29.1	32.4	37.3	59.2	105.7	145.0	217.7
	Jenkinson	20.7	29.9	32.5	39.8	61.3	118.8	164.4	216.5
	Gumbel	21.7	30.5	35.3	44.7	64.1	125.2	182.5	238.0
Avalon 1000	Log Pearson	28.2	56.8	59.3	69.2	95.9	148.0	193.2	197.2
	Jenkinson	25.8	45.5	50.4	60.3	88.5	152.4	189.3	205.6
	Gumbel	26.1	42.9	47.1	57.2	82.6	150.5	186.4	225.5
Taita	Prev.Max. Depth	12.9	18.3	20.3	28.7	43.2	82.8	103.9	136.9
	Dec.20,Max. Depth	11.2	21.6	28.9	49.9	88.6	180.4	258.5	287.5
Avalon	Prev.Max. Depth	17.0	30.0	33.0	42.0	58.0	107.0	130.0	136.0
	Dec.20,Max. Depth	6.9	12.3	18.6	35.0	60.6	154.7	230.6	264.5

3. EFFECT OF THE EVENT

3.1 On Streams and adjacent Areas

3.1.1 Introduction

The effects of this high intensity rain falling continuously over such a long period were two-fold. Firstly, the high flows exceeded the capacity of culverts and stormwater systems which had been designed in most cases for 5 to 10 year return period storms and others which were unauthorised and under capacity. Secondly, the super-saturation of the soil and weathered rock mantle resulted in landslides which brought down trees and other debris into the already overloaded watercourses. This material blocked culverts completely in many cases and resulted in stormwater and debris leaving the normal channels and flowing uncontrolled over roads and private properties. Effects on areas which suffered major damage are described below.

3.1.2 Pinehaven-Silverstream Area (Map I)

This area is drained by the Heretaunga drain-Hulls Creek which flows from the Trentham Military Camp area and is joined adjacent to Silverstream Railway Station by the then piped main drainage channel from the Pinehaven area. By 4.30 a.m. on 20 December, the stream had exceeded the capacity of the culvert on the Silverstream Railway Underpass, two vehicles being submerged to up to two thirds of their height. By 6 o'clock, the channels in the Pinehaven area were full and water was beginning to overflow onto roadways. Minor slips resulting in partial blockages of streams and culverts began occurring by 7 o'clock and before 9 o'clock several large slips had occurred in the Pinehaven and Elmslie Road areas, completely blocking culverts, filling stream channels, threatening houses in Pinehaven Road and half burying three houses in Elmslie Road.

At the same time, it is apparent (following an aerial inspection of the catchment) that further large slips occurred, particularly in the catchment south east of the end of Pinehaven Road, sending tons of debris down the channels. These earth movements resulted in any flood carrying structures downstream whose capacity was already exceeded, being rendered completely inoperative and the flood waters being forced to find the lowest point by flowing through private property, houses, across streets and finally back into the stream channel.

The extent of the flooding is shown on Map I.

The principal areas of damage due to flooding and debris deposit were Upper Pinehaven Road, Elmslie Road and the low area near the junction of Pinehaven and Blue Mountains Road. It is apparent that the long period of high intensity rainfall resulted in the upper soil layers being saturated to such an extent that the slips mentioned above occurred. It is also apparent that these slips caused debris dams in the catchment, some of which allowed water to build up behind

them until such time as they were overtopped or gave way. This resulted in a surge of water and debris flowing down Pinehaven and Elmslie Roads causing, in the case of Elmslie Road, severe property damage. The Heretaunga Drain channel above the Pinehaven Stream confluence also proved inadequate from a capacity point of view and, although no aggradation and erosion occurred and no major property damage was suffered, the stream flowed around houses in the area as shown on Map I.

3.1.3 Stokes Valley Area (Map II)

Stokes Valley consists of a main catchment draining into the Stokes Valley Stream which runs more or less south-north with a subsidiary catchment known as Tui Glen, draining into a stream which is piped through long lengths at its lower end and joins the main Stokes Valley Stream channel about one third of its length from its mouth at the Hutt River.

Damage in the Stokes Valley area can be generally classified into two types, i.e.

(a) caused by slips occurring in small but steep channels in the Manuka Street/Kamahi Street area, which blocked the piped stormwater culverts progressively down the streets, leaving the flood waters to find their own passage down to the valley floor through private property with further erosion and deposition of material. In addition, run-off from the catchment above Tawhai Street caused erosion of the stream bed with subsequent deposition of the material downstream,

and

(b) general flooding due to the inadequacy of both the piped and open channel stormwater system to cope with the extreme rainfall experienced.

A brief description on specific areas now follows.

3.1.3.1 Tui Glen Area

It is likely that capacity of the stormwater system of Tui Glen was exceeded if it was not already blocked by 6.00 a.m. on Monday 20th.

At this time, Glen Road was a fast flowing torrent flowing across Stokes Valley Road to rejoin the main stream through properties just below the junction. An inspection made after the flooding had subsided revealed that several slips had occurred in the catchment which resulted in deposition

of the slip material on the valley floor as soon as the stream channels which received the slips flattened out or attempted to enter a pipe. A 1050mm diameter concrete pipe culvert some 350m long which was intended to take some of the excess flow from the Upper Tawhai Street area was in the process of construction and these pipes actually floated out of the trench which had been largely backfilled, indicating unfortunately that they contained no water. In one case up Kereru Grove, a catchment of approximately 4ha was drained through a 9" diameter pipe. A slip occurred in this catchment which brought down approximately 100m³ of material. Needless to say, the pipe blocked and all excess water went down the street. At the eastern end of Tawhai Street, where subdivisional activity was proceeding, the deposition of slip material by the stream at the flattening of the grade resulted in severe blockage of the intake to the piped stormwater system and the overcoming of two smaller culverts which had been constructed as access ways to sections across the stream. It is apparent that this stream then rushed down the road and through private property, blocking culverts and aggrading the stream bed as it went.

In Kamahi Street a large slip blocked culverts resulting in water being turned into the street where it flowed down the street, scouring out seal and kerbs. They turned back through private properties into the stream. In Manuka Street, a large slip near the top of the road overwhelmed the culvert under the road and as a result, debris and flood waters were propelled across the road into private property on the low side. This material, together with further material, eroded as the high flood passed down the stream, resulting in the blocking of many more culverts and water finding its own path to the main channel, causing damage to property as it went.

The main Stokes Valley Stream is piped between the back of the Fire Station and the concrete channel at the south end of Delaney Park. A very large catchpit with railway rail grill work had been constructed at the time the pipe was put in and according to observations made by City Council staff, this catchpit coped until about 11.00 a.m., when it became completely filled with debris.

The main channel below the shopping centre proved to be incapable of carrying the flood flows and according to an eye-witness there was 150mm of water across the Rawhiti Street bridge by 6.00 a.m. and debris levels and observations made by others during the peak of the storm indicate that both the Stokes Valley Road bridge and the Thomas Street bridge decks were awash. At the Eastern Hutt Road bridge, the water flowed around each of the slightly lower approaches to the bridge but did not reach the deck. This extremely high level resulted in the flooding of at least 10 houses in the Stokes Valley Road area. At 10.30 a.m. the Service Station at the entrance to Stokes Valley was inundated to a depth of 150mm below the tops of the petrol pumps.

3.1.4 Belmont Area (including Kelson) (Map II)

This suburb of Lower Hutt consists of the developed hillside areas above the Western Hills fault scarp and the small area of residential housing between the motorway and the river below Kelson. There is one major watercourse draining the areas behind the Western Hills fault scarp in this vicinity, namely Speedy's Stream, which enters the Hutt River at the foot of Kelson adjacent to the Belmont School. The rest of the hillside area between Melling Bridge and Manor Park is drained by many small streams draining the plateau area above S.H.2 directly to the river. These streams in general come down very steep channels usually with a gradient in the order of 1 to 1 into pipe culverts under the motorway and the old Western Hutt Road and discharge into the Hutt River. Observations made at 6.45 a.m. on Monday 20th, indicated that already some of these culverts were overwhelmed by the flows. This was not helped by partial clogging of the entrances to the culverts by naturally occurring debris from the channel edges, brought down by these higher flows. Between about 9.00 a.m. and 11.00 a.m. the continuing heavy rain caused several major slips to occur in the valleys, resulting in the complete blockage of most of the pipe systems and the resultant flood of debris and water added to the closure of S.H.2 and caused flooding around some houses and factories in the motorway vicinity. These slips generally had no other effect apart from the ones which occurred to the north of Speedy's Stream above the Belmont on the Flat area. Here severe gully erosion resulted in a slip engulfing a house, completely destroying it. Gully erosion in several others deposited debris in the stream channel blocking the culvert under the motorway, resulting in water and debris filling a low-lying area comprising several houses between the old Western Hutt Road and S.H.2. Drainage from some of the Kelson subdivision passes down some of these watercourses. However, similar gully erosion occurred in watercourses which receive no more drainage than they had 50 years ago. As the rain continued large amounts of mud and silt from the slips and gully erosion flowed across the motorway and onto streets and houses in Belmont on the Flat. Charles Street being the lower street leading to the river was most affected. In this street three houses were flooded to a depth of about 1 meter and the street was left covered with about 300mm of mud and silt. Similar damage was experienced by the houses along Norfolk Street where the flow of surface water down the motorway spilled over the embankment and into these properties. While in some cases some of the culvert entries had small catchpits and grill work, no normally sized catchpit could have coped with the amount of debris which came down these particular gullies.

Speedy's Stream drains a catchment incised into the plateau bounded by Hill Road on the south and Kelson on the north. The stream runs in a very narrow steep sided valley the sides of which are largely undeveloped and covered in scrub. The top on the western side is largely pasture and towards the lower end on the eastern side urban development (Kelson) has taken place. It is apparent from aerial inspection that a considerable number of major slips has occurred in the undeveloped portion of the catchment as well as some below

Kelson. Because of the steep-sided nature of the streams, many of the slips may well have come down and temporarily dammed the stream until such time as the water built up behind them and burst over the top, resulting in a flood wave removing most of the dam and any other similar dams formed by slips below. A flood wave, loaded with a considerable amount of debris, was observed to pass down the stream between 10.00 and 11.00 a.m. completely overwhelming the culvert under S.H.2 adjacent to Belmont School. At this point the water burst over the partially blocked culvert onto the Major Drive S.H.2 intersection as well as through the pedestrian subway on the southern side. The water flowing through the subway caused flooding in the Belmont School vicinity and the rest of the water caused excessive deposition of debris and mud over S.H.2 before it found its way back into Speedy's Stream channel on the downstream side of the culvert where further erosion of the channel took place. While most of the water followed the original channel into the Hutt River, some passed across the Belmont Domain. The fast moving flood waters upstream of the culvert eroded into the steep face of the embankment on Major Drive which Lower Hutt had attempted to stabilise with a gabion retaining wall in recent years. This retaining wall seemed to have held although erosion has now taken place upstream and downstream of it. The watermain which passed across the stream just west of the culvert had the anchor block on the southern side completely washed away and as a result water supply to Belmont on the Hill was cut off until such time as temporary repairs could be made on 22 December. When the culvert blocked Ministry of Works and Development staff were quickly on the scene and were able to clear the culvert face, resulting in the full flow flowing through the culvert before mid-day. This prompt action almost certainly reduced the amount of damage which could have occurred to Belmont School.

3.1.5 Harbourview, Normandale and Maungaraki Areas (Map II)

The Harbourview area drains generally into a deeply incised channel leading into a 54" diameter pipe laid under a very high road embankment and under S.H.2 and the railway line into the Hutt River. A large slip occurred adjacent to the roadway and this together with other smaller slips in the catchment added tonnes of debris to the channel just above the culvert entrance. While this culvert did not block on 20 December, the further heavy rain on the night of 31 December caused this material to be washed into the culvert blocking it and causing an impoundment of water behind the embankment. The use of explosives was necessary to clear this blockage.

A similar situation occurred in main channel draining the Normandale area, which is piped from the first hairpin bend on Miro Miro Road under S.H.2, the railway line and the Alicetown area into the Hutt River. This pipe became blocked at its intake and the resultant flood waters were diverted down Miro Miro Road into Normandale Road, some

passing across the Normandale overbridge, the rest diverting around the side, flooding S.H.2, the Melling railway line and the properties to the east of this. At the same time, a considerable amount of debris was deposited, particularly on S.H.2 and the railway line. The road surface above this pipeline on Normandale Road/Miro Miro Road was scoured out to some depth by the fast moving flood waters.

In the Maungaraki area, flood detention dams installed as part of the subdivisional development operated effectively apart from one notable exception. In the case of the Percy's Reserve Detention Dam, the dam was filled and the spillway operated efficiently with only a small scour hole being developed at the discharge end of the spillway.

