NRL - F/55

DEPARTMENT OF HEALTH
NEW ZEALAND

ENVIRONMENTAL RADIOACTIVITY ANNUAL REPORT

1975

NATIONAL RADIATION LABORATORY
P. O. BOX 25-099, CHRISTCHURCH
NEW ZEALAND

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TERMS OF REFERENCE AND ACKNOWLEDGEMENT

In September 1957 the New Zealand Department of Health was charged, under a Cabinet directive, with the responsibility for monitoring environmental radioactive contamination in New Zealand and also in any Pacific areas with which New Zealand was associated.

The Department delegated this responsibility to its National Radiation Laboratory at Christchurch where the measurement of radioactive fallout became a natural extension of the work of the Laboratory in the fields of radiation protection - the control of radioactive pollution and the safe use of ionizing radiations in medicine, education, research and industry.

The National Radiation Laboratory therefore undertook responsibility for sample collection, analysis, and interpretation of data on environmental levels of radioactivity. The network of collecting stations shown in Fig. 1 was subsequently established. In addition to the New Zealand sampling, monthly collections of rainwater have also been provided from Fiji and Rarotonga. Within New Zealand, collections were made, and samples were provided, by officers of this and other Government Departments (particularly the staff of the New Zealand Meteorological Service), and by the managers of milk processing plants. Their continued co-operation is gratefully acknowledged as it has made possible the Laboratory's routine monitoring programme.

The Environmental Radioactivity Section of the Laboratory was responsible for the organisation of the monitoring operations, sample analyses, and reporting and interpretation of results:

Mr. L. P. Gregory	Officer in Charge, Monitoring Operations, Radiochemistry, Editorial Work.
Mr. T. Baltakmens	Professional Officer, Radiochemistry.
Dr. K. M. Matthews	Professional Officer, Gamma Spectroscopy (started July 1975).
Mr. G. N. Connor	Technical Assistant (part-time).
Miss M. Roberts	Technical Assistant (started June 1975).

The assistance of the mechanical and electronic workshops, the draughting and clerical sections of the Laboratory is gratefully acknowledged.

H. J. YEABSLEY
DIRECTOR.

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SUMMARY

During 1975 the country-wide average deposition of strontium-90 on New Zealand remained at the low levels recorded during the previous two years:

A maximum "country-wide average" deposition of 3.6 millicuries per square kilometre occurred in 1964 after the large scale U.S.S.R. and U.S.A. atmospheric nuclear tests in 1961 and 1962. Annual deposits then decreased to a minimum of 0.8 mCi/km^2 in 1968 as a result of the partial test ban treaty.

During the period of French atmospheric nuclear tests in the South Pacific, commencing in 1966 and finishing in 1974, smaller annual deposits, reaching a maximum of 1.4 mCi/km^2 in 1971, occurred. Since then levels have decreased and during the last three years have remained at about 0.3 mCi/km^2, i.e. less than one-tenth of the 1964 maximum. It is estimated that about 23% of the total strontium-90 deposition on New Zealand can be attributed to French nuclear tests.

The concentrations of strontium-90 and caesium-137 in milk reflect the changes in fallout deposition. The average levels during 1974 and 1975 were the lowest since measurements commenced.

French underground nuclear tests in the South Pacific commenced in mid-1975. Since then continuous monitoring has also been conducted at six Pacific Island stations, to detect any leakage from these tests. No fresh fission products have been detected since this programme started.

During 1975 the levels of radioactive contamination were small percentages of the reference levels. It is considered, therefore, for the reasons discussed under "Reference Levels" p.3, that these levels do not constitute a public health hazard.

In addition the radiation dose resulting from the long-term average levels, since measurements commenced, is small compared not only with natural background but also with common variations in natural background.

CONTENTS

INTRODUCTION

This report continues the series of annual reports concerned mainly with long-term levels of environmental radioactivity in New Zealand and at Fiji and Rarotonga. Sample collecting stations in New Zealand are shown in Fig. 1. The present report should be read in conjunction with the previous re-designed annual reports (1) especially the first of these which summarised all the earlier quarterly and annual reports, and discussed global fallout and specific radionuclides of potential health significance.

During the period 1966 to 1974 inclusive France conducted eight separate series of atmospheric nuclear tests in the Tuamoto Archipelago in the South Pacific region. The results of this Laboratory's extended programmes, monitoring short-term levels of fallout from these tests, were published (2).

Commencing June 1975 French nuclear tests in the South Pacific have been conducted underground and since then gamma radiation monitoring has been conducted several times daily at Penrhyn Island and continuous air filter and rainwater monitoring has been undertaken at Rarotonga, Aitutaki, Tonga, Samoa, and Fiji. The location of these monitoring stations was shown in previous reports (2). It has been reported that underground tests occurred on June 6, 1975, November 26, 1975 and 3 April, 1976. The Laboratory's monitoring programme is designed to detect any venting of fission products from underground tests in the South Pacific. Results of this programme are given in this report.

The unit of radioactivity (the Curie) and the sub-units used in practical measurements are defined on the inside back cover. Units used for expressing the deposition of radioactive fallout, and the concentration of specific radioactive substances in various environmental media are included.

POTENTIAL HEALTH HAZARD AND REFERENCE LEVELS

There are no internationally accepted "permissible levels" for the exposure of people to fallout from nuclear weapons testing. Most of the measurements recorded in this report concern such contamination and it is considered necessary in the public interest to provide some guide by which the significance of the values may be appreciated.

Development of Reference Levels

The simplest procedure is to compare measured values with those which would give the annual "Dose Limits" suggested by the International Commission on Radiological Protection (3). The I.C.R.P. dose limits were established for

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(1) "Environmental Radioactivity":
Annual Report 1971, Report No. NRL-F/48, June 1972
Annual Report 1972, Report No. NRL-F/50, April 1973
Annual Report 1973, Report No. NRL-F/52, June 1974
Annual Report 1974, Report No. NRL-F/54, June 1975

(2) "Environmental Radioactivity. Fallout from Nuclear Weapons Tests Conducted by France in the South Pacific... and comparisons with previous test series." Report Nos: NRL-F/47, March 1972 (Summarising all previous monitoring results); NRL-F/49, October 1972; NRL-F/51, November 1973, and NRL-F/53, November 1974.

(3) Recommendations of the International Commission on Radiological Protection: ICRP Publication 9. Pergamon Press, 1966.

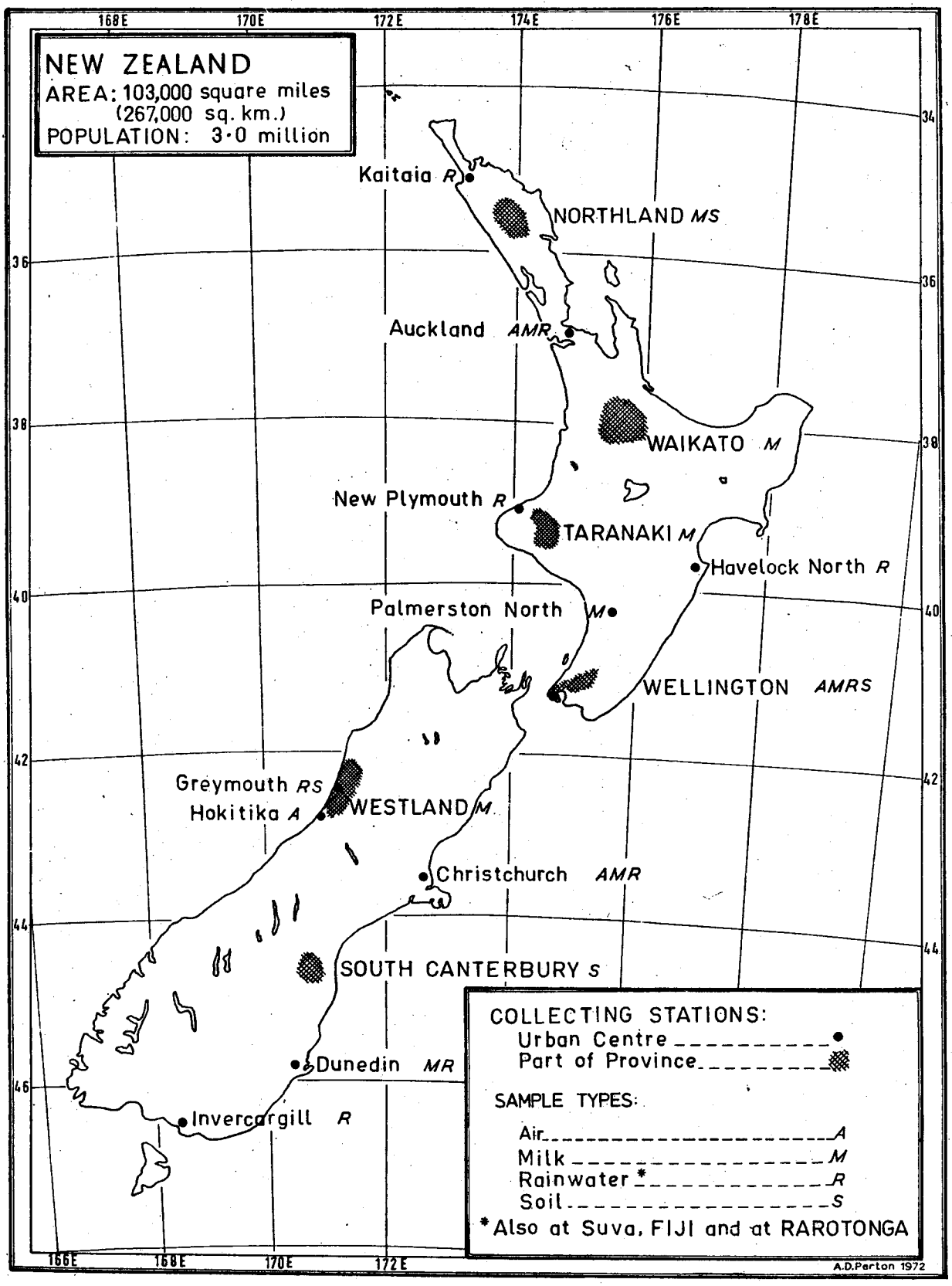

Fig. 1 Collecting stations in New Zealand

individual members of the public so that the risks from controllable radiation sources should be no greater than other risks regularly accepted in every day living. These dose limits are in fact one-tenth of the annual Maximum Permissible Doses for radiation workers. The Commission emphasizes that all controlled radiation exposures should be kept to the minimum practicable and that the risks should be justified in terms of benefits that would not otherwise be received. Although the latter criterion does not apply in the present case, the following "Reference Levels" have been derived from these dose limits, making allowance for the risk to children. In no case is a reference level greater than one-third of the concentration which, if maintained indefinitely, would lead to a dose limit. The media and radionuclides listed are those generally accepted as the key items for monitoring fallout contamination, and the units of concentration are those used in the reports of this Laboratory.

Reference Levels

In Milk :	Strontium-90 (picocuries per gram of calcium)	270
	Caesium-137 (picocuries per gram of potassium)	7,000
	Iodine-131* (picocuries per litre)	200
In Air :	Mixed fission products between 10 and 80 days old (picocuries per cubic metre)	300
In Rainwater :	Mixed fission products between 10 and 80 days old (picocuries per litre)	6,000

The I.C.R.P. dose limits specify annual exposures and therefore for those concentrations which can change rapidly with time, such as mixed fission products in air or in rain, or iodine-131 in milk, the average values over the year, rather than transient values, should be compared with the reference levels.

If, during any single year, the average levels do not greatly exceed the reference levels then any resulting increase in risk to the health of an individual would be insignificant. Such a non-beneficial irradiation of the general population should be prevented if practicable but should it occur it would not justify the disruption and risks associated with remedial action and therefore would not be described as a public health hazard.

Comparison of Reference Levels with Natural Radiation Background

Under the condition of continuing weapons tests, long-lived radioactive debris, accumulating in the environment, and the regular presence of short-lived material, may cause exposure over many years. In this context it is helpful to compare the average (over many years) of the annual doses from fallout with that due to background radiation to which the human race has always been exposed.

The level of background radiation varies markedly from place to place. For reference purposes, however, the "average" annual dose received from the natural environment may be taken as about 120 millirads.

There are a number of areas with large populations where the annual background dose is several times this value. No survey has to date demonstrated that there is a health hazard associated with living in such a region. On the other hand it has not been possible to demonstrate that there is a threshold dose below which no effect on health is produced.

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* Not a routine measurement (see NRL-F/53 for results of ^{131}I measurements during the special monitoring programmes).

If the reference levels were maintained indefinitely, they would each lead to a dose rate of the same order as that received from average natural background radiation. Thus if a long term average level is expressed as a percentage of a reference level then the resulting risk will be about the same percentage of any risk which may be eventually attributed to radiation from the natural environment.

GAMMA RADIATION MONITORING AT PENRHYN ISLAND

No increases above the normal background radiation level have been detected at Penrhyn Island since this monitoring programme started in July 1975.

BETA ACTIVITY OF AIR FILTER AND RAINWATER COLLECTIONS

1. FISSION PRODUCTS IN AIR

Normally the short-lived decay products of naturally-occurring radon account for most of the beta activity in air. Ground level air over continents has a beta activity commonly ranging between 60 and 600 picocuries per cubic metre, but under certain conditions the beta activity may be up to ten times the upper value of this range. Air filter samples which are collected for measurement of fission products are held for four days to allow this natural radioactivity to decay away and are then measured for residual beta activity which is due to radioactive fall-out. Hereafter the term "total beta activity" refers only to this residual radioactivity due to fission products.

During 1975 air was monitored continuously at four New Zealand stations and also since mid-year at the five Pacific Island stations: Rarotonga, Aitutaki, Tonga, Western Samoa, and Fiji. The filters were changed three times each week (Table 8, Appendix gives the maximum, minimum and average levels during each month for each station).

In the absence of fresh fission products in the atmosphere, the levels of "total beta activity" in air have usually been less than 0.1 picocuries per cubic metre (typically < 0.01 to 0.03 pCi/m^3). Since 1959, however, when measurements first commenced at Christchurch, transient increases in the levels, due to atmospheric nuclear tests, have been observed. These increases are illustrated in Fig. 2, where average monthly levels are shown for the four New Zealand stations.

The increases caused by nuclear tests, conducted by the United States in the Pacific in 1962, and by the French in the South Pacific from 1966 to 1974 are apparent. The progressive reduction in the levels after each test series is also apparent. This is particularly noticeable after the 1966 and 1967 French tests in which weapons in the kiloton range only were tested. The relatively rapid removal from the troposphere by deposition is characteristic of such tests. The 1968, 1970 and 1971 French test series, however, have each included one or more weapons in the megaton range and the higher altitude of injection of fission products caused a delay in the subsequent transfer to the troposphere. During the 1972 and 1973 French low power nuclear test series, fresh fission products in air were occasionally present at extremely low levels, barely detectable above the residual level from previous tests. The 1974 French nuclear test series, however, comprised seven low to intermediate power tests. During the latter half of 1974 fresh fission material was readily detectable, but at levels which were, in most cases, less than those measured during Pacific tests prior to 1972.

The monthly levels shown in Fig. 2, averaged for each year since 1966 where possible, are shown in Table 1:

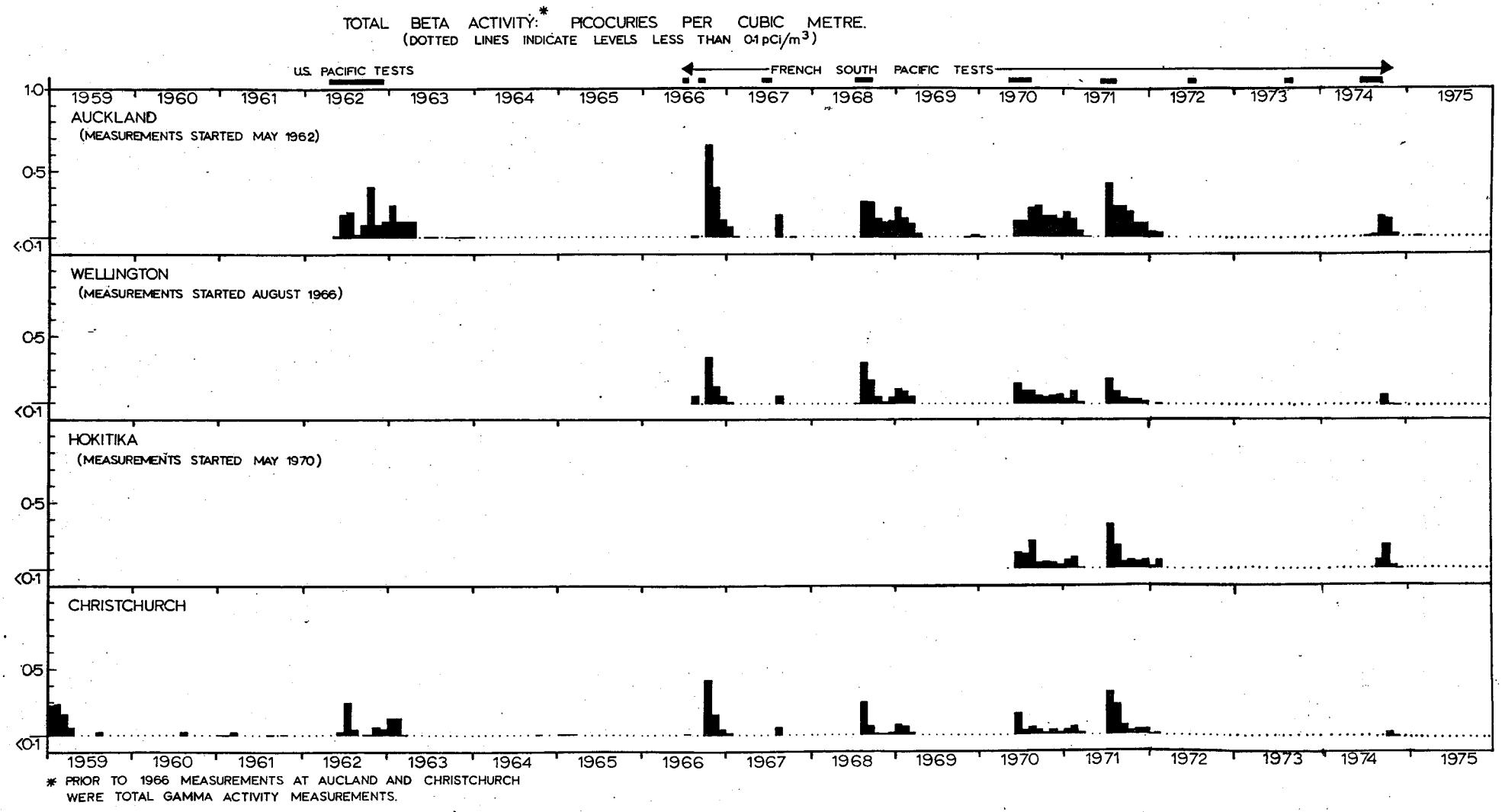

Fig. 2 Fission products in air - monthly averages

TABLE 1 - Total Beta Activity in Air - Annual Averages (pCi/m^3)

	Auckland	Wellington	Hokitika	Christchurch
1966	0.14	0.10*		0.11
1967	0.08	0.05		0.06
1968	0.12	0.10		0.07
1969	0.12	0.09		0.07
1970	0.16	0.12	0.12*	0.10
1971	0.21	0.12	0.16	0.15
1972	0.06	0.05	0.05	0.05
1973	0.02	0.01	0.02	0.02
1974	0.08	0.05	0.07	0.05
1975	0.03	0.03	0.03	0.02

* Estimate

At the start of 1975 levels at the New Zealand stations were about 0.1 pCi/m^3 or less as a result of the 1974 atmospheric nuclear tests. During the first half-year they fell steadily to about 0.02 pCi/m^3. During the second half levels remained at or below the limit of detection (0.01 pCi/m^3) at all stations including the five Pacific Island stations which were then in operation.

During 1975, levels of fission products in air were very small fractions of one percent of the Reference Level.

2. FISSION PRODUCTS IN RAIN

The routine weekly funnel and bottle collections of rainwater at four New Zealand stations continued during 1975, and since mid-year, collections were also made at the five Pacific Island stations providing air filter samples. The rain samples were measured for total beta activity. Increases in the levels of fission products in rainwater samples have occurred concurrently with increases in air radioactivity. Weekly depositions at the New Zealand stations have been totalled for each month, and are shown in Fig. 3 as millicuries per square kilometre per month. It is evident that peak depositions coincide with nuclear tests. The difference in levels at Greymouth and Christchurch illustrates clearly the rainfall dependent nature of fallout deposition. Although these two stations are geographically close, and are at approximately the same latitude, they are separated by mountain ranges and represent the extremes in rainfall for the four stations.

The monthly depositions shown in Fig. 3 are summed for each year and listed in Table 2. (It should be realised that such a presentation of the results, although allowing a useful comparison, is not entirely valid where fresh fission material is concerned because much of the material deposited during the year will have decayed by the end of the year.)

At the Pacific Island stations the total depositions for the second-half of 1975 ranged from 2 to 4 mCi/km^2. The results for the individual depositions, and the average concentrations are given for each station in Table 9 Appendix. The average concentrations for the New Zealand stations ranged from 7 to 14 pCi/litre during 1975. The corresponding values for the Pacific Island stations ranged from 2 to 4 pCi/litre during the second half 1975. These concentrations are very small fractions of the Reference Level.

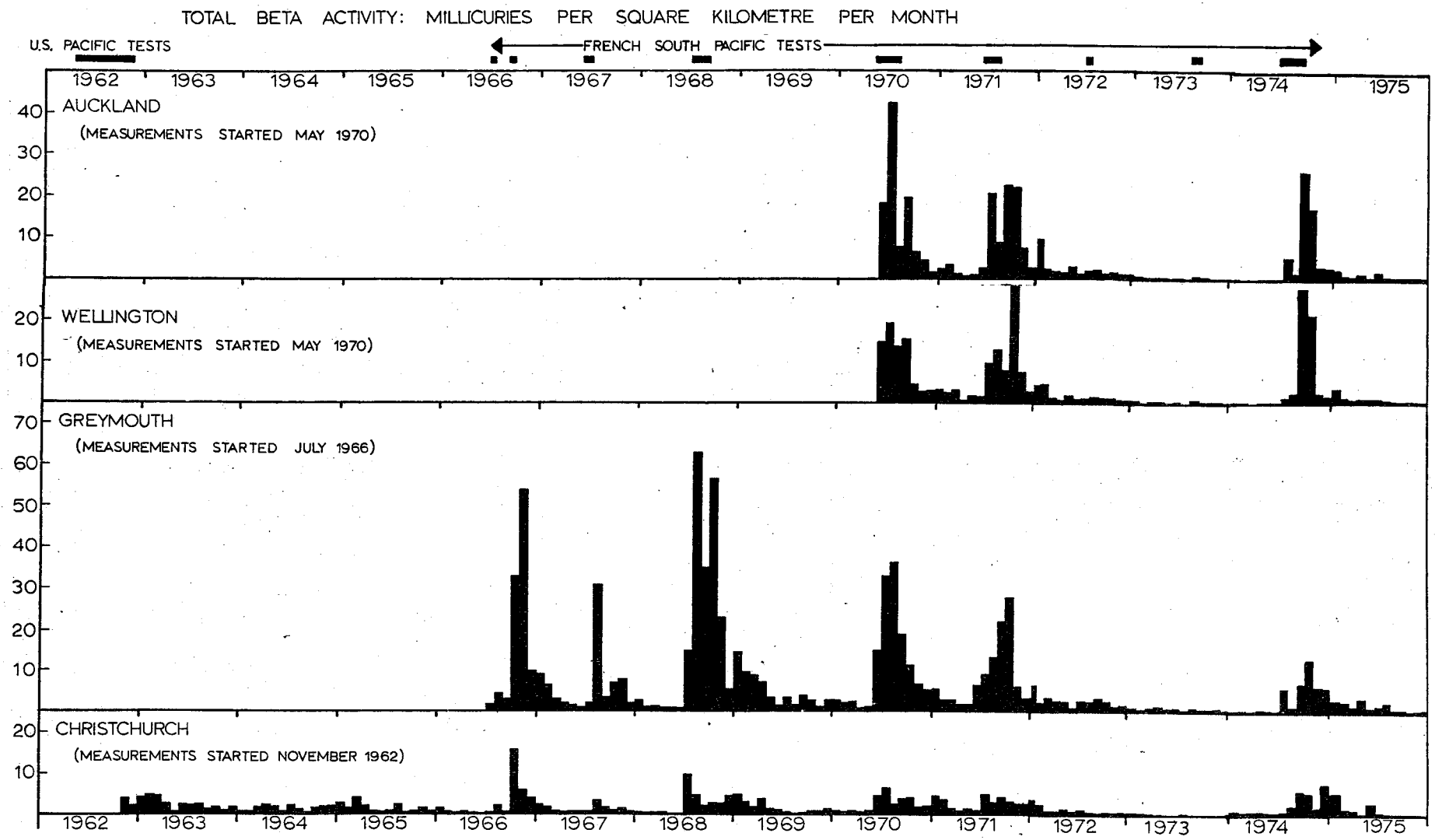

Fig. 3 Fission products in rain - monthly deposition

TABLE 2 - Total Beta Activity in Rain - Sum of Monthly Depositions During Each Year (mCi/km^2)

	Auckland	Wellington	Greymouth	Christchurch
1963				28
1964				15
1965				17
1966			106**	32
1967			77	14
1968			205	28
1969			61	18
1970	101*	75*	133	26
1971	98	80	99	32
1972	25	22	33	15
1973	5	7	8	4
1974	59	60	42	22
1975	9	13	19	13

* May to December only.
** July to December only.

SPECIFIC RADIONUCLIDES

The most potentially hazardous long-term fallout radionuclides are strontium-90 and caesium-137. Fig. 4 shows the periods of nuclear testing in the Pacific and the New Zealand "country-wide average" values of strontium-90 deposition and concentration in rain. The levels of strontium-90 and caesium-137 contamination in New Zealand milk are also shown. These levels are discussed in detail in the following sections:

1. STRONTIUM-90 IN RAIN

(a) At Nine New Zealand and Two Pacific Island Stations

Rainwater has been collected on a routine monthly basis since 1960. Collections are made in high-walled stainless steel pots and each month the contents are measured for strontium-90. (Monthly results for individual stations are given in the Appendix in Table 10 and Fig. 10).

The large scale northern hemisphere (U.S.S.R.) and Pacific area (U.S.A.) nuclear tests, which were conducted in 1961 and 1962 before the signing of the Partial Test Ban Treaty, resulted in a delayed stratospheric fallout over New Zealand. The maximum deposition from these tests was recorded in late 1964 and early 1965. Thereafter the annual deposition steadily decreased until 1968.