The detention dam near the Dowse Drive/S.H.2 intersection failed due to overtopping. This dam had no spillway, but had a high level intake which unfortunately proved inadequate to cope with the flow. It is noted that this is the second time this dam has failed since 1973. Failure occurred on the first occasion during construction of the high level intake. The failure of this dam resulted in the embankment being scoured out and a flood wave of debris-laden water passing across S.H.2 and flooding industrial premises on the Hutt Road, in particular the premises of Clyde Engineering Ltd. on the eastern side of the railway line.

Elsewhere in these areas various other slips occurred and, together with minor gully erosion, caused partial blockages of piped stormwater systems which, in any case, would have been inadequate at the height of the storm.

3.1.6 Waiwhetu Stream (Map II)

The Waiwhetu Stream reacted very quickly to the high intensity rainfall and by 10.00 a.m. was already in a very high stage resulting in the flooding of the garages under the houses on the small private roads across the stream, from the end of St. Ronan's Avenue. Apart from this flooding, there was no other property damage attributable to the stream flooding above the Whites Line East bridge.

Very shortly afterwards the water was already above the soffit of both pedestrian bridges connecting Riverside Drive with Te Whiti Park. Below the Whites Line East bridge the stream rose in the Haywards Terrace vicinity early in the day, causing flooding around houses. Below the Bell Road bridge, the high stream flow together with the extremely high tides associated with the low barometric pressure, resulted in the flooding of Parkside Road in several areas.

However, the principal area of concern with the Waiwhetu Stream was the area between Wainui Road bridge and Bell Road bridge as at about 2.00 p.m. the water was already up to the soffit of the Wainui Road bridge and would have been expected to have gone higher with the incoming tide. At that time the stream was some 200mm above the top of the

low point of the stopbank on the western side just upstream of the bridge and as a result, several houses in the low-lying area of Riverside Drive opposite the D.S.I.R. Chemistry Division were flooded. This stopbank had been constructed as a joint effort between the Hutt River Board and Lower Hutt City in an attempt to protect these houses. A flood pumping station was also constructed. It is apparent that the flood flow of the stream would have overtopped the stopbank whether the pumping station had been operative or not. In fact, of the three pumps in this pumping station, two had been removed to enable maintenance work to be done on the third. The non-functioning of this pumping station did, however, result in flood waters being trapped behind the stopbank well after the level in the Waiwhetu Stream had receded below the stopbank. (See Map II.)

3.1.7 Korokoro Stream

The Korokoro Stream drains a catchment of 1616ha (4000 acres) and runs in a southerly direction into the harbour at the western end of Petone Beach. Following ground and aerial reconnaissance after the flood, it is apparent that on 20 December more than ten large slips occurred in the undeveloped part of the catchment on both sides and because of the gorge-like nature of the catchment below Stratton Street, these slips must have partially or completely blocked the channel until such time as they were washed away by a build-up of flood waters behind the fallen material. At this stage the flood waters would have quickly eroded the slips resulting in a large flood wave carrying a considerable quantity of material, including pine trees, arriving suddenly at the Cornish Street area. This torrent quickly blocked both the bridge and building under the control of Mogal Transportation Ltd. diverting water both down Cornish Street and through the container storage area back to and through the Mogal building, as well as to the north-east through N.Z. Motor Corporation's land. At one stage water over 1 metre deep passed down the right-of-way alongside the old building at the end of the street, causing damage to contents after bursting in a door.

The water level in Cornish Street at one stage was approximately 1.5 metres deep and flooded all the factories and warehouses in Cornish Street. This debris-laden water blocked the three-barrel culvert under the Esplanade overbridge resulting in its diversion to the south under this overbridge and into the sea in the vicinity of the rowing sheds. The water which was diverted through N.Z. Motor Corporation's Yard and the Grand National Hotel flowed across the N.Z. Railways new car despatch yard, the Hutt Road and the Esplanade into the sea opposite Odlin's drying shed. At this point it caused considerable erosion to the foreshore and undermined the Board's 500mm steel Orongorongo watermain causing a bad leak to develop. Inspections both on the ground and from the air indicate that both the old Petone Borough Council water supply dam and the old Petone Woollen Mills' water supply dam were not affected. Prior to the storm, the stream channel including the culverts under the State Highway, the railway main line and the ramp to the Esplanade were in good

condition, having been cleared in May and June of 1976 by Board staff on behalf of the authorities responsible for the various bridges. Above the commercial area, the high flow swept away all the vegetation on the river flats for a considerable distance. This material augmented by trees and debris from slips blocked all the bridges and culverts and in spite of its proximity to the harbour, the general area was severely flooded.

3.1.8 Ngaauranga Stream (Map III)

Following the flooding, an inspection was made of the Ngaauranga Gorge area and, in particular, of all quarries operating adjacent to the Gorge. This revealed that there is little evidence of a large volume of silt and rubble having been scoured from the quarry faces. There is, however, evidence of gully erosion throughout the catchment, the eroded material being caught in the valleys of the quarry floors.

Serious erosion has taken place behind the abattoir where the stream emerges from a narrow channel and turns through 90 degrees. This eroded material was washed into the stream and blocked a culvert, forcing water through the old abattoir building and ground which picked up stacked cases, pallets, timber, bags and materials. This material proceeded downstream and blocked or seriously impeded the entrance to the culvert above the sewage treatment plant, just under the railway overbridge. A large slip also occurred downstream of the railway overbridge and the south-west corner of John Burns steel fabricating factory was undermined by the rapid flow. Debris also blocked or seriously affected the flow through the culvert under S.H.1 which discharges on to the old Meat Works side of the road. These blocked culverts resulted in flood waters being diverted onto S.H.1, flowing down the road and either back into the channel in the vicinity of the traffic lights or else under the S.H.2 bridge into the sea.

3.1.9 Kaiwharawhara Stream (Ngaio Gorge) (Map III)

The high intensity rainfall in the catchment resulted in high stages in the stream. At between 9.00 a.m. and 10.00 a.m. on 20 December two slips occurred near the top of the Ngaio Gorge Road directly into the stream. Photographs taken at the height of the storm indicate that these were contributed to by torrents of surface water flowing over the edge of the road. It is likely that these slips partially blocked the stream causing temporary dams until they were breached and resulting in a debris-laden flood wave down the stream. Flooding occurred in the N.Z. Electroformer's factory buildings including one which had been constructed within the last 12 months. Because of the confined nature of this area the swiftly moving water proceeded to pick up more debris including a large rubbish bin and several cars and washed these further downstream. In the vicinity of a panel beaters,

just above the stormwater tunnel, the flood wave picked up a car, washed it into the channel and slammed it against the entrance to the stormwater tunnel. This car together with accumulated debris effectively blocked the tunnel causing the flood waters to rise behind it and flow across into the tank farm of the Atlantic Oil Co. where it impounded temporarily until the earth bund around the tank farm was overtopped just above the Atlantic Company's yard area. Once this overtopping occurred, fast moving flood waters quickly removed the bund on the downstream side resulting in the complete and rapid flooding of the Atlantic Company's yard area before the water found its way back into the main channel. Further downstream adjacent to the road, the inability of the S.H.1 bridge and the N.Z. Railway bridge to cope with the flood flows resulted in extensive flooding of the area in the vicinity of the S.H.1 Ngaio Gorge intersection.

3.1.10 Karori Area (Map III)

Erosion of the bare surfaces of a large subdivision involving extensive earthworks in the course of construction at Sunshine Avenue resulted in the stormwater drain under Karori Park being blocked with resultant surface flooding. The main Karori Stream channel was unable to cope with the flow and flooded properties in the Darwin Street/Ranelagh Street and South Karori Road areas. In the South Karori Road area the presence of willows and bridges with inadequate waterways would have reduced the capacity of the stream.

3.1.11 Porirua Stream and Tributaries (Map IV)

The band of prolonged high intensity rainfall which caused the flooding and damage in the Hutt Valley also passed across the southern end of the Porirua Stream catchment. Heavy rain was experienced in the Belmont Gully area (the major tributary of the stream) running to the west of Newlands/Paparangi (not to be confused with Belmont in the Hutt Valley). This catchment being an essentially rural and undeveloped catchment did not suffer any notable damage due to the high stream levels. Some flooding occurred in the vicinity of the culvert just north of Downer's Yard which is below the confluence of the Belmont Stream and the main stream from Johnsonville. Flooding also occurred in the yard areas around the houses built in the floodway of a stream north of this culvert. Most suffered only flood damage to back yards although some bridges and services were washed away. The bridge north of the northern entrance to the sewage treatment plant was overtopped although it is likely that one of the two barrels of this culvert was partially silted up before the storm event. Further down the stream, yard flooding occurred around the houses just south of the Tawa Borough boundary. Access bridges and services were also affected. In the Tawa Borough area, the capacity of the channel as it exists was exceeded at several points resulting in minor flooding of yards in the vicinity of Hattricks factory, flooding across the road opposite the

St. Francis School and flooding of the Tawa Primary School grounds. The worst area of flooding on the stream occurred south of the Linden Avenue bridge where several properties in Findlay Street had water in their houses. Others had garages flooded and several private pedestrian bridges across the stream were washed away.

The flood waters covered Linden Park and were generally back in the channel at the Porirua City/Tawa Borough boundary. A sewer crossing of the stream adjacent to Wall Place provided some obstruction to the flood waters by accumulating debris and causing the flood waters to spill out of the channel again at the bend, behind the N.Z. Concrete Research Association's building. This flood water flooded two factories to a depth of 1 to 1½ metres and then found its way behind a private stopbank which had been constructed without authority some months before and which runs from just north of the factories mentioned above to behind the grocery warehouse of Moore Wilson & Co. This stopbank restricted the channel to some degree, particularly at its upstream end causing flood water to build behind it and flow behind the stopbank. Moore Wilson's premises were flooded to a considerable depth and much stock was damaged. The flood waters were finally diverted back into the stream by a tributary just above the Milk Supply Depot. North of this point surface flooding did not occur until the Association Football Club's Grounds. This was contributed to some extent by the choked nature of the channel below this point.

It is relevant to emphasise at this point that the damage and flooding which occurred in the Tawa Borough and Porirua City was due to high intensity rainfall falling only in the upper part of the catchment.

3.1.12 General

The description above of the effect of this storm is limited to the effects on those areas adjacent to or related to the larger watercourses in the area hit by the storm. It should be noted, however, that elsewhere surface flooding of roads and streets and yard areas occurred due to blockage by debris or general inadequacy of piped stormwater systems to cope with a storm of this magnitude. Damage to property also occurred in the Ngaio, Khandallah and Johnsonville areas where culverts became blocked with debris and streams flowed down streets through properties and caused the same pattern of aggradation of stream beds with the eroded material widely deposited as elsewhere.

Throughout the 100 square kilometre area affected by the heavy rain very small streams became raging torrents with an astonishing amount of stream bed erosion.

3.2 On Major Rivers in the Area of the Storm

3.2.1 Hutt River below the Mangaroa Confluence

The river rose slowly throughout the morning of 20 December and peaked at approximately 11.40 a.m. This peak was measured reliably at 1120 cumecs (42,000 cusecs). Following the peak, the river fell slowly against an incoming tide due at 16.50 NZST and dropped further overnight. In spite of newspaper reports to the contrary, none of the flood defences on the Hutt River designed to cope with 2833 cumecs were endangered at any time, in fact above the Melling Bridge, beyond the influence of the tide, the river did not approach the toe of the stopbanks and within the limits of measurement the flow was similar to that recorded on 5 October 1971. After the river had receded, inspections of the channel indicated that there was a small slip on a steep bank opposite the stopbank car park, Lower Hutt City, and the river road which forms a bund on the western side of the Silverstream Cut. North of the Silverstream Road bridge the berm was overtopped, causing a few minor washouts at this point. Minor remedial work will be required in certain areas, involving the planting or re-establishment of willows and a moderate amount of debris on the mowable grass berms will need to be removed before they can be mowed.

Inspections made following the flood indicate that apart from debris removal no extra maintenance work above normal will be required.

3.2.2 The Mangaroa River

Following an inspection after the river had subsided, it was noted that the south-west abutment to the Wallaceville Road bridge was threatened and although the bridge is not in danger at present, some remedial work will be necessary to remove the danger of further erosion at this point. Further up the valley the Narrow Neck Stream abutment was also threatened and while the bridge is not in danger, remedial work will be required. Approximately half a kilometre south of the Whiteman's Valley Golf Course, further upstream again, a combination of a blocked drain on the road causing surface flow of water over the road and a minor attack by the river to the road embankment, which is some 6 metres high, caused a moderate slip reducing the road at this point to one lane. An aerial inspection of the catchment indicates no major slips apart from the ones detailed above although some bank erosion has occurred on private property which will require attention.

3.2.3 The Hutt River above the Mangaroa Confluence

No notable damage was reported. An aerial inspection of the Kaitoke/Te Marua area revealed no major slips or damage.

3.2.4 The Akatarawa River

Bank protection on a property just above the Karapoti Road junction constructed last year under a Board Approval Scheme suffered minor damage and remedial works to be completed as maintenance of that original Board Approval work will be necessary. Apart from this, no other notable damage has been reported or observed. An aerial inspection of the lower end of the catchment was made and no major slips were observed in that part of the Catchment.