During the years 1966 to 1974 smaller scale French nuclear tests were conducted in the South Pacific each year except 1969. Each of these test series, lasting from one to three months and comprising from three to eight nuclear explosions, has taken place during the southern hemisphere winter. To date 41 nuclear devices are reported to have been exploded in the atmosphere during these tests, most of them being in the low to medium power (kiloton) range. However, megaton explosions are reported to have occurred twice in 1968, twice in 1970 and once in 1971 (2). As a result of these tests the annual deposition of strontium-90 over New Zealand increased during the period 1969 to 1971 reaching a maximum in 1971 which, however, was only about one-third of the peak value in 1964. During 1972 the annual deposit again fell to the 1968 value and since 1973 levels have

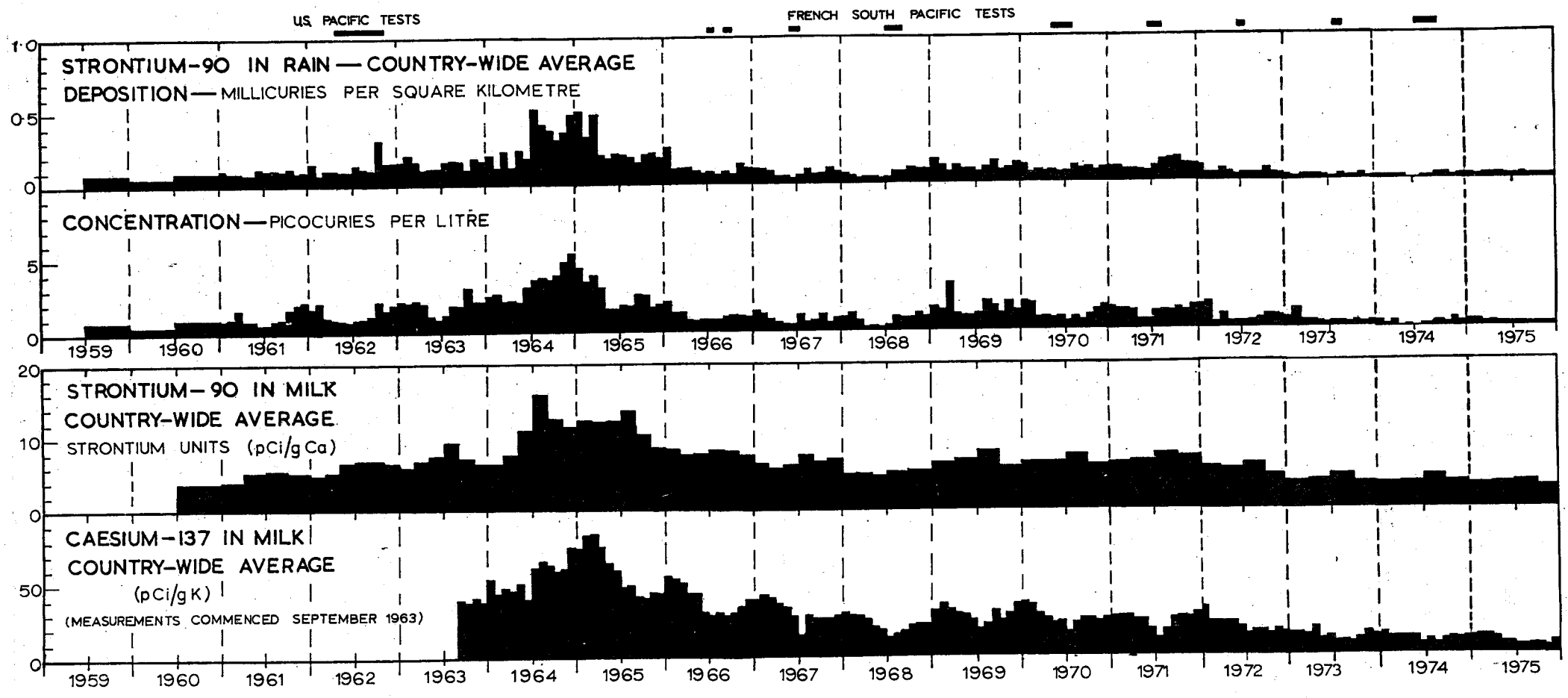

Fig. 4 Country-wide average levels of long-lived radionuclides in rain and milk

remained at less than half the 1968 value. Table 3 lists the annual deposition at each station and the "country-wide average" since measurements commenced:

TABLE 3 - Annual Deposition of Strontium-90 (mCi/km^2) and Mean Annual Rainfall (cm)

	New Zealand Stations										Pacific Islands	
	KA	AK	NP	HN	WN	GM	CH	DN	IN	Average	SU	RA
1960		1.2		0.7	0.8	1.5	0.5		0.5	0.9		
1961		1.1		0.8	1.1	2.2	0.7		1.2	1.2	1.0	
1962		1.8		1.0	1.8	2.8	0.7		1.2	1.6	1.6	
1963	1.8	2.0	2.0	1.0	2.0	3.7	1.2	1.0	1.7	1.8	2.4	
1964	4.1	4.0	5.3	1.6	3.4	7.8	1.3	1.8	3.0	3.6	2.5	
1965	3.1	2.9	4.2	1.7	3.9	5.9	1.7	2.0	2.8	3.1	2.0	
1966	1.6	1.3	1.9	0.8	1.6	2.2	0.7	0.7	1.1	1.3	1.2	
1967	1.0	0.9	1.3	0.5	1.0	1.7	0.4	0.6	0.9	0.9	0.8	0.9*
1968	0.9	0.7	1.0	0.6	0.9	1.4	0.4	0.4	0.5	0.8	1.0	0.7
1969	1.5	1.3	1.5	0.7	1.1	2.2	0.7	0.7	1.2	1.2	1.3	0.7
1970	1.0	0.9	1.2	0.6	1.2	2.1	0.5	0.5	0.7	1.0	0.9	1.0
1971	2.0	1.3	1.9	1.0	1.2	2.5	0.7	0.8	1.1	1.4	1.5*	0.9*
1972	0.9	0.7	0.9	0.5	0.8	1.8	0.4	0.6	0.9	0.8	0.9	0.8
1973	0.4	0.3	0.3	0.2	0.4	0.6	0.2	0.2	0.3	0.3	0.4	0.6
1974	0.3	0.2	0.3	0.2	0.3	0.5	0.2	0.2	0.2	0.3	0.3	0.3
1975	0.3	0.2	0.3	0.2	0.3	0.6	0.2	0.2	0.3	0.3	0.2	0.1
Rainfall	137	117	149	76	131	240	60	63	105		306	205

The New Zealand stations are: Kaitaia, Auckland, New Plymouth, Havelock North, Wellington, Greymouth, Christchurch, Dunedin and Invercargill. The Pacific Island stations are: Suva Fiji and Rarotonga. The mean annual rainfall is for 1963 to 1975 inclusive (at Rarotonga, for 1967 to 1975).

* Estimate

At the two Pacific Island stations the values, in general, have been similar to the New Zealand country-wide average during the past nine years. However, it is interesting to note that during the year of maximum deposition of stratospheric fallout in 1964, the deposit at Suva was significantly lower than the New Zealand average, despite the much higher annual rainfall in Suva. This illustrates a significant characteristic of stratospheric fallout, namely that the tropics receive less global fallout than the mid-latitudes.

In Section 3, Fig. 6, the half-yearly country-wide average depositions of strontium-90 attributed to the early 1961-1962 U.S. and U.S.S.R. tests, and to the French tests, are plotted separately.

(b) Comparison With Two Northern Hemisphere Stations

Two collection sites in the northern hemisphere where continuing measurements of deposition of strontium-90 in rain have been made since about 1954 are Milford Haven in the United Kingdom and New York City. The published results

(4), (5) for annual deposition at these collecting stations are compared with the New Zealand country-wide average annual deposition in Table 4.

It will be seen from Table 4 that the peak depositions from the 1961, 1962 stratospheric injections occurred in 1963 at the northern hemisphere stations and in 1964 in New Zealand. The delay in deposition in the southern hemisphere is explained by the delay in interhemispheric transfer of stratospheric debris. Table 4 shows also that the maximum annual deposits at the two northern hemisphere stations were about six times higher than the New Zealand maximum and that depositions subsequently fell rapidly and became about the same at all three stations from about 1969.

TABLE 4 - Annual Deposition of Strontium-90(mCi/km^2)

	Northern Hemisphere Stations		New Zealand
	Milford Haven (U.K.)*	New York City	
1954	2.0 (to end of 1954)	2.8 (Feb.-Dec. incl.)	
1955	2.4	3.6	
1956	2.5	4.4	
1957	2.6	4.4	
1958	5.4	6.2	
1959	5.7	8.7	
1960	1.8	1.6	0.9
1961	2.5	2.4	1.2
1962	9.3	12.3	1.6
1963	20.9	23.8	1.8
1964	11.7	15.9	3.6
1965	4.8	5.5	3.1
1966	3.1	2.4	1.3
1967	1.2	1.6	0.9
1968	1.2	1.3	0.8
1969	0.9	1.4	1.2
1970	1.2	1.5	1.0
1971	1.4	1.4	1.4
1972	0.6*	0.7	0.8
1973	0.3	0.4	0.3
1974	0.6	0.9	0.3
1975	0.4	(0.5) to end of June	0.3

* Starting 1972 deposition is evaluated in a bulked sample from seven United Kingdom stations (including Milford Haven).

2. STRONTIUM-90 CUMULATIVE DEPOSITION

The annual depositions listed in Table 4 have been totalled, corrected for radioactive decay, and are presented in Fig. 5 as cumulative deposition. In

(4) "Radioactive Fallout in Air and Rain: Results to the end of 1975". United Kingdom Atomic Energy Authority, AERE-R 8267.

(5) "Environmental Quarterly, January 1, 1976". Health and Safety Laboratory, Energy Research and Development Administration, New York, HASL-298.

order to show the range in New Zealand, the values for the highest rainfall station Greymouth, and the lowest rainfall station Christchurch, are also presented. (The dotted portions of the curves for the New Zealand stations up to mid-1959 are estimates based on some soil measurements undertaken by the U.S. Department of Agriculture at that time.)

For the northern hemisphere stations the most significant feature of Fig. 5 is the steep rise in the curves during the years of maximum fallout rate, and the relatively high cumulative deposition after 1964. The plateaux in these curves represent a sharp drop in the rate of fallout. This is evident at about 1960 after the Test Moratorium of 1959 and 1960, and also after about 1965 following the Partial Test Ban Treaty. The interesting situation was reached after 1966 that the reduction due to radioactive decay of the accumulated strontium-90 was slightly greater than the annual increment from fallout, so that there is a distinct downward trend in each curve.

In New Zealand, however, where the total accumulation is much less, the reduction due to radioactive decay has been less significant. The injection of fresh fission material into the southern hemisphere during the French nuclear tests has caused a rate of fallout somewhat greater than the rate of radioactive decay, thus resulting in the continuing slight upward trend, to the end of 1972, as shown in Fig. 5. Since 1973, however, this trend has been reversed, the reduction by radioactive decay being slightly greater than the increment from fallout.

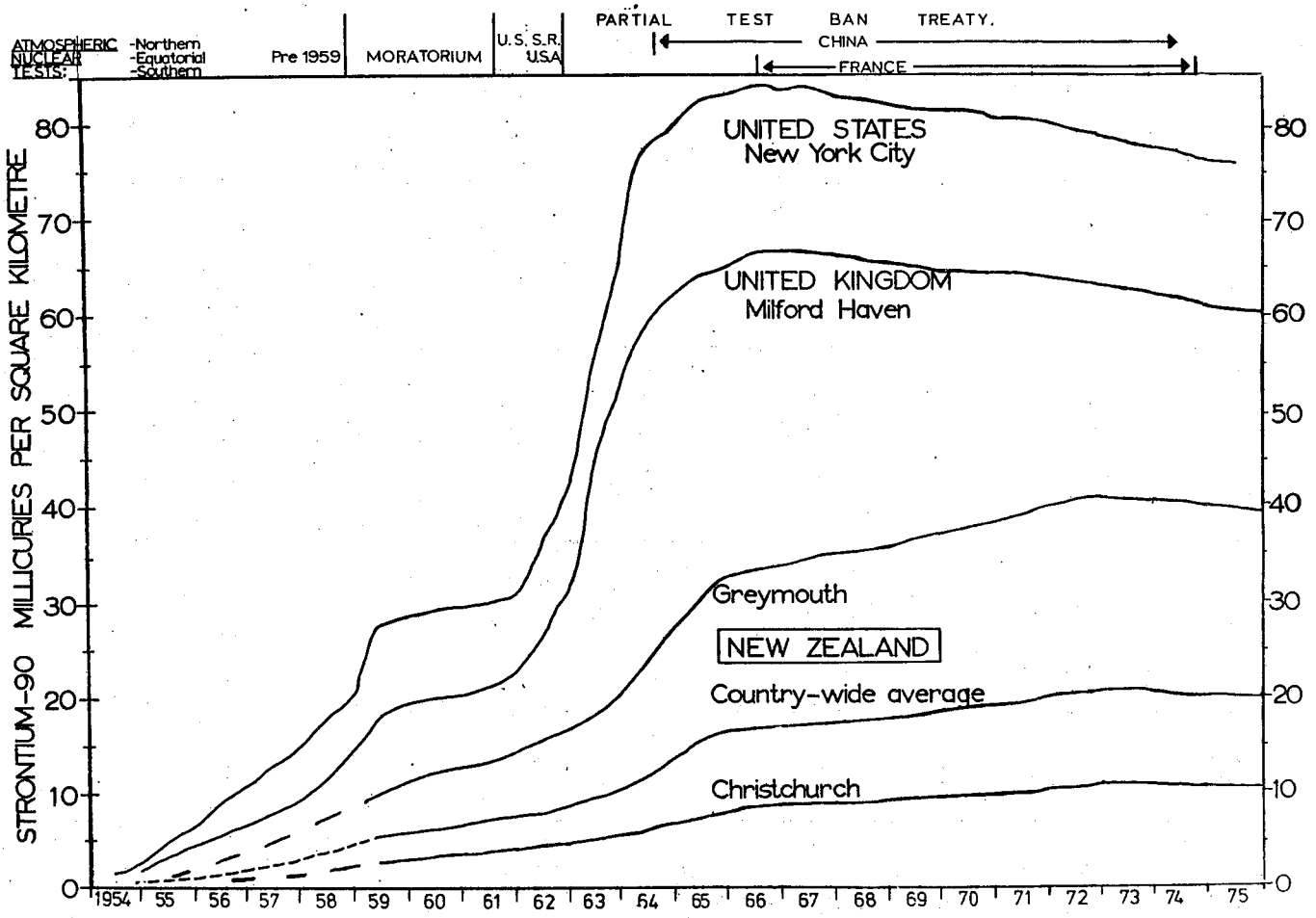

Fig. 5 Cumulative deposition of strontium-90 - comparison

The accumulated deposit has also been measured directly in soil from selected sites. Results to the end of 1972 were given in the 1973 Annual Report (1). Such direct measurements often give values which are low compared to those from rainwater measurements. This low bias may be due to insufficient depth of sampling particularly at some sites where the soil properties may be implicated. A survey is in progress to determine how far strontium-90 and caesium-137 have penetrated into the soil at five selected sites in New Zealand.

3. STRONTIUM-89/STRONTIUM-90 ACTIVITY RATIOS

During and following atmospheric nuclear test programmes, the routine rainwater collections are analysed for strontium-89 as well as strontium-90. The activity ratio $^{89}Sr/^{90}Sr$ is then calculated for each collection. (Values for the deposition of strontium-89 and the activity ratio during 1975 are given in Table 11 in the Appendix.)

The usefulness of such information in allowing estimates of the origin of strontium-90 was discussed especially in the 1973 and 1974 reports (1), where the graphical presentation of the ratio at mid-month was given for each station since 1962. This presentation is continued and completed for 1975 in Fig. 7. The value of the ratio continued to fall during 1975 following the 1974 atmospheric tests. By September and October the limit of detection was reached, and because there were no atmospheric tests in 1975 these measurements were then discontinued.

The conclusions reached from an analysis of the data of Fig. 7 are summarised and shown in Fig. 6. By totalling the half-yearly deposits of strontium-90 and correcting for radioactive decay it has been calculated that at the end of 1975 about 23% of the cumulative deposition on New Zealand originated from French Pacific tests.

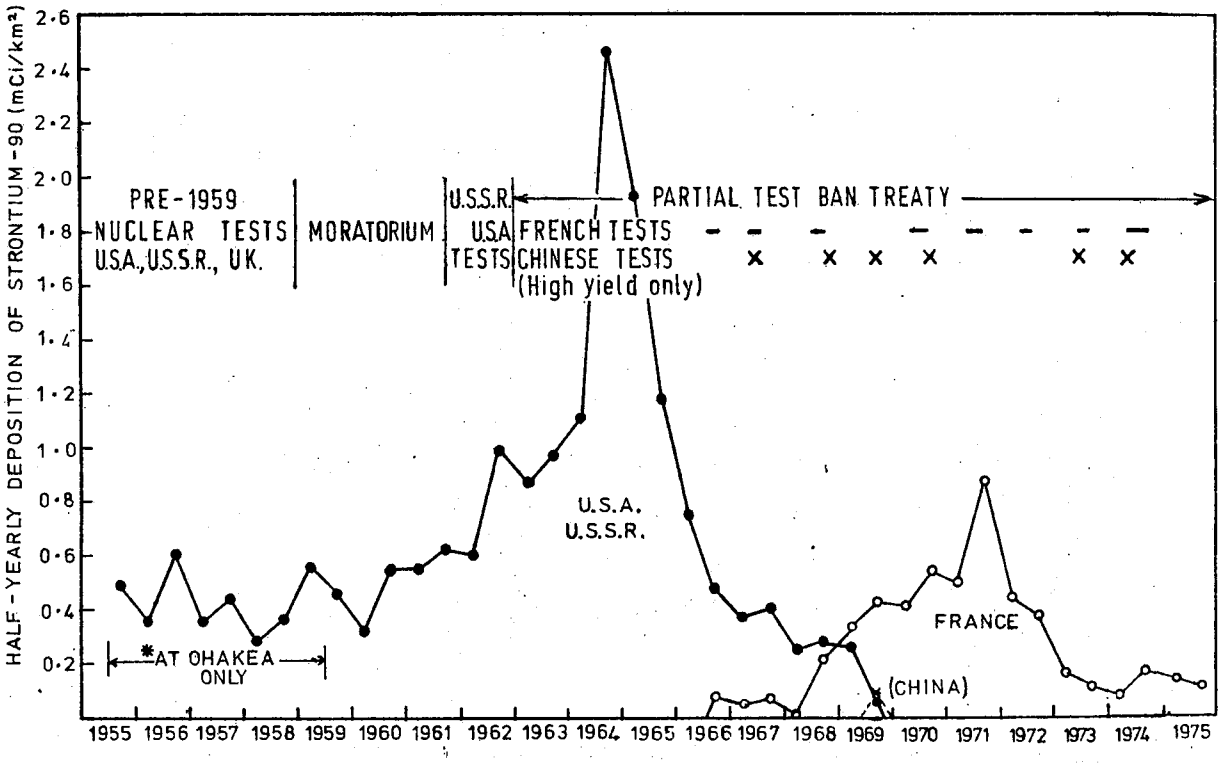

Fig.6 Half-yearly average deposition of strontium-90 on New Zealand from atmospheric nuclear tests by various countries

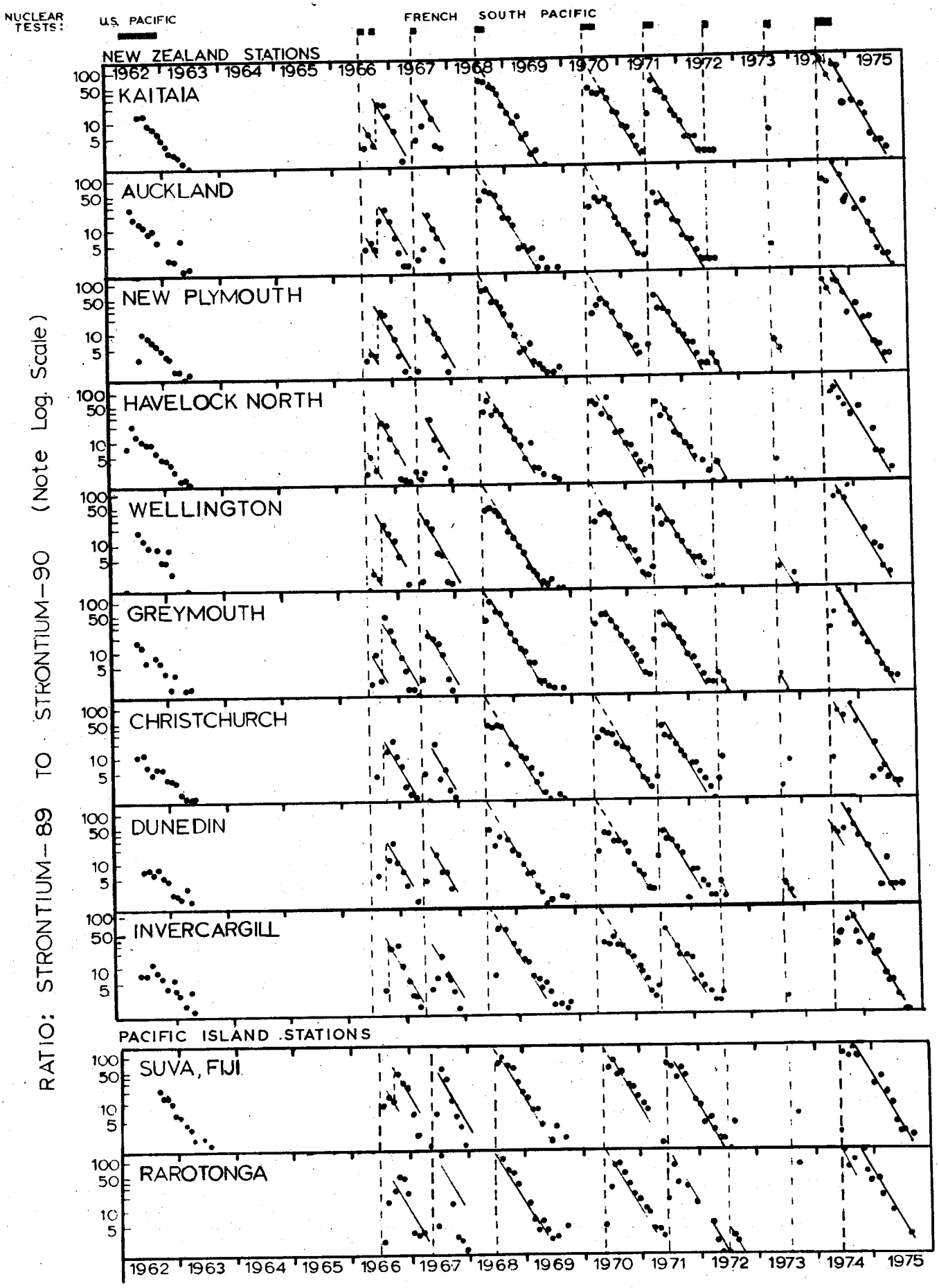

Fig 7 Strontium-89 / Strontium-90 ratio in rainwater

The annual strontium-90 deposits at Suva and Rarotonga have been generally similar to those in New Zealand since 1966. Prior to that results from Suva only are available and the deposits were then generally less than the New Zealand average deposit.

4. STRONTIUM-90 IN MILK

(a) At Nine New Zealand Stations

The "country-wide" average concentration of strontium-90 in milk during both 1974 and 1975 was 3.5 Strontium Units. This was the lowest level recorded since measurements commenced in 1961. (See also Fig. 4 for comparison with deposition levels. Individual results are given in the Appendix in Table 12 and Fig. 11.) Table 5 lists the annual averages for each station and the country-wide averages:

TABLE 5 - Average Levels of Strontium-90 in Milk, 1961 - 1975 ("Strontium Units" : pCi/g Ca)

	ND	AK	WK	TA	PN	WN*	WD	CH	DN	Average
1961	4.5		4.1	7.1			12.7	1.6		
1962	6.3	5.5	4.9	9.4	4.3		13.5	2.1	3.0	6.1
1963	7.5	5.3	5.6	9.9	4.9		17.2	2.7	3.7	7.1
1964	11.2	9.1	9.5	17.1	7.1		26.0	2.6	4.1	10.8
1965	10.6	9.4	9.8	16.7	8.4	8.8	28.8	4.3	7.4	11.6
1966	6.5	6.1	6.3	12.5	4.8	6.1	22.7	2.4	4.0	7.9
1967	5.1	5.2	5.0	10.4	3.9	5.4	17.8	1.9	3.1	6.4
1968	4.1	3.8	4.1	8.0	3.6	4.8	14.0	1.6	2.4	5.2
1969	6.3	6.0	5.4	9.4	5.8	5.1	17.9	1.7	3.0	6.7
1970	5.2	5.1	5.2	9.7	3.6	4.7	21.0	2.2	2.5	6.6
1971	7.3	5.8	6.0	10.2	5.0	4.8	18.3	2.0	3.0	6.9
1972	4.8	4.6	4.4	8.2	5.0	4.1	14.7	1.9	3.1	5.6
1973	3.8	3.4	3.5	5.7	2.7	3.5	10.8	1.2	1.9	4.1
1974	3.3	3.0	2.7	5.4	2.5	3.0	8.8	1.3	1.9	3.5
1975	3.1	2.7	3.0	5.1	2.4	3.4	8.7	1.2	1.6	3.5
Average	6.0	5.4	5.3	9.7	4.6	4.9	16.9	2.0	3.2	6.6

The stations are: Northland, Auckland, Waikato, Taranaki, Palmerston North, Wellington, Westland, Christchurch, and Dunedin.

* Wellington average 1965 - 1975.

Average levels in New Zealand milk reached maximum values of 10.8 and 11.6 pCi/g Ca during 1964 and 1965 when the rate of strontium-90 deposition was also a maximum. Milk levels then fell steadily reaching a minimum of 5.2 pCi/g Ca in 1968, about half the 1964-65 maximum. This indicated that the level in milk was dependent mainly on fallout rate rather than on the cumulative deposit in the soil. However, during the period 1965-1968, milk levels decreased at a slower rate than the strontium-90 deposition because of some uptake by grass of the deposit in the soil. After the start of French Pacific nuclear tests in 1966, milk levels increased slightly during the period 1969-1971. However, following the subsequent decline in deposition during the period 1972 to 1975 milk levels again declined reaching the minimum recorded level of 3.5 pCi/g Ca in 1974 and 1975.

Milk samples from the lowest and highest rainfall stations, i.e. Christchurch and Westland, give the range of strontium-90 contamination in New Zealand milk. Generally the extent of this range is from about one-third to nearly three times the country-wide average.

(b) Comparison with two Northern Hemisphere Stations

In Fig. 8 the country-wide average levels of strontium-90 in New Zealand milk are compared with levels in New York City milk (5), and in Canadian milk (6).