3.3 Effect on Recent Subdivisions

It should be noted that only subdivisions that the Board had direct dealings with since its inception and in the path of the storm and in the fringe areas, are reported upon. The report does not cover older and fully established subdivisions.

Subdivision No.1 -- Hazelwood -- South Karori Road

This subdivision was on the fringe of the storm and inspection shows little evidence of slips or erosion. The Armco culvert did not appear to have any great flow of water through it during the storm. There was minor flooding of the properties adjacent to the South Karori Road.

Feast Estates/West Subdivision -- South Karori

Some debris was deposited at the bottom of the cut and fill area but there were no slips or signs of serious erosion on the subdivision itself.

Broad View Subdivision -- South Karori

The existing stormwater system which flowed in an open channel past a silt trap serving the subdivision caused a wash-out which resulted in the wall of the silt trap and all debris from the subdivision being washed into the yards of some flats, the Karori Kindergarten and eventually blocked a 24" diameter pipe through the back of Karori Park. The major damage was the silting of the lawns and gardens of the houses concerned, the Kindergarten, and the complete blocking of the pipeline. When this happened, silt and stormwater passed over Karori Park itself and then into the open drain alongside Karori Park, under the road at the bus turning area and then down past the school.

Pavan Lands Proposed Subdivision -- Silverstream Road, Crofton Downs

The subdivision has not yet started and is subject to Town Planning approval. An existing culvert pipe near the

Silverstream boundary of the property became blocked causing water to flow over ground and wash out the anti-scour pad at the downstream end of the culvert. Serious erosion in the gullies on the steep slopes at the top end of the catchment produced great screes of debris on the valley floor and a considerable amount of material was deposited behind earthmoving machinery which was parked on the property at the end of Silverstream Road. Deep scouring of the gullies on all sides of the catchment occurred.

Ridvan Gardens - Fox Street, Ngaio
(known to the Board as the Kilmister Subdivision)

There is no subdivisional activity started as yet but one large silt trap has already been built and this acted efficiently as a detritus pit and stopped eroded material from being washed down the new streets into Fox Street and Awarua Street. Although the houses and streets suffered, it was purely from water and not silt and debris from the site. Erosion of the gullies is estimated in places to have cut down the existing stream bed by at least 10ft. This particular area is immediately below Mt. Kaukau.

Broadmeadows Subdivision - Johnsonville

This subdivision has been established for two or three years and extensions are at present underway. There is evidence of water damage to streets and other paved areas where velocities were high on steep slopes. A small amount of property damage occurred at the end of streets and run-off from the subdivision caused scouring of bushed gullies above Kim Street with considerable movement of material.

West Park Subdivision - Johnsonville

This subdivision is in the very early stages of construction and does not appear to have caused any problems. The silting of the stream in the area appears to have been soft silt eroded from the area below Kaukau in the Johnsonville Reserve.

Grenada Subdivision - Johnsonville

This major subdivision appears to have been on the periphery of the storm. The Belmont Stream culvert surcharged at entry but no serious flooding resulted. No slips or erosion were evident, although the toe of one fill batter slumped.

Bellvue Lands Ltd. - Newlands

No works started in this area at present but gullies show signs of severe erosion with the deposition of debris at

the bottom.

Residential Lands -
Major Drive - Kelson (new area)

No slips or erosion problems although there is evidence of the slips in the surrounding hills. Observation shows that rainfall intensity is high to the north and east of the subdivision where water has cut deep channels through existing partly formed roads an onto adjacent farmland. Some evidence of a thin layer of silt having been deposited in grassed paddocks.

Lower Hutt City Corporation Subdivision -
Holborn, Stokes Valley

Some wash-out of the silt trap on the eastern slopes descending into Stokes Valley adjacent to George Street evident. A new house site and the roadway were affected. On the western side only, severe erosion has taken place with the deposition of debris at the bottom of the gullies, along the Eastern Hutt Road. No significant slips occurred on this subdivision.

Wellington Education Board School Site - Stokes Valley

Some evidence of erosion in the gully at the toe of the steep fill batter but otherwise the subdivision has not been affected, nor has there been any silt transfer onto adjoining properties.

Kingsley Heights Subdivision - Upper Hutt

This subdivision was probably on the edge of the belt of heavy rain. There is no evidence of major slips or severe erosion, although some silt did enter the drain adjacent to the Upper Hutt City Corporation's Nursery.

Housing Corporation Block - Benge Block, Upper Hutt

No evidence of slips or severe erosion.

Parkdale Subdivision - Akatarawa

No signs of either erosion or silt removal. This subdivision was also outside the path of the band of heavy rain.

James Laurie & Redwood Subdivisions - Tawa

Although outside the path of the main storm, heavy rainfall resulted in some minor siltation of lawns in properties below the subdivisions.

3.4 Effects on Quarries

3.4.1 Ngaauranga Gorge Area

As mentioned above, an inspection of quarries operating in the Ngaauranga Catchment revealed little evidence of large volumes of material having been eroded from the quarry faces. However, erosion further up in the catchment behind the quarries and bank erosion in the vicinity of the main channel caused considerable deposition of material on quarry floors.

3.4.2 Horokiwi Area

The major works in this catchment are the Horokiwi Quarry and the Wellington City Council Horokiwi Tip. Gully erosion extends well back into the hills beyond or toward and beyond Cottle's tip, but apparently no further. Much of the eroded material from the catchment appears to have been dropped either on the floor of the quarry or behind the concrete wall alongside the S.H.2.

3.4.3 Western Hills Quarries (Adjacent to S.H.2)

Slips and gully erosion occurred above River Shingle & Sand (1935) Ltd.'s quarry although there is no evidence that the hard rock quarry faces suffered undue erosion. The flat working floor of the quarry served as a trap to this eroded material, catching most of it and reducing the amount deposited on S.H.2. The newly commissioned waste water treatment plant and the old ponding system have been buried by this eroded material.

Further north at Belmont Quarries Ltd., some minor slips have occurred and some eroded material has been deposited on the flat working areas of the quarry. The access road to the quarry was cut off by slips, but these slips could not be attributed to quarrying operations. Some flood water crossed S.H.2 adjacent to the quarry, because of the blockage of the culvert from the quarry, but no debris escaped therefrom.

3.5 Effects on Roads, Bridges and Railways

As a result of the overloading of channels alongside and culverts and bridges under roads and railways in many areas, together with the terrific volume of debris brought down some of the channels, road and rail communications were severed in numerous places.

Severe flooding of the main access roads to Pinehaven and Stokes Valley in the morning of 20 December cut off road access to both these suburbs to all but high axled four-wheeled drive vehicles. Following the cessation of rainfall, most of this major flooding subsided reasonably quickly to a level which enabled access to be taken by ordinary trucks and other vehicles involved in cleaning up operations. Minor flooding due to blocked drains and sumps up to axle level in many areas of

Lower Hutt City and around Trentham Military Camp resulted in many cars being trapped and access generally being limited to certain areas.

In the Hutt Valley, the main disruption was to the arterial road and rail services which run adjacent to the Western Hills fault scarp. The worst disruption was in the vicinity of Cornish Street where the Korokoro Stream, with all crossings blocked, flowed at depth down Cornish Street, depositing tonnes of debris over S.H.2, washing vehicles away and then washing across the main Hutt Valley railway tracks, removing ballast and damaging cables for signalling equipment.

This flooding and deposition of material resulted in S.H.2 being closed at this point from 9.00 a.m. on Monday until Tuesday afternoon and the railway connection between Wellington and the Hutt Valley being cut from about the same time until Wednesday afternoon. Further north, in particular at the intersection of Dowse Drive below the Maungarakei Dam, underneath the Normandale overbridge, north of Melling Bridge, at Speedy's Creek and opposite practically every channel down the Western Hills fault scarp, the road was either severely flooded and/or buried with silt, gravel and trees to a considerable depth. This resulted in S.H.2 being completely closed until very late on the night of 20 December and then only partially opened over the next two days, while a massive clearing operation was mounted by the Ministry of Works and Development employing just about every front end loader and large earth haulage truck in the Wellington Region. The railway line was also cut in two places between Lower Hutt and Melling by flood waters sluicing the ballast away from below the tracks. This sudden cutting of road and rail communications, particularly on Monday 20th resulted in many Hutt Valley people who work in Wellington being stranded there either overnight or at least until very late on the 20th.

In Wellington City, the S.H.1 was cut practically all day at the Ngaio Gorge Road intersection due to the inadequacy of the bridge and channel to cope with the flow of the Kaiwharawhara Stream. Elsewhere in Wellington City, surface flooding occurred which subsided reasonably quickly following the cessation of rain and the clearing of minor blockages.

Some collapses of unsupported road batters, both above road surfaces and below road surfaces occurred. The most seriously disruptive being two large slips which occurred from below the road near the top of the Ngaio Gorge. These have resulted in the road being limited to one way at these points and will result in an expensive retaining wall having to be constructed to reinstate the road. Elsewhere, slipping occurred from batters above the road and in batters below the road surface. However, it is not considered that this slipping is any worse than elsewhere in the catchments. This problem was not noted on any of the major arterial routes where some extremely high cut batters were able to cope with minor slips on their faces, most of the material being held on the benching. Most of the washouts occurring on roads appear to have been caused by a concentration of surface water run-off running over the edge of road surfaces due to the inadequacy of the stormwater systems, either through blockage or just from the sheer magnitude of the event.

Problems were experienced in some new hillside areas where the road surface immediately adjacent to the kerb and channel was scoured to a depth greater than 300mm in parts by fast moving stormwater rushing down the kerb and channel and the road surface immediately adjacent thereto. The excessive water having to be carried by these channels was to some degree a result of the high intensity rainfall, but in some cases, normal stormwater sumps were being overpassed by the fast flowing stormwater, or blocked, resulting in an ever increasing volume downstream.

Apart from minor undermining of the abutments of two bridges on the Mangaroa/Whiteman's Valley Road, no damage was suffered by any public bridges as a result of the flooding. However, in many areas, private bridges which proved to have inadequate waterways or insecure abutments were overcome and either washed away or damaged. This resulted in access to many private properties being cut off for a period.

Local authorities in the areas concerned, the Ministry of Works and Development and New Zealand Railways were faced with a massive task of clearing many kilometres of road and rail of flood waters and flood debris in an effort to restore the rail and roading systems to full use. By working 24 hours a day in some cases in the early stages, all services were completely restored by Christmas Eve. As a result considerable credit is due to both the staff and workmen of these organisations and contractors, many of whom worked long hours to ensure a minimum of disruption to the anticipated Christmas holiday traffic.

3.6 Effects on Services

3.6.1 Electricity

In the Hutt Valley, two general distribution sub-stations were flooded and power was cut in the Belmont area for most of 20 December. Elsewhere, three other substations serving special industry, such as Malleable Castings, were flooded and silted up and some are still not yet restored. However, as far as the domestic consumers were concerned, all power was restored to all areas by the evening of 20 December. Thus apart from a six hour cut in the Belmont area, there was no general disruption of the electricity supply in the Hutt Valley.

In Wellington, a similar situation occurred. Three sub-stations were flooded and approximately four power poles brought down by slips. There were no widespread power cuts and any interruptions to power were reinstated by the Evening of the 20th.

3.6.2 Water

The Board's own delivery mains were undermined in three places, one at the Esplanade opposite Odlin's factory and also in the Ngauranga Gorge behind the abattoirs and in the Khandallah area. The watermains, however, remained intact.

After flowing over the Petone Esplanade, the Korokoro Stream undermined the 540mm (21 inch) Orongorongo/Karori watermain at the edge of the road. This resulted in a subsidence which broke two gibault joints. The 620mm (24 inch) Wainui main on the Hutt Road was damaged during culvert clearing operations on 22 December. Board staff worked throughout that night to restore the main.

The Kaiwharāwhara pumping station at the S.H.1 Ngaio Gorge Road intersection was flooded and problems were experienced with drying out of switchboards and motors. A recently installed float-operated cutout system had prevented major damage by cutting power to the motors before water reached them, but a motor which had been partly submerged later, unfortunately, burnt out after running satisfactorily for several hours. In spite of these problems consumers were little affected.

In Lower Hutt the thrust block/abutment on the watermain crossing Speedy's Stream and serving the Belmont on the Hill area was undermined and washed away on the south side of the stream. This resulted in water being cut to this area from about 11.00 on Monday, 20 December until repairs were effected restoring water on Wednesday, 22 December. In the meantime, Lower Hutt City supplied residents with water where necessary from tankers. Several private supplies of water from small dams and weirs on hillside streams serving as yet unreticulated areas of Belmont were damaged or destroyed by the high flows. In most cases, residents effected temporary repairs or reinstatement.