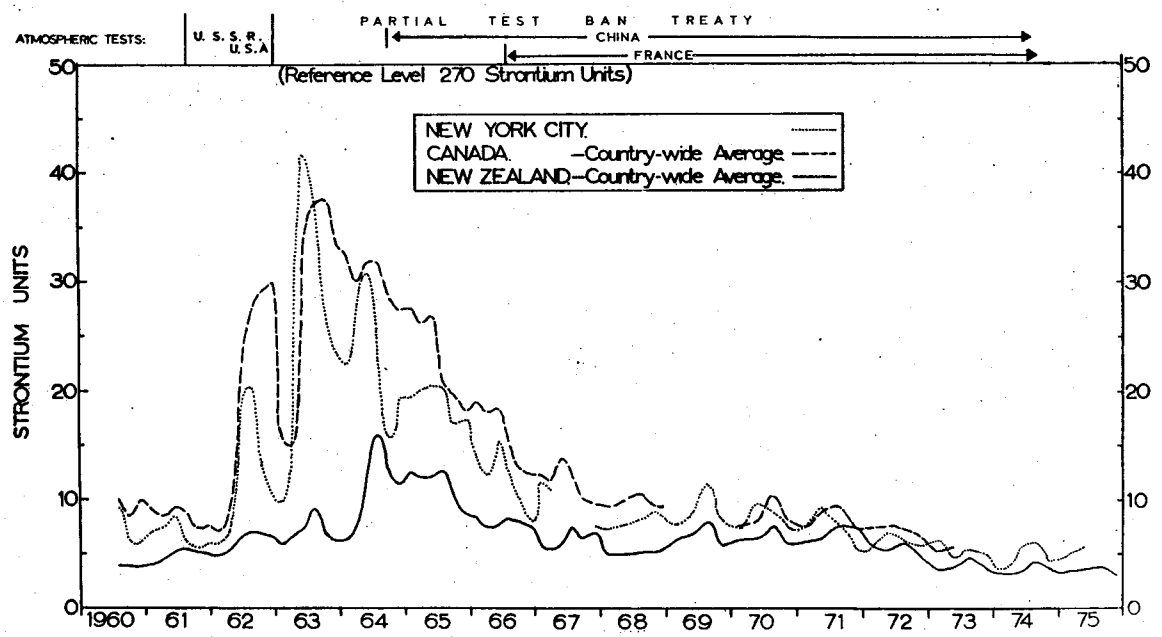

Fig. 8 Strontium-90 levels in milk - comparison

Fallout from the 1961 and 1962 tests resulted in maximum strontium-90 levels in milk in Canada and at New York City in 1963 and 1964, whereas maximum levels in New Zealand occurred about one year later in 1964 and 1965. Fig. 8 shows that the maximum levels in the northern hemisphere were two to three times higher than those in New Zealand. Subsequently levels decreased and in recent years, with similar rates of strontium-90 deposition in both hemispheres, milk levels have also been about the same.

(c) Comparison of Measured Levels with the Reference Level

In order to assess any potential health hazard arising from ingestion of strontium-90 in the diet (or in milk, which for practical purposes we may assess in place of diet as a whole), it is essential to consider long-term average levels. The dose to the critical organ, bone, over an extended period, establishes the degree of potential somatic risk. Therefore the levels in diet must also be considered over similarly extended periods. Results of direct measurements of strontium-90 in human bone in New Zealand were given in the 1974 annual report (1).

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(6) "Data from Radiation Protection Programs"; "Radiation Surveillance in Canada"; "Environmental Radioactivity Surveillance": Reports of the Radiation Protection Bureau, Health and Welfare, Canada.

During the period 1962 to 1975 inclusive the country-wide average level in milk was 6.6 "Strontium Units" or about 2.4% of the reference level. The highest average level was at Westland, 16.9 S.U. (6.3% of the reference level), and the lowest average level was at Christchurch, 2.0 S.U. (0.7% of the reference level).

5. CAESIUM-137 IN MILK

(a) At Nine New Zealand Stations

The average level of caesium-137 in milk during 1975 was also the lowest since measurements commenced in 1964. (Individual results are given in the Appendix in Table 13 and Fig. 12. See also Fig. 4 for comparison with strontium-90 levels in rain and milk.) Table 6 lists the annual averages for each station and the country-wide averages:

TABLE 6 - Average Levels of Caesium-137 in Milk (pCi/g K)

	ND	AK	WK	TA	PN	WN	WD	CH	DN	Average
1964	49	51	69	168	19	25*	76	7	11	53
1965	54	53	84	185	26	29	77	11	18	60
1966	37	33	60	141	11	18	43	4	9	39
1967	26	26	48	123	7	13	33	3	5	31
1968	15	18	36	102	3	7	21	1	3	23
1969	27	26	41	101	5	9	38	2	4	28
1970	22	18	35	89	6	11	39	4	5	25
1971	23	18	36	80	7	9	30	3	5	23
1972	21	15	28	72	2	7	22	2	4	19
1973	14	9	21	49	3	4	14	1	2	13
1974	7	7	16	41	2	3	8	1	1	10
1975	9	7	14	34	1	3	8	1	1	9
Average	25	23	41	99	8	12	34	3	6	28

See Table 5 for station names.

* Estimate

The highest levels were recorded in 1964 and 1965 and they have steadily decreased since then except for a slight increase in 1969 and 1970. The higher levels at Taranaki due to the "soil effect" have been discussed in the 1971 annual report of this series (1).

(b) Comparison of Measured Levels with the Reference Level

During the period 1964 to 1975 inclusive the country-wide average level was 28 pCi/g K which is about 0.4% of the reference level. At the highest level station, Taranaki, the average level over the same period was 99 pCi/g K, about 1.4% of the reference level, whereas at Christchurch, the lowest level station, the average was 3 pCi/g K, about 0.04% of the reference level.

6. LEAD-210 IN RAIN

The measurement of lead-210 deposition in rain was continued during 1975. The evaluation was made in samples from the stations routinely supplying rainwater collections for strontium-90 determination.

Lead-210 is a naturally-occurring radionuclide produced in the atmosphere by decay of gaseous radon which is exhaled from land surfaces. The subsequent deposition of lead-210 is rainfall dependent, like strontium-90, so that high rainfall areas such as Greymouth show elevated values compared to low rainfall areas such as Christchurch.

Individual station monthly deposits, since May 1967 when measurements were started at all stations, are shown in Fig. 13 Appendix. Earlier results, including higher levels during 1965 at four stations, and levels in milk, were discussed in the 1971 annual report of this series (1).

Table 7 lists the annual deposition at each station and the country-wide average since measurements commenced:

TABLE 7 - Annual Deposition of Lead-210 (mCi/km^2)

	New Zealand Stations										Pacific Islands	
	KA	AK	NP	HN	WN	GM	CH	DN	IN	Average	SU	RA
1967*	0.62	1.15	1.72	0.73	1.02	2.38	0.36	0.56	0.99	1.06	1.25	0.60
1968	1.75	1.64	2.08	0.84	1.86	3.20	0.64	0.76	1.06	1.54	2.46	0.61
1969	1.83	1.33	1.54	0.88	1.20	3.94	0.56	0.92	1.29	1.50	1.91	0.98
1970	1.43	1.00	1.82	0.63	1.52	3.09	0.65	0.74	0.92	1.31	1.85	0.85
1971	2.07	1.04	0.96	0.65	1.26	2.34	0.52	0.74	1.09	1.19	1.83	-
1972	2.28	1.62	1.99	0.88	1.70	3.41	0.70	1.22	1.31	1.68	2.65	-
1973	1.92	1.42	2.29	0.80	1.80	3.31	0.48	0.67	0.81	1.50	2.11	-
1974	1.24	1.08	1.76	0.76	1.61	2.85	0.71	0.66	0.58	1.25	1.86	4.00
1975	1.61	1.51	1.81	1.12	1.97	3.94	0.92	0.91	1.11	1.66	2.91	1.40

See Table 3 for station names.

* May to December only.

NOTE: Where practicable estimates have been made for those months designated N.S. in Fig. 13 Appendix.

During the last eight years the annual deposition in New Zealand has averaged about 1.5 mCi/km^2. During the same period the annual deposition of weapons test strontium-90 at the same stations has averaged about 0.8 mCi/km^2. At the Pacific Island stations lead-210 depositions at Suva are generally somewhat higher, and at Rarotonga generally somewhat lower, than those in New Zealand.

The New Zealand country-wide average monthly deposition of lead-210 is shown in Fig. 9. The average deposition is about 0.12 mCi/km^2 per month with a range of slightly less than one-half to about twice this value. There does not appear to be any marked seasonal variation nor change in the average deposition since 1967.

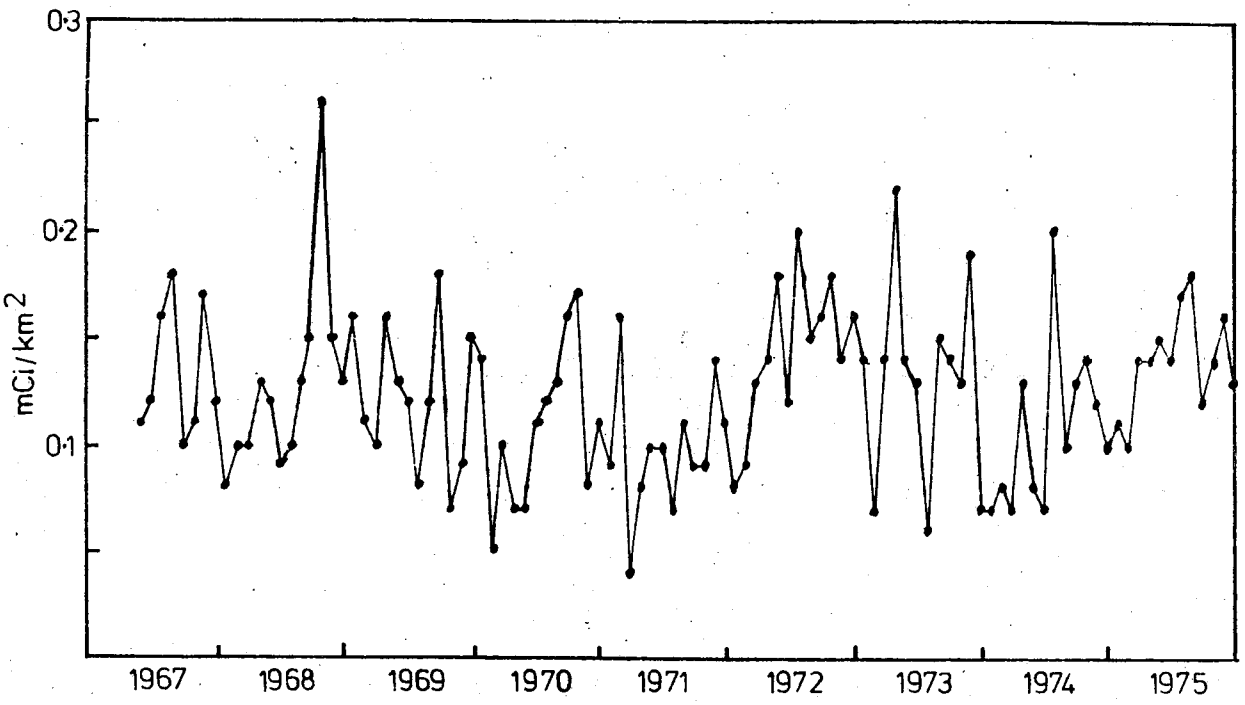


Fig. 9 Country-wide Average monthly Deposition of Lead-210

MISCELLANEOUS

1. INTERCOMPARISON OF MEASUREMENTS

During 1975 this Laboratory again participated in intercomparison measurements of strontium-90, strontium-89, iodine-131, caesium-137, barium-140, and potassium in liquid milk samples provided by the U.S. Environmental Protection Agency.

2. HUMAN MILK STUDY

During 1975 a pooled sample of human milk from about twelve mothers was provided by the Perinatal Metabolic Unit of the Palmerston North Hospital. The naturally-occurring radionuclides potassium-40, radium-226, and lead-210, and the artificial radionuclides strontium-90 and caesium-137, in this sample were measured at the Laboratory as part of a detailed study of human milk being conducted by the Unit. The amount of sample available for analysis precluded measurements in duplicate.

The activity concentrations measured together with the standard deviations of the results were:

Potassium-40	530	±	10	pCi/litre
Radium-226	0.46	±	0.02	pCi/litre
Lead-210	0.11	±	0.01	pCi/litre
Strontium-90	0.27	±	0.04	pCi/litre
Caesium-137	4	±	2	pCi/litre

These levels for human milk appear reasonable and consistent with dietary levels in "normal" areas of the world.

3. TECHNICAL INFORMATION ON MEASUREMENT PROCEDURES

Technical information on collection procedures and methods of evaluation used in obtaining the results published in this report were discussed in the 1971 annual report of this series (1). Many of the radiochemical procedures have been published by the Laboratory as detailed technical reports. These were listed in the 1974 annual report of this series (1) and are available on request.

APPENDIX

List of Tables and Figures in the Appendix

TABLE 8 - Total Beta Activity of Air Filter Samples : 1975 (pCi/m^3)

		New Zealand				Pacific Islands				
		AK	WN	HK	CH	FJ	SM	TO	AI	RA
Jan.	Maximum	0.15	0.10	0.13	0.10					
	Minimum	0.03	0.05	0.03	0.03					
	Average	0.09	0.08	0.07	0.06					
Feb.	Maximum	0.19	0.15	0.18	0.24					
	Minimum	0.03	0.02	0.05	0.03					
	Average	0.11	0.08	0.09	0.07					
Mar.	Maximum	0.11	0.10	0.10	0.08					
	Minimum	0.03	0.04	0.01	0.02					
	Average	0.07	0.06	0.06	0.05					
Apr.	Maximum	0.07	0.05	0.05	0.04					
	Minimum	0.01	0.02	0.01	0.02					
	Average	0.04	0.03	0.03	0.03					
May	Maximum	0.06	0.03	0.03	0.03					
	Minimum	0.02	0.01	<0.01	0.01					
	Average	0.03	0.02	0.02	0.02					
Jun.	Maximum	0.06	0.04	0.06	0.02	0.02	0.02	-	0.07	0.05
	Minimum	<0.01	0.01	0.01	0.01	<0.01	<0.01	-	<0.01	<0.01
	Average	0.02	0.02	0.02	0.02	0.01	-	-	-	0.02
Jul.	Maximum	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.02	0.03
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Average	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01
Aug.	Maximum	0.03	0.03	0.02	0.02	0.03	0.03	0.06	0.03	0.03
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
	Average	0.01	0.01	<0.01	<0.01	0.01	0.01	0.02	0.02	0.02
Sep.	Maximum	0.02	0.02	0.02	0.01	0.03	0.02	0.02	0.02	0.03
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Average	0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Oct.	Maximum	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Average	0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01
Nov.	Maximum	0.02	0.01	0.02	0.02	0.01	0.02	0.03	0.02	0.02
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Average	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Dec.	Maximum	0.03	0.03	0.01	0.01	0.02	0.01	0.02	0.01	0.02
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Average	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1975	Average	0.03	0.03	0.03	0.02	-	-	-	-	-
Jul.-Oct.	Average	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01

The stations are: Auckland, Wellington, Hokitika, Christchurch, Fiji, Western Samoa, Tonga, Aitutaki, and Rarotonga.