In the days following the storm, during the cleanup operations, several watermains ranging from the Board's own 24" main on the S.H.2 to 4" mains in Stokes Valley and three quarter domestic services were accidentally broken by earth-moving machinery clearing streets and channels of flood debris.

3.6.3 Telephone Services

Most people found telephone communication increasingly difficult from about 9.00 a.m. on 20 December. Enquiries made to the divisional engineer of the Post Office responsible for the Wellington/Hutt Valley area indicate that about 30 cables were affected by slips and flooding on that day and that 75 per cent of these were repaired within 2 days.

Of these cable faults only one could be considered to have been a major fault and that was a 3000 pair cable linking Wellington with Lower Hutt which was broken where it runs adjacent to the railway line and S.H.2 over the Korokoro Stream. Considerable delays were experienced in repairing this cable due to the fact that it lay buried for so long and the opening of the railway line and S.H.2 took precedence to repairs to telephone services.

No Exchanges were affected by flooding.

Apart from cable faults it appears that the apparent disruption of the telephone network was a direct result of overloading of exchanges due to too many people making too many calls for too long a period. An immediate relief from this overloading was

apparent following radio requests to members of the public to refrain from making unnecessary telephone calls and for brevity in those which were considered absolutely necessary.

3.7 Effect on Stored Chemicals and other potential Pollutants

As a result of the severe flooding a number of warehouses in Lower Hutt, Petone and Wellington had stock water-damaged and in some cases washed from the warehouses, and some hazardous chemicals were affected.

One store contained plastic drums of high test hypo-chloride many of which were damaged and contaminated with water during the flooding. H.T.H. being a powerful oxidising agent had to be handled very carefully. Board staff arranged for the most dangerous drums to be taken to Cottle's industrial tip where it was fired under strictly controlled conditions. Some which was in not such a dangerous condition was collected and given out to the Hutt County Council to use in Pinehaven for disinfection purposes where sewers were ruptured. A very small amount of H.T.H. was disposed of into the Hutt River or the sea at Petone because the containers had reached a stage where they were about to either burst or ignite.

The warehouse of Park Davis, a proprietary drug manufacturer and an importer was flooded and considerable quantities of drugs were washed out onto the street. The Health Department accepted responsibility for the removal of these drugs after the event as there was a danger that children could have picked them up. Elsewhere in the region other chemicals, including dye stuffs, boric acid, lime and a number of unlabelled and unidentified chemicals were washed out onto the streets and into streams. All these were picked up, salvaged if possible or otherwise disposed of safely at either the Silverstream or Cottle's tip.

Several service stations were flooded. However, all were checked for oil and petrol leaks by Board staff and then by territorial local authorities' Dangerous Goods Inspectors. These did not prove to be a problem.

3.8 Effects on Board Operations - Communications

Problems caused by the effects of the storm led to the declaration of limited Civil Emergencies by Upper Hutt City, Lower Hutt City and Hutt County. Offers of assistance by Board staff were made to the local authorities concerned, but matters affecting the Board's own operations were continued on a normal service basis in the absence of any Regional Civil Defence Organisation. In the early stages some local authorities were unaware of problems arising in adjacent areas. As in the handling of any emergency, little action can be taken from the Central Organisation until accurate information is available from the periphery. In this respect, the value of radio telephone equipped vehicles was borne out strongly.

For a time, telephone communication was not available between Upper Hutt, Lower Hutt and Wellington and with the S.H.2 impassable for long periods at several places between Wellington and Upper Hutt for reasons of flooding and later traffic congestion, Radio remained the only means whereby Wellington based staff could communicate with those in the Hutt Valley. Faults in telephone cables in Wellington affecting senior staff added to problems outside working hours. Overloading of outside trunks at the Wellington City office building meant long delays in making telephone calls from that office. Telephone contact with Wellington City Service Reservoirs remained in all but one case however. The fact that most of the Board's Wellington based radio equipped vehicles are operated through the Wrights Hill repeater station and those based in the Hutt Valley through the Mt. Climie station, resulted in some limitations to communication, but a sufficient number have dual channel facilities to enable contact to be maintained.

Commercial radio stations rendered a most valuable service in broadcasting significant news and for those with portable radios, a reasonable picture of the whole situation was possible.

A further source of information came from staff reading radio messages between vehicles operating other services, and in one case from the use of a Transistor Radio equipped with a VHF band with which many services such as Traffic and Police can be monitored.

As it happened, instances of damage to water supply installations resulting from the storm were few. The main problem is dealing with damage in Wellington City was main roads blocked with traffic which in some cases prevented service vehicles reaching the site of the damage. In the Hutt Valley flooding and debris on roads was the main limiting factor in service vehicle movement.

Communication Summary

The tremendous importance of the normal Post Office operated Radio Telephone Service was amply borne out during the emergency. Commercial radio stations rendered a valuable information service. This means of presenting an accurate overall picture to service personnel affected, as well as the public should be exploited to the full and means of keeping at least one station operating in an emergency such as a severe earthquake to supply accurate general information must have high priority.

Knowledge of which roads are available to service vehicles is essential, and it may be necessary for certain vital organisations to have emergency access to a Traffic Department channel set up for the purpose.

NOTE: The above comments relate only to experiences of Board staff and do not purport to cover the Civil Defence operations as a whole.

4. ECONOMIC IMPACT OF THE STORM

4.1 General Description of the Damage

The storm caused widespread damage to property and disruption of communications, giving rise to a cumulative breakdown in the economic functioning of the region during the storm, and a diversion of productive effort into clean up and repair work after the storm. Attempts were made by householders, commercial firms and roading and other servicing authorities to minimise damage and disruption but the magnitude of the flood flows overwhelmed these efforts. The rail service was put out of action, and although alternative public transport services were provided where possible, many people were cut off from home or work following the complete severing of the main routes of the transportation network.

The economic costs of the storm are only part of the costs. They exclude any accounting of the strain, worry, inconvenience, unsightly damage and environmental disruption caused by the storm. There was also one life lost as a direct result of the storm. The total economic cost is, however, much more than the direct damage to property and extra servicing costs. The breakdown of the communications system, the diversion of effort into cleaning up and repair and the closing down of operations and the inability to undertake work until damaged machinery and equipment is repaired or replaced, all give rise to lost production. The repair and replacement of damaged property implies a diversion of goods and services, that would otherwise have been available for other uses, into returning the Wellington Region to its condition prior to the storm. The damage caused by the storm

thus has widespread and longer term economic impacts through the economy because of these linkage effects.

4.2 Damage to Property and Services

The direct financial cost of storm damage, as far as could be determined from present estimates, is given in the table below.

<u>Damage to Property</u>	<u>\$ (Thousands)</u>
MWD responsibility	25
Education facilities - C.I.T.	50
High Schools	minor
Primary and Intermediate Schools	100
Health facilities - Hospital Board	300
Others	*
Housing Corporation	10
Other Government Departments	*
Local Authorities (mainly Parks and Reserves)	359
<u>Private Property</u>	
Private Insurance cover	
- The Insurance Council collected a rough total of \$5.0M. Total figure unknown but expected to be higher.	5,000 +
Earthquake and War Damages Commission	
Flood damage claims at 18.1.76 348, 62 claims assessed at \$3,017,000	
Landslip damage claims at 18.1.76 81, 18 claims assessed at \$68,000. By 20.1.76 about 500 claims, total probably around \$10.0M.	10,000
Uninsured	1,000 +
Total claims on aid fund are nearly \$1.0M. This excludes most damage to gardens etc. which could double this figure.	
<u>Damage to Services</u>	
Roading	
- State highways	491
Local Authority roads	798
Railways	
- Clean up and repair	100
Alternative transport (very approximate estimate)	20
Post Office	35
Electricity	
- NZED services	*
Local distribution services	*
Local Authorities and Regional Water Board	
- Removal of blockages Channel clearing and restoration	410
Local authority services	429
<u>Emergency Services</u>	
Civil Defence (emergency aid and clean up)	53
Others (Police, Traffic, Fire, Ambulance)	*

TOTAL ESTIMATED 19,180

* not available at time of writing report.

4.3 Cost Sharing

The funding of repair and replacement costs depends on the level and type of insurance and the controlling authority. Damage to Government property and other assets is covered by the particular department or local authority responsible, and extra servicing costs must be carried by the respective authorities. For damage to private property insurance companies cover all flood damage costs up to the limit of water damage cover provided in the particular policy. The Earthquake and War Damages Commission (E and WDC) pays out on damage not covered by the insurance companies up to the total insurance liability (normally a fire risk cover). The E and WDC also pays for landslip damage to houses. The uninsured and uninsurable damage must be carried by the property owners.

All economic loss from lost wages or lost production must be carried by the individuals and firms concerned. The time spent by people cleaning up their houses and gardens may involve a loss of wages due to time taken off work or a loss of leisure time. The economic gain firms would have been able to make through the 'value added' by their production or servicing efforts if the storm had not occurred is generally an unrecoverable loss.

The loss covered by insurance or by Government agencies is always less than the direct financial loss incurred as a result of the storm, and this direct financial loss is less than the total economic loss which affects all persons in a particular commercial chain of operations and ultimately the National economy.

The prevention of storm damage involves a cost sharing but a different sharing to that arising from storm damage. The primary responsibility for ensuring that subdivision plans and the siting of buildings take proper consideration of drainage and flood routing lies with local authorities. This planning may or may not increase the development costs incurred by private developers or public development agencies. Remedial measures designed to reduce an existing flooding problem may attract a central government subsidy. The share of the cost that must be raised by the locality affected by the remedial measure may be obtained through local authority rates or agreed shares if agreement can be reached on a suitable division of costs. Without such agreement the local share can be raised through a special rate but this rate must be based on a classification according to benefit calculated in terms of the degree to which the flooding potential is reduced, unless the Wellington Regional Water Board agrees to contribute on a regional basis.

If remedial measures are carried out to reduce flooding and the local share is obtained from a classified rating, the people affected by flooding rather than those responsible for it may be carrying the cost. This is especially so if the flood problem has been greatly aggravated by urbanisation further up the catchment. The flood prevention

measures are, then, in reality measures required for the proper disposal of stormwater originating from the upstream improved sections.

The subsidy assistance for flood prevention measures in urban areas is less than for similar measures in rural areas. The damage sustained in rural areas is mainly uninsurable losses - fence damage, stock and crop losses etc. In urban areas a large proportion of the damage is normally covered by insurance but the Earthquake and War Damages Commission often carries a lot of the cover. This is possibly due to firms taking out water damage cover only up to a level they feel necessary to cover damage from events not classed as 'extraordinary' and, therefore not eligible for Earthquake and War Damages Commission cover. Central government has thereby accepted liability for a major proportion of damage sustained in urban areas, while providing greater assistance for flood prevention in rural areas.

The greater subsidy assistance in rural areas is based partly on the desire to stimulate agricultural production, the subsidy being a means of providing investment finance to the agricultural sector. The importance of agricultural production for export earnings means investments in this sector have substantial ramifications throughout the economy justifying investment aid. Flood damage in urban areas can, however, have similar detrimental effects on economic production. Damage solely confined to residential areas still directly affects the total economic well-being of the nation by diverting goods and services into this area to rectify the damage and thus withdrawing them from other uses.

When there is widespread damage, as in this storm, the sudden increase in demand for goods and services required for reconstruction can add significantly to inflationary pressures. This is especially so if there are difficulties in reducing expenditure in other areas to divert purchasing power into the area. Remedial and prevention activities can be spread over time and properly budgeted for. The less the damage caused by unpredictable natural events with exceptional damage potential, the less need there is to find large amounts of money quickly.

There is thus a strong case for the increase in the rate of Soilcon Subsidies in the urban area as losses in this sphere can be of even greater moment to the National economy than damage in the rural sector.