NOTE: The filters were changed three times weekly on Mondays, Wednesdays, and Fridays. Individual results are available on request.

TABLE 9 - Total Beta Activity of Weekly Rainwater Samples 1975 : Deposition (mCi/km^2), Rainfall (cm)

The collection period is from the date shown to the start of the next collection.
N.S. No sample or result available, ( ) estimated result.

AUCKLAND			WELLINGTON			GREYMOUTH			CHRISTCHURCH			FIJI			SAMOA			TONGA			AITUTAKI			RAROTONGA		
Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2
Jan 3	7.2	0.6	Jan 3	nil	0.1	Jan 4	nil	0.4	Jan 3	<0.1	1.2															
Jan 10	1.9	0.6	Jan 10	2.3	1.6	Jan 11	2.0	1.0	Jan 10	6.9	2.2															
Jan 17	2.8	1.0	Jan 17	3.7	1.7	Jan 18	1.2	0.7	Jan 17	0.8	0.8															
Jan 24	<0.1	<0.1	Jan 24	0.9	0.4	Jan 25	3.6	0.9	Jan 24	3.3	0.8															
Jan	11.9	2.2	Jan	6.9	3.8	Jan	6.8	3.0	Jan	11.0	5.0															
Jan 31	1.0	0.3	Jan 31	1.2	0.3	Feb 1	1.6	0.6	Jan 31	0.2	0.6															
Feb 7	<0.1	0.2	Feb 7	0.1	0.3	Feb 8	7.7	0.7	Feb 7	0.2	<0.1															
Feb 14	0.6	0.1	Feb 14	2.8	0.4	Feb 15	3.1	0.6	Feb 14	0.1	<0.1															
Feb 21	0.5	0.2	Feb 21	0.8	0.2	Feb 22	11.5	0.9	Feb 21	4.8	0.7															
Feb	2.1	0.8	Feb	4.9	1.2	Feb	23.9	2.8	Feb	5.3	1.3															
Feb 28	5.0	0.4	Feb 28	3.3	<0.1	Mar 1	7.9	0.4	Feb 28	1.9	0.4															
Mar 7	–	N.S.	Mar 7	4.8	0.5	Mar 8	10.3	0.5	Mar 7	11.3	0.7															
Mar 14	6.5	0.2	Mar 14	1.4	0.1	Mar 15	0.5	0.1	Mar 14	0.5	<0.1															
Mar 21	0.8	<0.1	Mar 21	7.9	N.S.	Mar 22	6.7	0.5	Mar 21	0.8	<0.1															
Mar	12.3	0.7	Mar	17.4	(0.9)	Mar	25.4	1.5	Mar	14.5	1.1															
Mar 28	2.2	0.2	Mar 28	–	N.S.	Apr 1	21.4	0.9	Mar 28	0.4	<0.1															
Apr 4	0.2	<0.1	Apr 4	0.4	0.2	Apr 5	5.6	0.7	Apr 4	0.9	<0.1															
Apr 11	<0.1	<0.1	Apr 11	0.6	<0.1	Apr 12	0.3	<0.1	Apr 11	0.1	<0.1															
Apr 18	2.3	0.4	Apr 18	4.9	0.3	Apr 19	5.1	0.4	Apr 18	<0.1	<0.1															
Apr 25	4.3	0.4	Apr 25	2.8	0.6	Apr 26	9.9	1.4	Apr 25	4.7	0.1															
Apr	9.1	1.1	Apr	8.7	1.2	Apr	42.3	3.4	Apr	6.1	0.3															
May 2	2.9	0.2	May 2	1.1	0.2	May 3	5.0	0.2	May 2	0.3	1.2															
May 9	0.6	<0.1	May 9	0.4	0.4	May 10	6.9	0.3	May 9	<0.1	<0.1															
May 16	1.3	<0.1	May 16	4.9	0.6	May 17	12.2	N.S.	May 16	1.5	1.6															
May 23	2.3	0.1	May 23	—	N.S.	May 24	1.1	0.2	May 23	0.3	0.1															
May	7.1	0.4	May	6.4	1.2	May	25.2	(1.2)	May	2.2	2.9															
May 30	3.0	<0.1	May 30	0.9	0.1	May 31	11.0	0.5	May 30	<0.1	<0.1	May 26	3.5	0.2	May 27	21.2	0.3				May 24	<0.1	0.2	May 23	<0.1	0.2
Jun 6	3.3	0.4	Jun 6	4.3	0.3	Jun 7	5.3	0.3	Jun 6	1.2	<0.1	Jun 2	5.2	0.3	Jun 3	3.8	0.2	Jun 9	2.7	0.2	May 31	0.4	0.4	May 30	1.9	0.3
Jun 13	12.7	1.0	Jun 13	15.0	0.6	Jun 14	0.7	0.7	Jun 13	10.3	0.2	Jun 13	–	N.S.	Jun 13	1.9	1.0	Jun 13	5.2	0.2	Jun 7	1.0	0.3	Jun 6	1.4	0.6
Jun 20	4.2	0.2	Jun 20	1.1	0.2	Jun 21	nil	0.2	Jun 20	0.9	0.2	Jun 20	<0.1	<0.1	Jun 20	1.6	<0.1	Jun 20	<0.1	<0.1	Jun 14	1.0	0.1	Jun 13	5.4	<0.1
Jun 27	1.2	0.2							Jun 27	2.6	0.1	Jun 27	1.2	0.1	Jun 27	1.4	<0.1	Jun 27	4.4	<0.1	Jun 23	0.8	<0.1	Jun 20	5.2	0.1
																								Jun 27	0.4	0.2
Jun	24.4	1.8	Jun	21.3	1.2	Jun	17.0	1.7	Jun	15.0	0.6	Jun	6.5	0.4	Jun	8.7	1.2	Jun	12.3	0.5	Jun	3.2	0.8	Jun	14.3	1.3

NOTE: Monitoring at the Pacific Island stations commenced about mid-year when France's underground nuclear test programme started.

TABLE 9 (continued).

AUCKLAND			WELLINGTON			GREYMOUTH			CHRISTCHURCH			FIJI			SAMOA			TONGA			AITUTAKI			RAROTONGA		
Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2	Date	cm	mCi/km^2
Jul 4	<0.1	0.3	Jun 30	2.5	0.2	Jun 28	6.2	0.4	Jul 4	0.4	<0.1	Jul 4	0.2	<0.1	Jul 4	4.6	<0.1	Jul 4	0.1	0.1	Jun 30	-	<0.1	Jul 4	<0.1	<0.1
Jul 11	2.8	0.1	Jul 4	6.9	0.2	Jul 5	5.0	0.2	Jul 11	0.3	<0.1	Jul 11	nil	<0.1	Jul 11	1.5	0.2	Jul 11	0.4	<0.1	Jul 7	-	<0.1	Jul 11	0.5	<0.1
Jul 18	1.3	<0.1	Jul 18	5.0	0.2	Jul 12	12.0	0.8	Jul 18	2.4	0.3	Jul 18	1.3	<0.1	Jul 18	<0.1	<0.1	Jul 18	0.5	<0.1	Jul 14	1.9	0.2	Jul 18	0.4	0.1
Jul 28	0.5	<0.1	Jul 25	0.6	0.2	Jul 19	4.7	0.2	Jul 25	1.4	(0.1)	Jul 25	nil	<0.1	Jul 25	16.8	0.1	Jul 25	4.3	0.1	Jul 28	0.6	<0.1	Jul 25	2.5	<0.1
						Jul 26	8.1	1.0																		
Jul	4.6	0.5	Jul	15.0	0.8	Jul	36.0	2.6	Jul	4.5	0.4	Jul	1.5	<0.1	Jul	22.9	0.4	Jul	5.3	0.3	Jul	2.5	0.2	Jul	3.4	0.2
Aug 1	1.1	0.1	Aug 1	2.8	0.1	Aug 2	4.7	0.2	Aug 1	1.3	<0.1	Aug 1	nil	<0.1	Jul 31	7.7	0.1	Aug 1	14.6	0.1	Aug 4	3.3	0.1	Aug 1	7.8	<0.1
Aug 8	1.9	<0.1	Aug 8	0.2	<0.1	Aug 9	1.1	<0.1	Aug 8	0.2	<0.1	Aug 8	nil	<0.1	Aug 8	2.2	<0.1	Aug 8	0.2	<0.1	Aug 11	0.7	0.2	Aug 8	2.4	0.1
Aug 15	2.5	<0.1	Aug 15	8.8	0.2	Aug 16	8.9	0.1	Aug 15	9.9	0.1	Aug 18	nil	<0.1	Aug 15	0.2	<0.1	Aug 15	<0.1	<0.1	Aug 18	<0.1	<0.1	Aug 15	0.1	<0.1
Aug 22	2.1	0.1	Aug 22	9.1	0.3	Aug 23	17.8	0.4	Aug 22	3.9	<0.1	Aug 25	nil	<0.1	Aug 22	0.9	<0.1	Aug 22	<0.1	<0.1	Aug 25	0.3	<0.1	Aug 22	0.9	0.2
Aug	7.6	0.3	Aug	20.9	0.6	Aug	32.5	0.7	Aug	15.3	0.2	Aug	nil	<0.1	Aug	11.0	0.1	Aug	14.8	0.2	Aug	4.3	0.3	Aug	11.2	0.4
Aug 29	3.3	0.1	Aug 29	3.8	<0.1	Aug 30	0.9	<0.1	Aug 29	0.4	<0.1	Sep 1	0.7	<0.1	Aug 29	1.0	<0.1	Aug 29	<0.1	<0.1	Sep 1	1.2	<0.1	Aug 29	1.4	0.2
Sep 5	2.6	<0.1	Sep 5	0.3	<0.1	Sep 6	2.9	0.2	Sep 5	0.4	<0.1	Sep 10	1.4	0.2	Sep 5	5.4	<0.1	Sep 5	0.4	<0.1	Sep 8	13.3	0.4	Sep 8	2.8	0.1
Sep 12	0.5	<0.1	Sep 12	0.3	<0.1	Sep 1	6.4	0.1	Sep 12	<0.1	<0.1	(16 day collection)			Sep 12	14.6	0.3	Sep 12	<0.1	<0.1	Sep 12	0.4	<0.1	Sep 12	1.0	<0.1
Sep 19	2.1	0.1	Sep 18	2.4	0.1	Sep 20	5.6	0.3	Sep 19	1.8	0.1				Sep 19	1.5	0.2	Sep 19	3.2	0.2	Sep 20	3.1	0.2	Sep 19	5.9	0.3
Sep 26	1.2	<0.1	Sep 26	2.7	(0.1)	Sep 27	0.6	0.1	Sep 26	<0.1	<0.1							Sep 26	0.7	<0.1				Sep 26	0.8	<0.1
Sep	9.7	0.4	Sep	9.5	0.4	Sep	16.4	0.7	Sep	2.6	0.2	Sep	2.1	0.2	Sep	22.5	0.6	Sep	4.3	0.3	Sep	18.0	0.6	Sep	11.9	0.6
Oct 3	1.2	0.1	Sep 28	2.2	0.1	Oct 4	nil	<0.1	Oct 3	1.4	<0.1	Sep 26	3.1	0.2	Sep 26	4.6	0.2	Oct 3	<0.1	<0.1	Sep 28	2.7	<0.1	Oct 3	1.2	<0.1
Oct 10	3.1	<0.1	Oct 9	1.6	0.1	Oct 11	5.4	0.2	Oct 10	<0.1	<0.1	Oct 7	1.3	<0.1	Oct 6	1.2	0.2	Oct 10	2.6	<0.1	Oct 6	<0.1	0.1	Oct 10	2.7	0.1
Oct 17	4.1	0.2	Oct 17	3.9	0.2	Oct 18	3.3	0.1	Oct 17	3.2	0.1	Oct 13	0.7	0.1	Oct 10	2.2	0.1	Oct 18	0.6	<0.1	Oct 13	4.5	<0.1	Oct 17	3.9	<0.1
Oct 24	1.2	<0.1	Oct 24	3.9	<0.1	Oct 25	5.2	<0.1	Oct 24	1.0	<0.1	Oct 20	7.0	<0.1	Oct 17	1.6	<0.1	Oct 24	4.4	0.1	Oct 20	3.4	0.3	Oct 24	3.8	0.2
												Oct 27	22.1	0.1	Oct 24	11.8	0.1				Oct 27	1.4	0.1			
Oct	9.6	0.4	Oct	11.6	0.5	Oct	13.9	0.4	Oct	5.6	0.2	Oct	34.2	0.6	Oct	21.4	0.6	Oct	7.6	0.2	Oct	12.0	0.6	Oct	11.6	0.4
Oct 31	3.3	<0.1	Oct 31	5.2	0.2	Nov 1	8.3	0.2	Oct 31	1.0	<0.1	Nov 4	9.0	0.1	Oct 31	4.2	<0.1	Oct 31	4.8	<0.1	Nov 3	4.5	<0.1	Oct 31	1.0	0.2
Nov 7	0.9	<0.1	Nov 7	1.7	<0.1	Nov 8	1.6	<0.1	Nov 7	1.1	<0.1	Nov 10	10.0	0.2	Nov 7	4.1	0.2	Nov 7	-	N.S.	Nov 10	8.5	0.2	Nov 7	6.2	0.1
Nov 14	0.4	0.1	Nov 14	5.6	0.2	Nov 15	0.9	0.1	Nov 13	1.2	<0.1	Nov 17	14.5	<0.1	Nov 14	4.9	0.1	Nov 21	7.1	0.2	Nov 15	1.0	<0.1	Nov 14	12.6	<0.1
Nov 21	4.0	0.2				Nov 23	4.3	0.2	Nov 21	0.6	<0.1	Nov 24	9.9	0.2	Nov 21	3.7	0.1	Nov 25	-	N.S.	Nov 24	5.1	0.1	Nov 21	4.9	0.1
Nov	8.6	0.4	Nov	12.5	0.5	Nov	15.1	0.5	Nov	3.9	0.2	Nov	43.4	0.6	Nov	16.9	0.5	Nov	(11.9)	(0.2)	Nov	19.1	0.3	Nov	24.7	0.5
Nov 28	0.8	<0.1	Nov 28	<0.1	<0.1	Nov 29	1.4	0.2	Nov 28	0.3	<0.1	Dec 1	4.2	0.2	Nov 28	3.8	<0.1	Nov 28	1.7	0.1	Dec 1	8.7	<0.1	Nov 28	0.5	<0.1
Dec 5	0.6	<0.1	Dec 5	0.3	<0.1	Dec 6	5.0	0.1	Dec 5	0.4	<0.1	Dec 8	8.7	<0.1	Dec 5	12.7	0.1	Dec 5	2.3	<0.1	Dec 7	7.7	<0.1	Dec 5	9.1	<0.1
Dec 12	0.4	<0.1	Dec 12	1.7	0.1	Dec 13	6.4	0.2	Dec 12	1.4	<0.1	Dec 15	1.2	<0.1	Dec 12	5.8	<0.1	Dec 12	0.7	<0.1	Dec 15	0.6	<0.1	Dec 12	2.4	<0.1
Dec 19	1.4	<0.1	Dec 19	9.2	0.1	Dec 20	1.9	0.1	Dec 19	2.1	<0.1	Dec 22	5.6	<0.1	Dec 19	12.6	<0.1	Dec 19	2.1	<0.1	Dec 22	3.1	0.1	Dec 19	2.9	<0.1
Dec 26	1.2	0.2				Dec 27	0.3	0.1	Dec 26	0.4	<0.1							Dec 26	0.5	<0.1				Dec 26	4.9	<0.1
Dec	4.4	0.3	Dec	11.2	0.3	Dec	15.0	0.7	Dec	4.6	0.1	Dec	19.7	0.4	Dec	34.9	0.2	Dec	7.3	0.2	Dec	20.1	0.1	Dec	19.8	0.2
TOTAL	111	9.3	TOTAL	146	12.6	TOTAL	270	19.2	TOTAL	91	12.5	TOTAL*	111	2.5	TOTAL*	160	3.9	TOTAL*	64	1.9	TOTAL*	79	3.1	TOTAL*	97	3.8