5. EXTENT OF SLIPPING

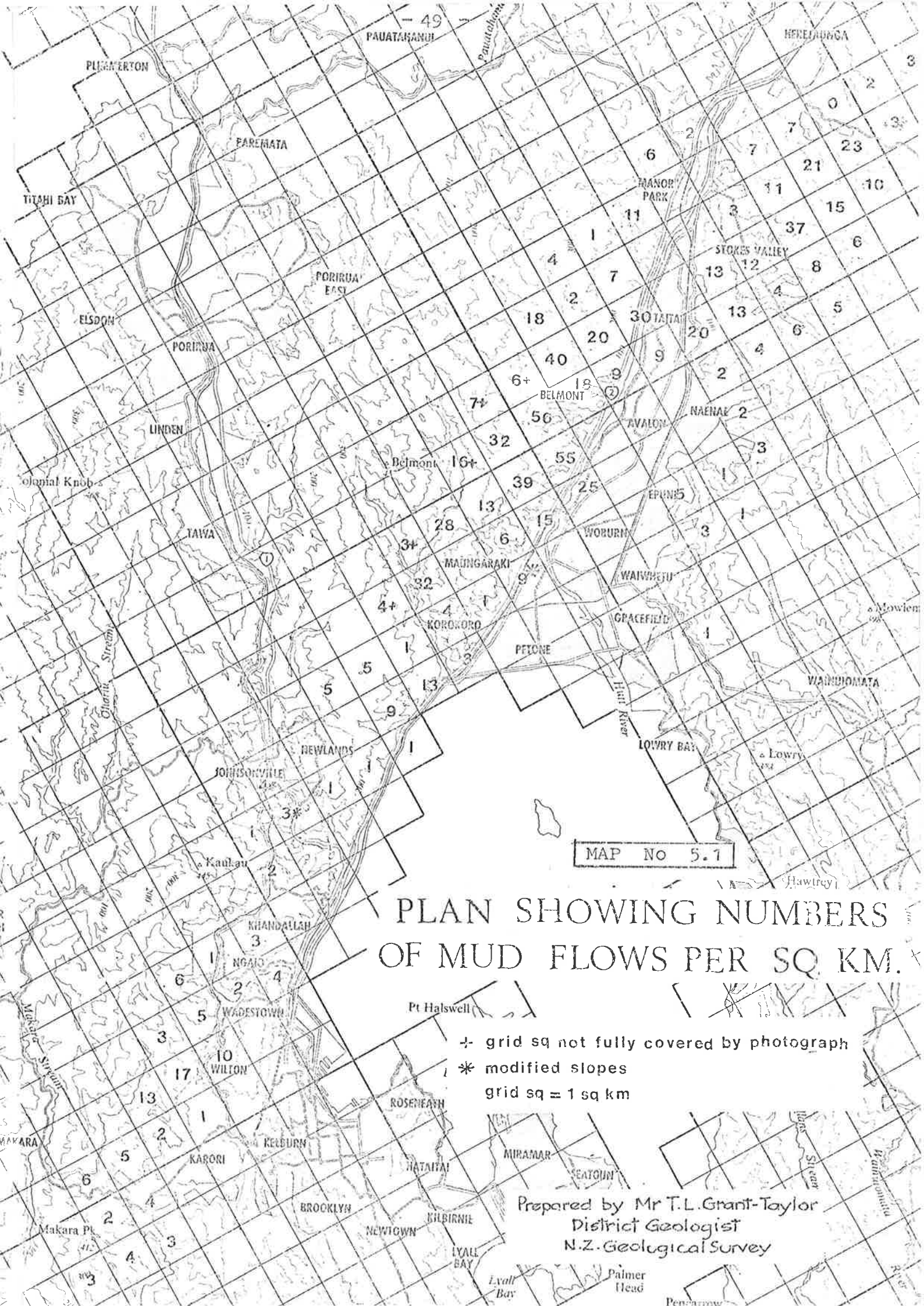
The storm caused extensive slipping, more correctly described as mud flows, and collapses of mud banks in urban areas. The area affected stretched from Haywards in the north-west along the watershed west of Belmont, through Newlands to the north of Johnsonville, west of Ngaio to Makara, to Karori West, Wilton, Wadestown, to 600 metres north of Pt. Howard, to Twhai Trig on the Eastern Hutt Hills just west of the watershed of the Eastern Hutt Valley, behind Naenae to Wingate, across Stokes Valley, Upper Pinehaven, middle of the Blue Mountain Road and to the side ridge north of the rifle range. There were no slips on the Wallaceville Road side but some occurred on the east side of the Mangaroa Range. There were none from there to Narrow Neck on the Whiteman's Valley Road but again, a considerable amount of slipping occurred about 400 metres to the west of High Misty. The peaks of damage occurred at Pinehaven and Stokes Valley at the mid point on the ridge where there was a density of about 180 slips in 9 square kilometres, Belmont with 290 slips in 8 square kilometres and at Karori where about 30 slips occurred in 2 square kilometres. These areas of high density natural slope were separated by areas otherwise rather similar with much less damage.

From the aerial photographs produced by the Board, Mr. T. Grant-Taylor, District Geologist of the N.Z. Geological Survey, has produced a map showing the number of mud flows as he prefers to call them per square kilometre over the affected area. (See Map 5.1 attached). Mr. Grant-Taylor has also supplied the following comment: -

"The debris that moved in the form of mud flows affected colluvium and loess. Rock falls and slumps occurred only in the formal sense from modified slopes. This event has produced effects on the landscape that appear to be similar to features now completely vegetated. Ancient scars with the same outline are visible in grassed areas. These show different degrees of rounding suggesting several generations of similar events.

The pattern of distribution of the sources of the mud flows not only during this storm but also from past events indicates that on natural slopes the sediments at greatest risk are poorly consolidated loess and colluvium on slopes that may be as flat as 20 degrees, and are sited in pre-existing hollows. These hollows form part of the headwaters of streams so that the debris from the mudflows in the rural setting was confined entirely to identifiable watercourses.

The collapses that led to the mud flows occurred only after a considerable degree of saturation of rather poorly permeable sediments had been reached and the water content was obviously such that the debris flowed like a liquid rather than the conventional slip. In the urban setting modification of the landscape had produced many unstable faces with unsupported incoherent sediments at the top at batter angles often unduly steep even for rock and excessively steep for



MAP No 5.1

PLAN SHOWING NUMBERS OF MUD FLOWS PER SQ. KM.

- + grid sq not fully covered by photograph
- * modified slopes
- grid sq = 1 sq km

Prepared by Mr T.L. Grant-Taylor
 District Geologist
 N.Z. Geological Survey

the incoherent cover.

The widespread topographic modifications altered the drainage pattern and obstructed high flood spillways on which there were culverts which became blocked with debris, causing overflows into steep roadways, many with unprotected verges, which were consequently deeply eroded and shed water and debris in quite unnatural routes which further aggravated damage. "

The N.Z. Geological Survey are preparing a detailed report on the slips which should be available in the near future.

The numbers of slips or mud flows shown on Map No. 5.1 are essentially those occurring in the rural area except in a few cases marked by asterisks where slips modified by subdivisional activity have been included. When the rainfall patterns are examined together with the incidence of slips it is seen that slips are most frequent in the zones of continued high rainfall from which it might reasonably be deduced that ground conditions and ground cover were less important factors. This point requires further detailed examination which it is hoped the Geological Survey will be able to make, but if it is so, a deduction which might be made is that the rainfall in the Belmont/Normandale area where the slips were greatest in number, might have received a higher rainfall than the rainfall diagrams indicate. The rainfall diagrams, however, are based purely on rainfall data and are the most accurate that can be produced from the rainfall intensity data which is available.

6. ADMINISTRATION OF WATERCOURSES

Until the formation of the Wellington Regional Water Board, responsibility for the control of watercourses in the Wellington Region was divided among the local territorial authorities, the Manawatu Catchment Board, the Hutt River Board and latterly the Porirua Stream Management Committee.

On its establishment, the Board took over responsibility for maintenance of certain rivers and streams which by arrangement with local territorial authorities had previously been accepted by the Manawatu Catchment Board and the Hutt River Board. Apart from the Hutt River and the Waikanae River, these were:--

- The Waiwhetu Stream, from the mouth to the end of Waddington Street.
- Black Creek, for which the Board pays Lower Hutt City three quarters of the cost of maintenance. Maintenance work is being undertaken by Lower Hutt City.
- Stokes Valley Stream, from the mouth to the confluence with Tawhai Stream.
- Waimeha Stream, Waikanae.

Subsequently, the Board on request assumed the function of the Porirua Stream Management Committee and agreed to continue to employ a Consultant to report on a flood control scheme for the Porirua Stream.

The intention of the Soil Conservation and Rivers Control Act 1941, although it is not specifically so stated, is that Catchment Boards should control watercourses in rural areas, but that powers to control watercourses in urban areas may be delegated to local territorial authorities. While these local authorities do have powers under the Municipal Corporations Act 1956 and the Land Drainage Act 1908, their delegated powers would be a little wider under the Soil Conservation and Rivers Control Act. Discussions have taken place during the past year between Board Officers and those of local territorial authorities with a view to determining which watercourses should be administered wholly by local councils and which should be administered by the Board. This matter has not been completely resolved as yet and local territorial authorities have continued to administer watercourses within their boundaries with the exceptions listed above. It must be realised that while the Board may delegate its functions, it still retains an overall responsibility.

Administration of watercourses includes the following matters: --

- (a) Approval of waterway dimensions under bridges and of any necessary bank protection upstream or downstream of the structure.
- (b) Approval of culvert dimensions and any inlet or outlet structure or protection work associated with the culvert.

- (c) Ensuring that the waterway is kept clear and that rubbish and other material is removed from both the banks of the stream and from any bridge or structure crossing the stream.
- (d) Dealing with erosion. This involves advising an owner what he may do to correct erosion. Any work authorised must not affect the waterway or cause any deleterious downstream or upstream effects.
- (e) Organising schemes to prevent flooding where warranted, by improvements to the watercourse.
- (f) Ensuring that buildings are not built on sites subject to flooding caused by storms of predetermined intensity.
- (g) Preventing planting which would reduce the efficiency of the watercourse.
- (h) Preventing removal of vegetation which might lead to erosion.

The financial responsibility for keeping streams clear lies with the property owner, unless the local authority relieves him of that responsibility by special agreement.

There is provision under the 1959 Amendment to the Soil Conservation and Rivers Control Act for action to be taken with the authority of the Soil Conservation and Rivers Control Council to prevent actions which are likely to cause landslip or deposits in watercourses where these effects can be foreseen.

Actions taken in upper catchments which may increase the rate of run-off are not covered very well by legislation. If such development is permitted by District Planning Schemes, then an increased rate of run-off must follow and owners of properties on which streams are sited are assumed to have anticipated such increased rates of flow and must accept it.

The problems with administration of watercourses in urban areas lies in the fact that application of the eight matters listed above (which are not exclusive) involves controlling the actions of property owners to a greater extent than many are prepared to accept. There are many cases where undersized bridges and culverts have been placed without authority, trees planted in such a way that flow is obstructed, walls and other structures built so that stream capacity is reduced. The effects are aesthetically pleasing to the property owner during periods of low flow but result in a lowering of hydraulic efficiency and indicate a lack of realisation that the main purpose of a watercourse is to carry water during periods of rain.

On the other hand, insufficient attention has been paid by urban authorities to examining stream capacities and in advising owners what their responsibilities are. In some cases, culvert dimensions have been approved which do not allow for subsequent subdivisional development upstream. In seeking to rectify this

problem, when development upstream does take place, local bodies find themselves legally restrained from spending public money on private property.

As is being found in certain areas, the establishment of a stream capacity adequate to take major floods may mean the removal of large numbers of trees and the construction of a concrete lined channel which may be efficient, but will not be regarded as beautiful.

The difficulties inherent in stream control in urban areas point to the desirability of planning so that important streams are in public reserves where the necessary maintenance can be carried out without inconvenience to property owners. This involves the design of flood channels and the establishment of reserves for them well ahead of urban development.

It must be remembered, however, that in the design of stream channel capacity, a particular intensity and duration of rainfall is allowed for. This may occur on average once every ten, twenty or fifty years. When this capacity is exceeded, flooding and damage is likely to occur. The value of such damage when the design event is exceeded must be based on a careful assessment of what is at risk and not on a rigid rule approach. Attention should be given to at least making provision to minimise damage should the design event be exceeded by planning to prevent the establishment of high value construction in the likely path of a flood.

Inevitably the watercourses in an urban area become affected by urban development whereby stormwater systems alter patterns of run-off until finally few surface streams exist. How effectively this is done and the magnitude of the event that can be coped with depends on the design of the stormwater systems. Surface flooding where it occurs is an important factor in sewer infiltration and hence in the design criteria for sewers. It is significant, therefore, that while Government subsidies are available for water supply, roads, sewerage and other matters, subsidies for all important stormwater systems are conspicuous by their absence.

7. FUTURE ACTION IN CONNECTION WITH MAJOR STREAMS

7.1 Porirua Stream

Work by the Board's Consulting Engineers has been proceeding for a considerable time but the preliminary study is close to completion. The scheme designed to cope with ultimate development of the catchment is likely to have severe environmental effects and efforts are being made to bring forward modified proposals which will provide adequate protection for some years with a staged series of major works for the future.

These preliminary proposals should be accelerated and provision for the first of these will be included in the next year's preliminary estimates for Board consideration.

7.2 Kaiwharawhara Stream

Preliminary proposals for upgrading the lower section of the Kaiwharawhara Stream were initiated by the Railways Department. These proposals have been referred to the Board and at present the Scheme outline has been referred to the Director of Water and Soil Conservation for technical approval. Discussions have taken place between staff of the various Government Departments and local authority and subject to financial agreement, it is hoped that firm proposals will be able to be put to the Board later this year.

7.3 Korokoro Stream

The extent of the damage to the commercial area in Cornish Street and elsewhere in the Petone area warrant an investigation in some detail into the contributing causes. This will involve examining the capacity of the various culverts and bridges with a view to determining whether action to upgrade existing structures is warranted.

Board staff are already doing preliminary work on this study. The stream as a whole must be examined and action taken above the commercial area to construct debris arrestors if these are thought desirable together with some means of preventing the excessive movement of shingle and other material which at present lies in the bed of the stream.

7.4 Stokes Valley Stream

The capacity of the lower end of the Stokes Valley Stream was exceeded during the December storm and some unsatisfactory features were observed. While the Hutt River Board initiated the construction of a short length of concrete lined channel prior to the Board's establishment, this section is somewhat isolated and needs to be

examined again in the light of a possible improvement to the stream all the way to the Hutt River.

7.5 Waiwhetu Stream

The stopbank at the lower end of the Waiwhetu Stream was overtopped by this storm which is surprising considering it was constructed in recent times. The effect of high tides and the relatively narrow mouth into the Hutt River could have been important factors. It is clearly desirable that the lower end of the Waiwhetu be examined in some detail with a view to determining where the deficiency lies.

7.6 Clearing of Watercourses

The amount of material brought down during the storm and the degree to which the beds of many small streams have aggraded is a matter for concern.

The estimated costs of dealing with this problem and of constructing debris arrestors where these are likely to be affected including money already spent for the various areas is as follows: -

Wellington City	\$134,000
Lower Hutt City	\$165,000
Hutt County	\$ 72,000
Petone	13,300
Tawa	5,000
Wellington Regional Water Board (various areas)	\$ 11,200
Total	\$400,500

The magnitude of this work and its unexpected nature warranted the seeking of a Government subsidy although subsidies for maintenance are normally associated with major schemes which have themselves attracted a subsidy.

An application for a subsidy has therefore been made to the Director of Water and Soil Conservation through the District Commissioner of Works in the normal way. There has been insufficient time for this matter to be considered by the Soil Conservation and Rivers Control Council at the time of writing this report.

7.7 Oversowing of Slips

Revegetation of the slip faces is desirable as soon as sowing is likely to be successful.

Areas of slip damaged hill country have been assessed visually and studied in some detail with the aid of aerial photographs taken subsequent to the event. There are some 80 hectares (200 acres) of slips and debris on improved pastoral lands and a further 60 hectares (150 acres) on regenerating lands in the Western Hills area. An additional 20 hectares (50 acres) of eroded areas are located in the Eastern Hills.

At an estimated cost of \$60 per hectare the total cost is estimated at \$10,000 for which a subsidy application has also been made. The subsidy rate if granted is normally 2 for 1 whereby the owner of the property pays one third. Arrangements for the owners contribution would be made by Board staff. This has yet to be done. To be successful this oversowing must wait until the autumn.

7.8 Heretaunga Drain - Hulls Creek

Although the lower end of this watercourse performed reasonably under the circumstances, flooding occurred at the railway underpass and in the higher reaches. Some examination of why this occurred and whether improvement works are required is desirable.

8. OBSERVATIONS AND CONCLUSIONS

8.1 General

In evaluating the significance of events which took place in the storm, the magnitude of the storm itself and its likely recurrence must be borne in mind. As has been deduced in section 2 of this report, the rainfall intensity over a 6 hour period gives the best index of the damage which resulted from super-saturation of the soil and the weathered rock mantle in the affected area. The return period for the 6 hour rainfall in the Kelburn vicinity is 200 years and for the worst affected Lower Hutt area greater than 1000 years. This means in effect that the degree of blocking of culverts and of stream aggradation which were major factors in the migration of streams from normal channels, can be regarded as rare. This statement would apply also to the degree of damage to houses due to landslides. This conclusion must be tempered, however, by the realisation that many landslides have not yet become stable and for some time to come will contribute debris and material to streams below. Revegetation of these slips and, where practicable, stabilisation by planting or other methods is desirable. In this connection an application for a Subsidy for aerial over-sowing of slips in rural areas has already been made to the National Water Authority.

The return period of the peak discharges is, however, not such a rare occurrence ranging from 50 to 200 years in the worst affected areas depending on location with respect to the maximum rainfall pattern. The relative magnitudes of peak discharges of various return period floods needs to be understood in this connection. For example, the 10 year return period flood will have a magnitude of approximately half that of the 100 year flood. This is itself a considerable flow and there were many examples of culverts and stream channels which would have been in trouble even with such a 10 year flood. There are, therefore, many matters to be noted and lessons to be learned from this storm which must influence local body administration in the fields affected. Houses are still being built in flood channels, undersized culverts continue to be installed and property owners continue to put their houses at risk by excavations which reduce the stability factor of banks. These and other matters deserve consideration.

8.2 Watercourses

Under present legislation the owner of property on which there is a watercourse is responsible to keep the watercourse clean and to ensure that no vegetation or structure obstructs flow along it. A feature of many watercourses through affected urban areas was a reduction in waterway efficiency, resulting from actions by owners although the

amount of material brought down into urban areas from rural areas by the storm of 20 December would have caused problems in any case. Rural owners have the same responsibilities and their actions must not result in movement of material into watercourses. Where as in the present case the majority of the material came from landslides unrelated in any clear fashion to actions of owners of rural land, the matter of urban owners' responsibility is not a simple one.

Even if responsibility for maintenance of watercourses through private urban properties were taken over by a local authority and costs met from a special rating system, the matter of access and damage to the properties is an almost insuperable problem for local bodies in many cases.

Before a proper Maintenance Programme can be undertaken, the dimensions of the watercourse and the design capacity on which the dimensions are calculated must be determined. In most cases this is not known at present so that property owners are not aware of what dimensions they should be aiming to maintain. What tends to happen is that when a watercourse is incorporated into a private subdivision further public attention to it becomes restricted and many property owners consider they have a right to do with the stream what they will. If in future it proves inadequate to carry the run-off from the catchment above, local authorities often find the only practicable solution is to lay a supplementary storm-water pipe down a public street at considerable cost to ratepayers.

The conclusions from the above comments are as follows: -

8.2.1 Watercourses of any significance should preferably not be incorporated in private urban properties but should be located in public reserves where they are a clear responsibility of a local authority in all respects.

8.2.2 Before any urban development takes place, whether the stream is to be in public or private property, the shape, dimensions and the line of the stream should be determined based on a design flood of up to 50 year return period if flooding is likely to affect many properties. If the stream passes through a commercial area, 100 year return period would be appropriate. To the dimensions thus determined must be added a sufficient width to enable proper access for men and machines necessary to maintain the stream. The stream dimensions and the access should then become an easement on the title on which planting and other activities are restricted to those which will achieve bank protection without reducing flow efficiency.

8.2.3 Regular inspections to ensure this efficiency is being maintained are necessary and all applications for crossings, such as bridges and culverts, must be carefully examined for their effect on flood flows.

If the above has to be done years after properties are established, as will be the case in some streams in the region, the disruption to properties will be considerable. This can be avoided by forward planning. The above also applies equally to the commercial areas where the owners must be prevented from stacking floatable material in flood channels from where it can be washed away to block culverts and bridges downstream.

Service pipes, such as sewers and watermains, laid across watercourses can be obstructions if they are not placed clear of maximum water levels. This is often difficult, particularly with sewers and large watermains but advance planning, particularly with new development areas, may help to minimise the necessity to cross at points where pipe levels are likely to cause problems by collecting debris.

8.3 Culverts

In the recent storm the single factor responsible for the greatest amount of damage was blocking of culverts by debris. In many cases the culverts were inadequate for the particular storm without blocking and this is not too surprising. Many, however, would have been inadequate in storms of lesser intensity. While the amount of debris brought down was exceptional during the 20 December storm, there are points to be noted which are applicable to future design.

The design of culverts under roads should be related to the importance of the road above it and the economic effect of disruption to traffic due to flooding. In extreme events when the culvert capacity may be exceeded, roads should be shaped so as to act as fords where practicable so that stormwater flow is channelled back to its natural watercourse.

During floods culverts carry varying amounts of debris other than water and additional capacity to deal with this must be provided. Unless the invert of the culvert is correctly placed with respect to the line and level of the stream bed it may have its capacity reduced much of the time by material lying in it. Where a roughly rectangular stream cross-section meets a circular culvert proper transition walls must be installed or excessive entry head loss with lowered capacity and possible bank erosion will result.

Multi-celled culverts are particularly susceptible to obstruction by debris. Single opening culverts are to be preferred unless there are compelling economic or other reasons to the contrary. Rectangular culverts have some advantages over circular ones, particularly in the larger sizes. Bridges are generally preferable to culverts from a waterway point of view.

The minimum size of a culvert must be such that it can be readily cleaned. In the case of a long culvert this may well determine the diameter.

It should be remembered that a 25 per cent increase in diameter gives approximately a 50 per cent increase in capacity which raises its usefulness in terms of flood return periods from a 20 year event to a 100 year event. This is achieved at much below a 25 per cent increase in total cost of installation.

Gratings on culverts may appear to serve a useful purpose but in most cases they are dangerous. Unless carefully designed they are likely to block and render the culvert useless. This is a field where some research is necessary to find the best means of preventing debris blocking culverts. For debris up to a certain size the fewer obstructions the better. For larger material likely to block the whole culvert it is necessary to trap the material some distance back from the culvert entrance. While one obvious action is to ensure debris is not available to block culverts, this is not practicable over long periods and the result is that when maximum culvert capacity is required culverts may be blocked and their capacity at a minimum by debris brought down by high floodflows from areas above normal water levels.

8.4 Roads

Many roads in the hills of the Wellington Region must of necessity be cut into banks but in the case of important arterial roads exceptional care should be taken to ensure road batters are stable and embankments not liable to erosion from flood waters. A cut which was initially stable may be rendered less stable by progressive weathering of the rock.

Roads of lesser importance can usefully act as watercourses in extreme events provided water can be guided back into a natural channel without damage. Where practicable, roads should be located below adjacent properties in order to hold flood waters for a period.

In Pinehaven there are two main tributaries, one flowing down beside Upper Pinehaven Road and one beside Elmslie Road. The siting of the road and the houses in these two areas are significantly different. Upper Pinehaven Road runs up the middle of the valley mainly beside the waterway and the houses are built on both sides of the road, generally above the level of the road and waterway. The flood flows could then flow down both the waterway and the adjacent road without affecting the houses. The damage in this area was mainly confined to garages, drive ways and garages. Elmslie Road is situated in a slightly wider valley and is set back from the waterway. There is a row of houses sited between the road and the waterway. They are generally below the level of the road and tend to be crowded close

to the waterway to fit in. In this area substantial damage to houses occurred, some houses being buried in silt and gravel up to the windows. The siting of roads relative to streams can therefore have significance.

During the storm many street sumps were observed to be ineffective on steep slopes. Where this happens the additional flow may overwhelm all subsequent sumps so that roads are unnecessarily awash. The design and spacing of street sumps is worthy of further consideration.

8.5 House Sites and Urban Development

Recently constructed subdivisions stood up well to the storm although some experienced slightly less rainfall than others. Involvement by geologists is greater now than in the past and there is evidence that this is producing some changes in design. For example, road batters appear to be less steep than was the case a few years ago.

The difficulties caused by increased run-off rates from developed areas is evident in some cases and few local bodies have solved the problem of how to upgrade watercourses to cope with this increased run-off. (See also Section above on watercourses.) In some cases large quantities of run-off have been concentrated and discharged into bush areas where previously little water flowed. Some of these require examination with a view to stabilisation.

While the landslides (mud flows) were widespread throughout the region the greatest damage to houses did not occur in subdivisions where large scale earthworks had been carried out, but in areas where the natural slopes had been allowed to remain for the most part and modified minimally to produce house sites and roads. Much excavation of house sites takes place by builders and property owners subsequent to the sale by the subdivider. In order to guard against this practice of subsequent slope modification such recent developers have placed a caveat on the titles restraining owners from doing further cutting of the property.

It is clear that development in steep country needs special attention. Whether some land should have been subdivided for housing at all is an important question but where it has been permitted all proposed cuts or other modification of the site should be required to produce a 'Certificate of Stability' as is the case in the Nelson area. In Nelson the Certificate is produced by a Registered Civil Engineer but it is felt that the advice from a competent geologist should be an important ingredient.

8.6 Forestry Operations

When an exotic plantation is established tree planting should not be permitted within a certain distance of watercourses. This is firstly to ensure that the trees do not fall into

watercourses during floods and secondly to preserve a belt of native bush or other vegetation which acts to trap silt and debris resulting from milling operations.

The National Water and Soil Authority has produced a set of guidelines for forestry operations designed to ensure that forest removal operations are conducted with due regard to damage to other vegetation and proper soil conservation practices. In view of the proximity of millable trees in the Pinehaven area to urban development it is desirable that these guidelines be enforced in this area. This could be done through Section 34 of the 1959 Amendment to the Soil Conservation and Rivers Control Act. This would mean that all the forestry milling operations would require to have Board approval and would be subject to conditions laid down by the Board. At the same time this could be made to apply to the stripping of topsoil of rural land which is occurring in the region. This is a highly undesirable practice which should be strictly controlled as it is the case in a number of Catchment Board Districts.