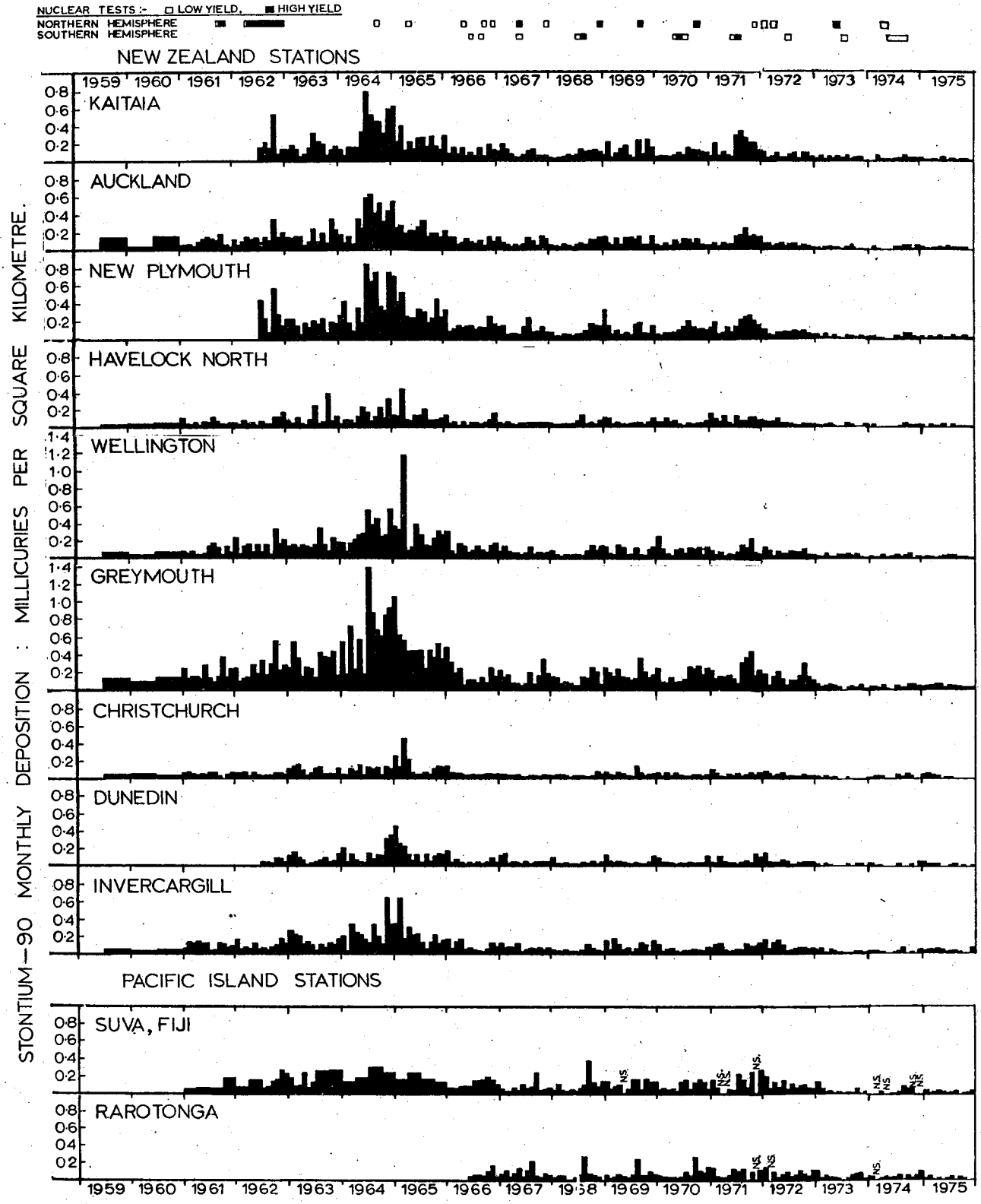
* since start of collection only.

Average Concentration (pCi/litre)																										
	8			9			7			14			2			2			3			4			4	

TABLE 10 - Strontium-90 in Rain 1975 : Rainfall (cm), Deposition (mCi/km^2), Concentration (pCi/litre)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
Kaitaia	Rainfall	5.3	3.7	8.9	14.8	2.9	19.3	6.3	13.4	17.5	21.3	13.3	3.3	130	
	Deposition	0.03	0.01*	0.01	0.02	0.01	0.05	0.01	0.03	0.02	0.03	0.03	0.01	0.26	
	Concentration	0.5	0.3*	0.1	0.1	0.4	0.2	0.2	0.2	0.1	0.1	0.2	0.3		0.2
Auckland	Rainfall	11.9	2.1	12.3	9.1	10.1	19.6	6.5	8.4	8.9	9.5	8.6	4.1	111	
	Deposition	0.03	0.01*	0.01	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	<0.01	0.24	
	Concentration	0.2	0.5*	0.1	0.2	0.3	<0.1	0.4	0.3	0.2	0.2	0.2	0.2		0.2
New Plymouth	Rainfall	13.4	3.3	12.9	12.5	15.1	13.9	15.4	18.3	8.5	15.2	8.2	8.5	145	
	Deposition	0.03	0.01*	0.03	0.02	0.04	0.02	0.02	0.04	0.02	0.03	0.03	0.02	0.31	
	Concentration	0.2	0.3*	0.2	0.1	0.3	0.2	0.1	0.2	0.3	0.2	0.3	0.2		0.2
Havelock North	Rainfall	5.9	1.9	10.4	4.0	7.5	9.1	3.8	5.4	5.2	3.7	7.6	10.8	75	
	Deposition	0.02	<0.01*	0.02*	0.01	0.01	0.02	<0.01	0.02	0.01	0.01	0.01	0.01	0.15	
	Concentration	0.3	0.3*	0.2*	0.3	0.2	0.2	0.2	0.4	0.2	0.3	0.1	0.1		0.2
Wellington	Rainfall	7.4	6.0	12.0	7.4	10.1	23.7	20.3	21.4	5.1	11.8	9.7	5.2	140	
	Deposition	0.02*	0.03	0.02*	0.01	0.02	0.03	0.04	0.04	0.02	0.02	0.02	0.01	0.28	
	Concentration	0.3	0.4	0.2*	0.1	0.2	0.1	0.2	0.2	0.3	0.2	0.2	0.2		0.2
Greymouth	Rainfall	8.6	23.9	47.1	17.6	29.2	17.1	33.8	35.2	15.3	14.3	15.1	15.1	272	
	Deposition	0.04	0.05	0.06*	0.08	0.08	0.03	0.06	0.05	0.04	0.03	0.03	0.03	0.58	
	Concentration	0.5	0.2	0.1*	0.5	0.3	0.2	0.2	0.1	0.3	0.2	0.2	0.2		0.3
Christchurch	Rainfall	11.0	6.1	13.9	5.8	2.3	12.4	7.1	15.3	2.4	5.6	3.9	4.4	90	
	Deposition	0.04*	0.05	0.03	0.02	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	
	Concentration	0.4*	0.8	0.2	0.3	0.2	0.1	0.2	<0.1	0.2	<0.1	0.2	0.2		0.2
Dunedin	Rainfall	6.4	5.9	6.2	2.1	3.1	2.2	6.8	9.8	4.7	5.2	5.9	4.1	62	
	Deposition	0.04	0.02*	0.02*	0.02	<0.01	<0.01	0.01	0.02	<0.01	0.01	<0.01	0.01	0.17	
	Concentration	0.6	0.3*	0.3*	1.0	0.2	0.2	0.2	0.2	0.1	0.3	0.2	0.3		0.3
Invercargill	Rainfall	3.7	8.4	11.0	15.5	10.4	7.7	12.8	6.5	6.7	6.7	5.3	15.4	110	
	Deposition	0.02	0.03	0.03	0.04	0.03	0.01	0.02	0.02	0.01	<0.01	<0.01	0.04	0.26	
	Concentration	0.7	0.4	0.2	0.3	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.2		0.3
New Zealand Country-wide Average	Rainfall	8.2	6.8	15.0	9.9	10.1	13.9	12.5	14.9	8.3	10.4	8.6	7.9	126	
	Deposition	0.03	0.02*	0.03*	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.27	
	Concentration	0.4	0.4*	0.2*	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2
Suva, Fiji	Rainfall	64.1	25.4	29.4	26.3	49.6	23.1	31.7	4.9	19.7	51.7	46.1	5.5	378	
	Deposition	.03	0.01	0.02	0.03	0.02	0.01	0.02	0.03	<0.01	0.01	0.02	0.03	0.23	
	Concentration	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	<0.1	<0.1	<0.1	0.5		0.1
Rarotonga	Rainfall	24.8	16.5	22.9	14.0	5.9	9.8	3.7	11.1	10.9	12.3	25.3	19.3	177	
	Deposition	0.01	0.03	*	0.02	<0.01	0.01	<0.01	0.01	0.02	0.01	0.01	<0.01	(0.14)	
	Concentration	<0.1	0.2	*	0.1	<0.1	0.1	0.2	<0.1	0.2	0.1	<0.1	<0.1		0.1

* No result available - any value given is an estimate.



Collections started at individual stations from July 1959 to June 1966 as shown
N.S. = no sample

Fig.10 Strontium-90 in rain - individual stations

TABLE 11 - Strontium-89 Deposition (mCi/km^2) and the Ratio Strontium-89 to Strontium-90 in Rain : 1975

Station	At mid-month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct
Kaitaia	Deposition	0.6	*	0.2	0.2	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	19	*	14	9	4	3	3	2	<1	-
Auckland	Deposition	0.6	*	0.3	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	19	*	24	9	6	3	2	2	1	-
New Plymouth	Deposition	0.8	*	0.4	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	29	*	13	14	5	4	2	2	-	-
Havelock North	Deposition	0.5	*	*	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	33	*	*	11	5	3	-	2	<1	-
Wellington	Deposition	*	0.3	*	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	*	13	*	8	7	3	2	<1	-	-
Greymouth	Deposition	0.7	0.6	*	0.6	0.3	<0.1	0.1	<0.1	<0.1	<0.1
	Ratio	17	11	*	7	4	3	2	2	-	-
Christchurch	Deposition	0.7	0.1	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	-	3	13	4	5	3	2	2	-	-
Dunedin	Deposition	0.6	*	*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	18	*	*	2	9	2	2	2	-	-
Invercargill	Deposition	0.5	0.4	0.4	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	21	13	14	6	4	4	2	<1	-	-
New Zealand Country-wide Average	Deposition	0.6	0.4	0.3	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	22	10	16	8	5	3	2	2	<1	-
Suva, Fiji	Deposition	0.6	0.4	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	21	29	14	8	4	3	3	<1	2	-
Rarotonga	Deposition	0.4	0.5	*	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio	39	17	*	8	-	<1	<1	3	-	-

* No Result Available

\- Not Detectable and Measurements Discontinued

Measurements were discontinued after October when the limit of detection had been reached at all stations.