8.7 Town Planning

It is evident that some areas have been zoned for urban development which are unsuitable on account of their topography and in some cases due to their relationship to watercourses and potential flooding. It is too late to be dealing with the problem at the building permit stage. A multi-disciplined approach to planning is required so that ground conditions can be examined in detail before land is designated for urban development, not after such designation.

It is noticeable also that only the major watercourses feature on District Scheme Plans. This means that persons examining such maps are unaware of watercourses and their attitude to them must be affected accordingly. The importance of ensuring access to watercourses for maintenance purposes is not adequately appreciated by town planners. Topographical features and slope of ground could well be shown on District Scheme maps for the information of the public.

Building permits are not usually required to show watercourses and building inspectors are not always aware that they exist. Thus building plans have been approved in some cases without adequate examination of factors relating to watercourses. The practice of referring proposals near streams to Board staff for comment is growing but is not yet universal.

8.8 Insurance

The December storm has revealed a large area of damage which is uninsurable including loss of value to land affected by slipping and cost of cleaning up after a storm. Undoubtedly, no insurance institution would cover such matters unless every effort had been made in the first place to minimise the risk. However, even where this had been done persons might well find themselves heavy losers in the disaster situation.

The use of the Earthquake and War Damages Fund appears to be a makeshift arrangement and the question arises as to whether there is not a need for a general Disaster Fund which would not erode the Earthquake and War Damages Fund. Perhaps this should also be compulsory and be based not on the extent to which the property owner takes out fire insurance, but on the capital value of property as determined by Government valuation and some factor related to risk. Some years ago a study of sales of Wellington City properties showed that the average length of time a property remained in one ownership was 14 years. Today's figure could well be a shorter period. This means that the actions of one owner may affect a subsequent owner and although the buyer might well be told to beware, the risks in this particular field are difficult for the average person to evaluate and with properties changing hands relatively frequently, a better form of insurance is desirable.

For commercial properties there are several types of insurance against water damage not well explained by insurance companies. Some commercial firms find on examination that their particular policy for water damage does not cover water from flooded streams. On the other hand, realising that the Earthquake and War Damages Commission will cover disaster damage to the extent of a fire insurance policy, there is a tendency for commercial firms to keep the fire insurance high and the water damage insurance low. This in effect means inadequate cover of insurable items which has been a matter of concern to the Earthquake and War Damages Commission.

The following extract from the 1976 report of the Earthquake and War Damages Commission is relevant in this connection: -

"Still of concern to the Commission is the amount being paid out from the Disaster Fund for commercial property losses. In the past year storm and flood damage to commercial properties accounted for more than 80 per cent of the payments from the fund.

The extraordinary disaster provisions were introduced at no extra cost to property owners at a time when this form of protection was not readily available on the open insurance market. No distinction was then made between domestic and

commercial property losses. Over the intervening years insurance companies have progressively expanded fire insurance contracts to provide cover against storm and flood damage and today this protection is readily available at a small extra cost.

In the opinion of the Commission there is selection against the Disaster Fund by the commercial sector. Insurance companies are quite prepared to grant an extension of cover where the risk is reasonable, but the Commission is being committed to accept storm and flood liability under the Disaster Fund for the less desirable insurance risk by virtue of the automatic cover attaching under the Act with the issuing of insurance policies restricted to fire cover only. The Commission has no control over the granting of a fire only cover by insurers, but it is evident that if storm and flood cover under the Act did not automatically attach to these fire only contracts many commercial property owners would be forced to take more precautions to preserve buildings and the contents of buildings from damage.

The Disaster Fund was originally designed to bridge certain gaps in the overall insurance portfolio available to property owners. The future solvency of the fund is essential to meet this very need and it is the opinion of the Commission that cover under the Act should not extend to that type of loss for which adequate alternative insurance facilities are available through the insurance industry."

8.9 Civil Defence

The limited experience from the December storm suggests the need for a Regional Civil Defence Organisation, particularly for dissemination of reliable information covering all local authorities, regional and sub-regional bodies and Government Departments.

It has not been possible to examine the performance of any of the Civil Defence Organisations during the December storm but there has been some criticism. It has been suggested that the National Fire Fighting Emergency Hand Book should be studied by Civil Defence Authorities. This is in line with a feeling that unless Civil Defence is built around operating service organisations, it will not function adequately in a widespread emergency situation.

9. RECOMMENDATIONS

This report must be regarded as a broad initial study of the flood event, many features of which warrant further consideration. Several specialist organisations are also known to be producing their own reports. Every deficiency noted warrants some action but more study is needed in some cases.

The following actions, however, are recommended now: -

1. That the Ministry of Works and Development be asked to investigate and if necessary conduct model tests to determine optimum culvert entrance design with particular reference to long culverts and with a view to dealing with solid material and floating material.
2. That the National Water and Soil Organisation be asked to press the Government to establish a policy with respect to subsidies whereby -
 - (a) urban works are on the same basis as rural works for subsidy purposes, and
 - (b) that major urban stormwater upgrading schemes qualify for a Government subsidy.
3. That the Board approve investigation work by Board staff on the following streams with a view to determining whether improvement works are warranted.

Korokoro Stream
Stokes Valley Stream
Waiwhetu Stream
Heretaunga Drain - Hulls Creek.

10. ACKNOWLEDGEMENTS

A very large amount of work in connection with this report has been contributed by Mr. J.A. Jones, Rivers Control Engineer, Mr. C.S. Hovey, Engineer - Rivers Control Section and Mr. K. Davis, Water Resources Officer of Wellington Regional Water Board staff.

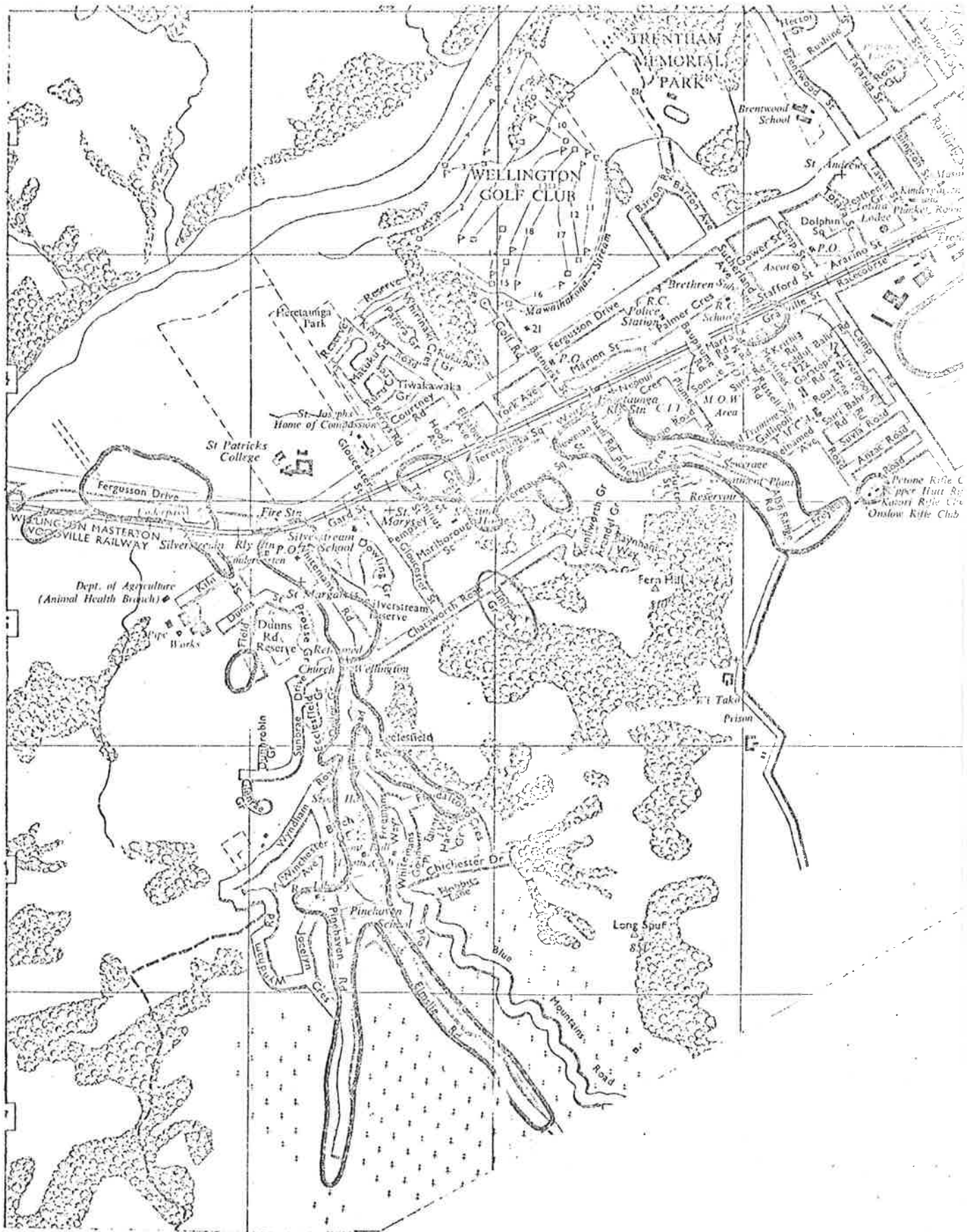
Valuable assistance, particularly regarding economic aspects, was provided by a team made available by the Water and Soil Division, Ministry of Works and Development, consisting of -

Mr. D.G. Knowles,	Operations Manager, Nelson Catchment Board.
Mr. D. Depledge,	Scientist, Water and Soil Division, Ministry of Works and Development, Wellington District.

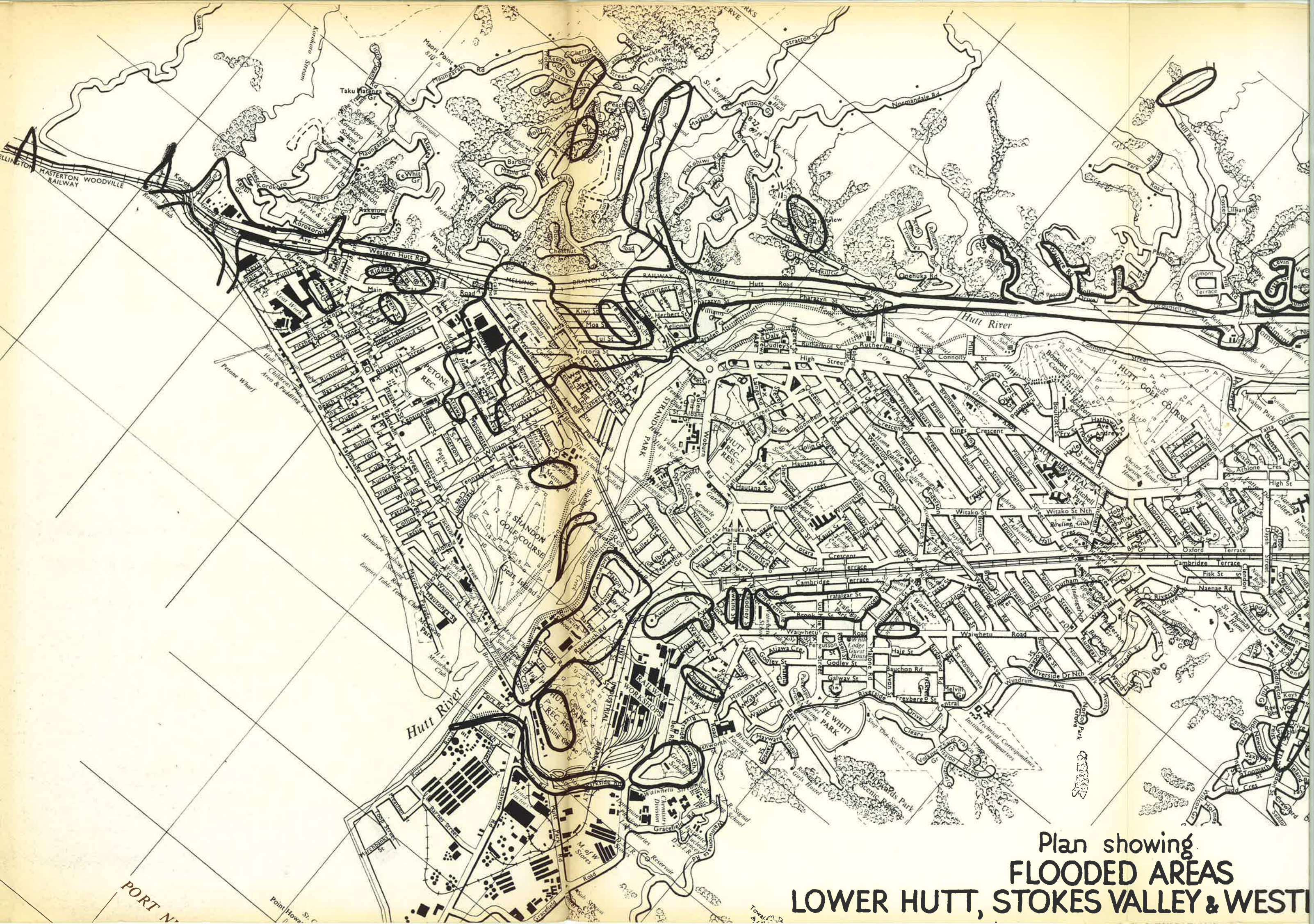
Mr. J.H. Ford, Liaison Officer, Water and Soil Division,
Ministry of Works and Development,
Head Office.

Mr. G.J. Williams, Design Engineer, Wairarapa Catchment Board.

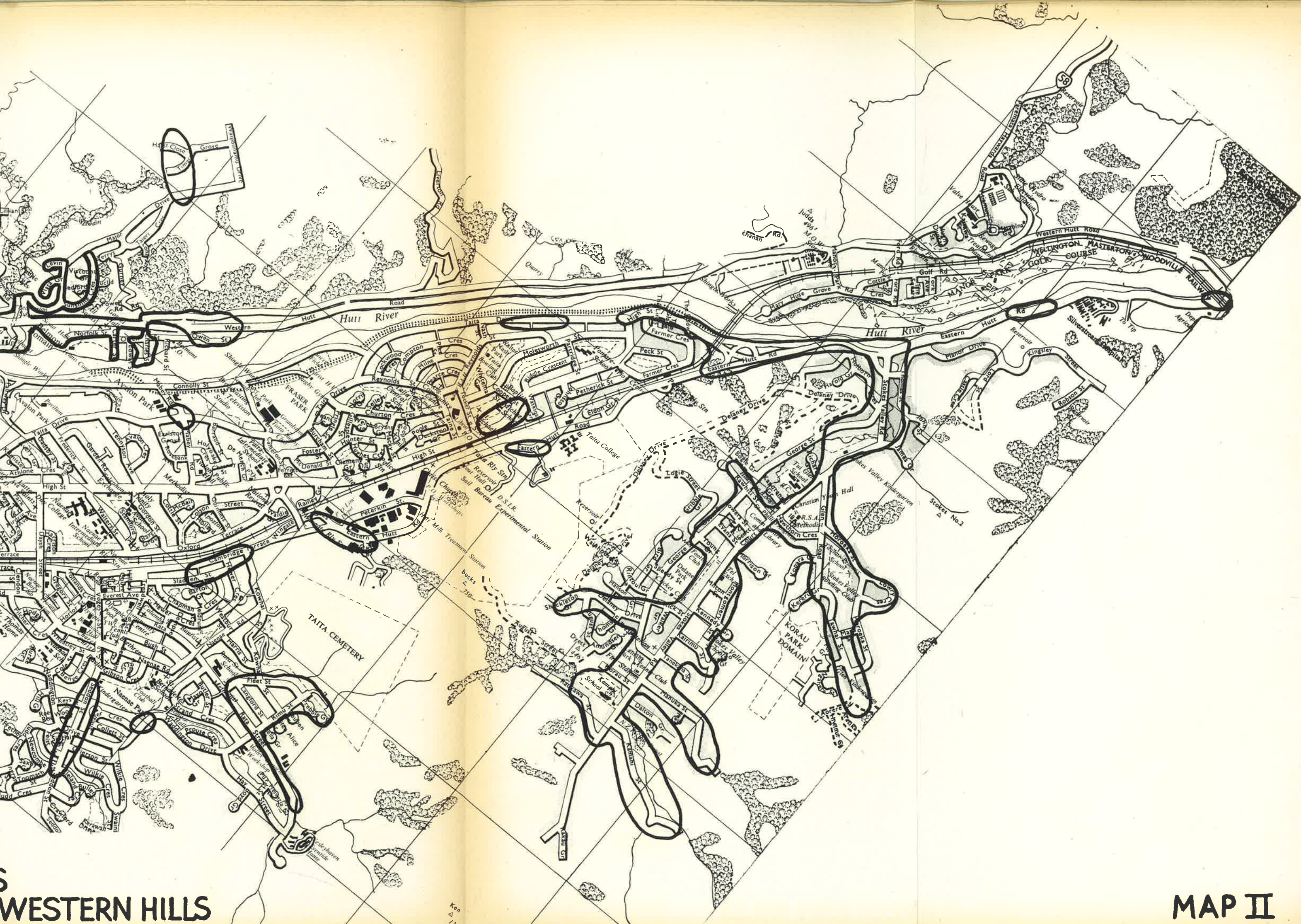
Assistance by way of discussion and contribution is acknowledged from Mr. T. Grant-Taylor, District Geologist, N.Z. Geological Survey, from Mr. A.I. Tomlinson of the Meteorological Office and from the engineers of many local bodies in the region.



Plan showing
FLOODED AREAS
PINEHAVEN - SILVERSTREAM



Plan showing
FLOODED AREAS
LOWER HUTT, STOKES VALLEY & WEST



Ken
A 1279

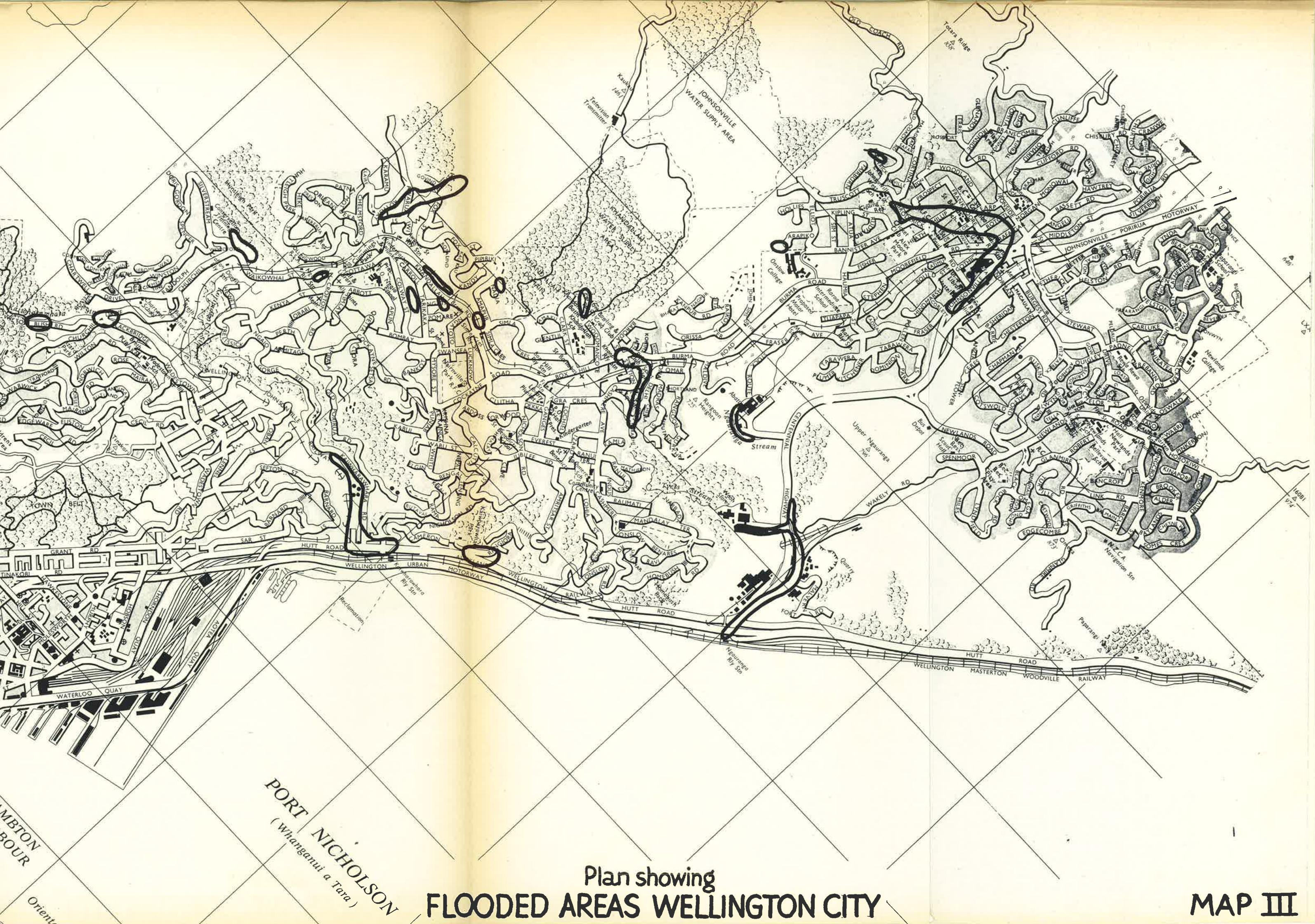


22
Makara High
1317
Makara Peak

SCALE 1 : 2000
0.5
1 Kilometre

LAMBTON HARBOUR

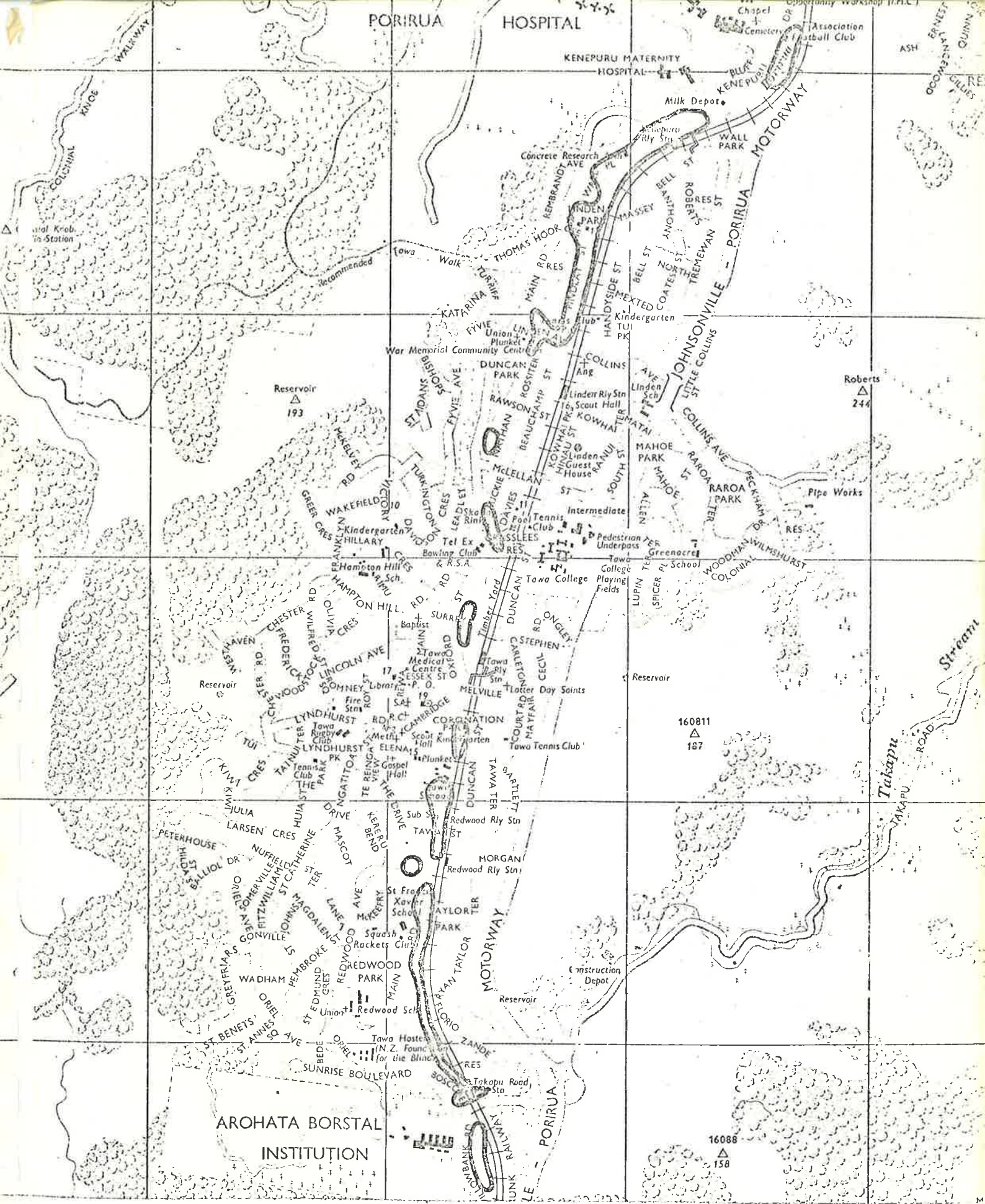
Orient



PORT NICHOLSON
(Whanganui a Tara)

Plan showing
FLOODED AREAS WELLINGTON CITY

MAP III



Plan showing
FLOODED AREAS
 ADJACENT TO PORIRUA STREAM
 (PORIRUA-TAWA AREAS)