TABLE 12 - Strontium-90 in Milk : 1975 ("Strontium Units" - pCi/g Ca)

	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average
Northland	3.1	2.8	3.1	3.2	3.1
Auckland	2.2	2.3	3.8	2.6	2.7
Waikato	2.3	2.9	4.1	2.7	3.0
Taranaki	5.8	5.4	5.4	3.7	5.1
Palmerston North	1.8	3.0	3.2	1.7	2.4
Wellington	2.8	3.9	3.9	2.9	3.4
Westland	9.6	9.8	7.6	7.6	8.7
Christchurch	1.2	1.2	1.4	1.0	1.2
Dunedin	1.8	1.5	1.6	1.3	1.6
Country-wide Average	3.4	3.6	3.8	3.0	3.5

TABLE 13 - Caesium-137 in Milk : 1975 (pCi/g K)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Northland	18	11	13	11	6	5	3	7	7	8	8	7	9
Auckland	9	11	10	9	3	7	5	8	6	4	5	7	7
Waikato	17	21	20	20	11	9	8	9	11	12	11	13	14
Taranaki	45	50	54	45	35	40	31	15	29	28	11	30	34
Palmerston North	<1	1	3	1	1	<1	1	<1	3	<1	1	2	1
Wellington	4	3	2	3	<1	<1	1	6	1	3	2	8	3
Westland	11	13	13	11	9	4	3	1	4	6	7	9	8
Christchurch	<1	2	3	<1	<1	2	<1	3	<1	<1	1	<1	1
Dunedin	1	2	3	1	2	<1	2	1	<1	<1	1	<1	1
Country-wide Average	12	13	13	11	8	8	6	6	7	7	5	9	9

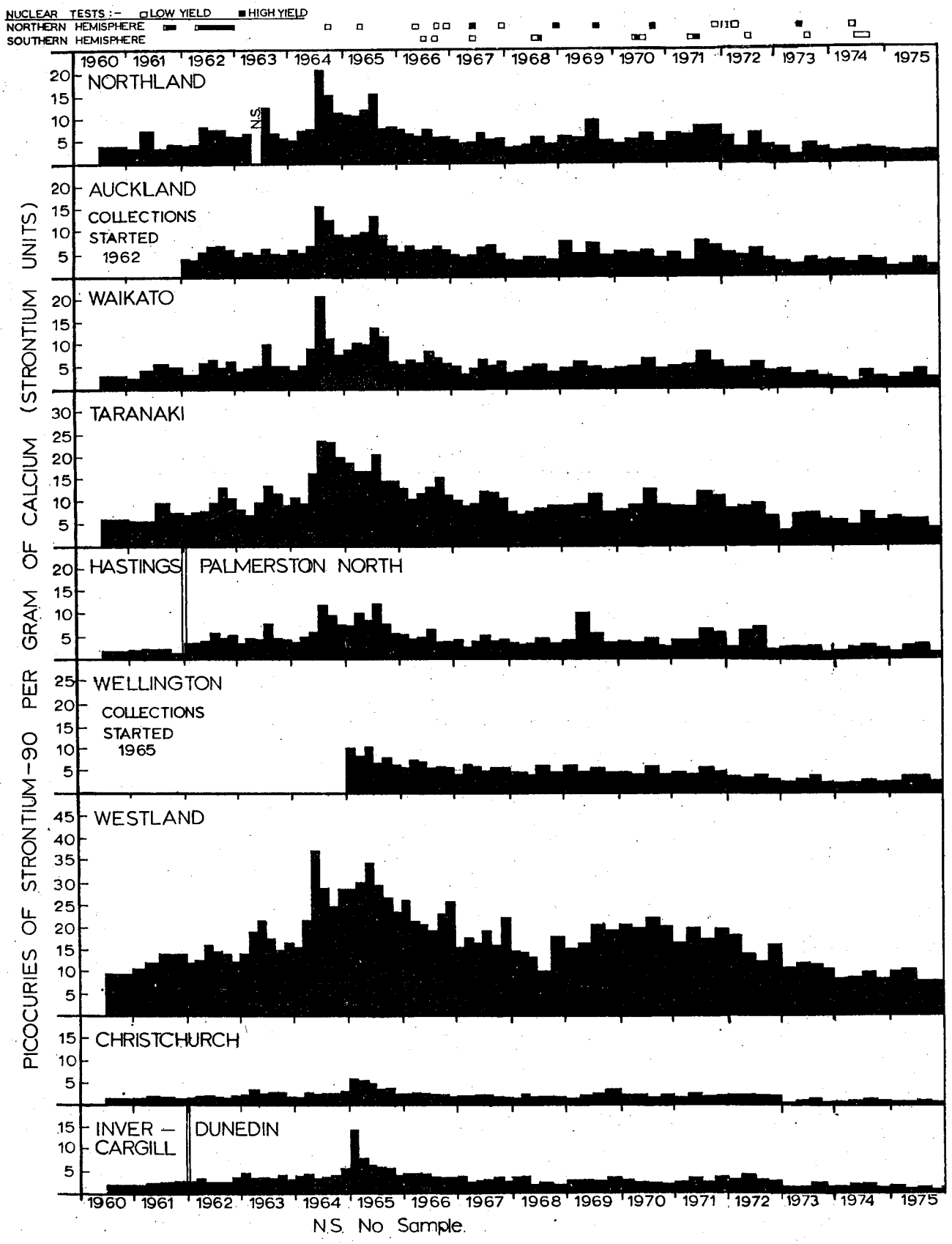


Fig.11 Strontium-90 in milk - individual stations

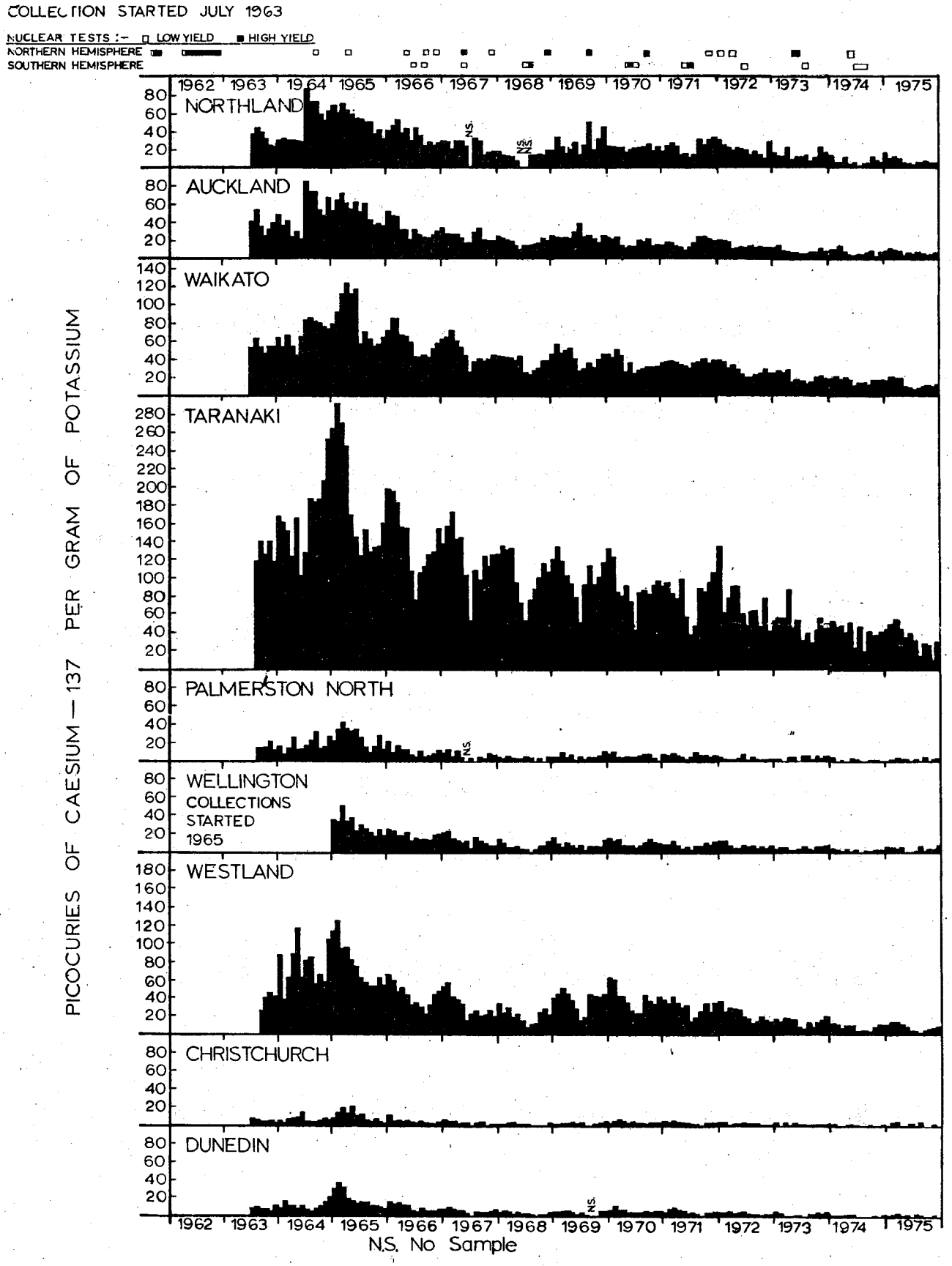
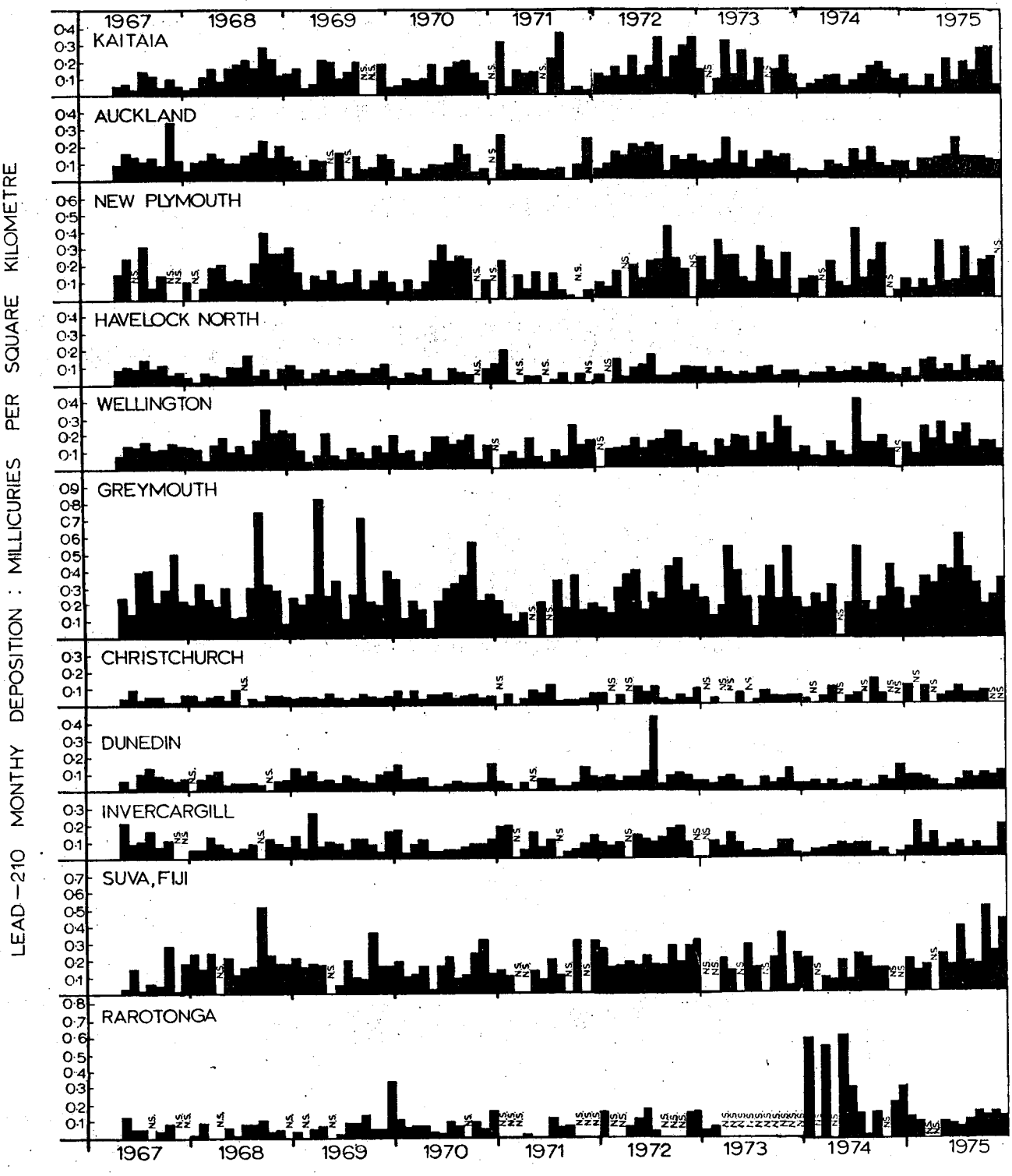


Fig.12 Caesium-137 in milk - individual stations



N.S. No Sample or No Results Available.

Fig. 13 Lead-210 in rain - individual stations

UNITS

The unit of radioactivity is the Curie (3.7×10^{10} disintegrations per second). This unit, however, is too large for environmental levels of radioactivity and smaller subdivisions are used:

the millicurie (mCi) . . . . . one thousandth of a Curie;

the picocurie (pCi) . . . . . one millionth of a millionth of a Curie (2.22 disintegrations per minute).

1. Fission product contamination in air is expressed as:

   Concentration - picocuries per cubic metre (pCi/m^3)

2. Radioactive fallout in rain is expressed as:

(a) Deposition - millicuries per square kilometre (mCi/km^2)

(b) Concentration - picocuries per litre (pCi/litre)

$$pCi/litre = \frac{mCi/km^2 \times 100}{\text{centimetres of rain}}$$

3. Strontium-90 contamination in milk and bone is given in "Strontium Units":

   picocuries of strontium-90 per gram of calcium . . . pCi/g Ca.

   Caesium-137 contamination in milk is given as:

   picocuries of caesium-137 per gram of potassium . . pCi/g K.

Note: One litre of whole milk contains approximately 1.2 g of calcium and 1.4 g of potassium.